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WEATHER MODIFICATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON WATER AND POWER RESOURCES

OF THE

COMMITTEE ON INTERIOR AND INSULAR AFFAIRS UNITED STATES SENATE

EIGHTY-NINTH CONGRESS

SECOND SESSION

ON

S. 2875

A BILL TO AUTHORIZE AND DIRECT THE SECRETARY OF THE INTERIOR TO CONDUCT A COMPREHENSIVE PROGRAM OF SCIENTIFIC AND ENGINEERING RESEARCH, EXPERIMENTS, TESTS, AND OPERATIONS FOR INCREASING THE YIELD OF WATER FROM ATMOSPHERIC SOURCES

MARCH 21–23, 1966

FIELD HEARINGS

RAPID CITY, S. DAK.—APRIL 11, 1966

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WEATHER MODIFICATION

MONDAY, MARCH 21, 1966

U.S. SENATE,
SUBCOMMITTEE ON WATER AND POWER RESOURCES
OF THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D.C.

The subcommittee met, pursuant to call, at 10 a.m., in room 3110, New Senate Office Building, Senator Clinton P. Anderson (chairman of the subcommittee) presiding.

Present: Senators Clinton P. Anderson (New Mexico), Henry M. Jackson (Washington), Frank E. Moss (Utah), Gordon Allott (Colorado), and Len B. Jordan (Idaho).

Present also: Senator George McGovern (South Dakota).

Professional staff present: Jerry T. Verkler, staff director; Stewart French, chief counsel; Roy M. Whitacre, professional staff member; Frederick O. Frederickson, special counsel, and E. Lewis Reid, minority counsel.

Senator ANDERSON. The hearings we are opening today on S. 2875 are, so far as I am concerned, the continuation of a 15-year effort to accelerate weather modification research.

I am looking forward to the hearings with considerable interest, for I see on the witness list men I met in 1951 in the General Electric Laboratories, when I journeyed there then with a subcommittee of this committee to learn something of the work in this field which Dr. Langmuir, Dr. Vonnegut, and Dr. Schaeffer were conducting. If I am not mistaken, I also met some of the other witnesses at about that same time.

In order to avoid taking time from witnesses this morning, the subcommittee several days ago printed a statement of the background and purposes of this hearing. It has been supplied to the witnesses for any guidance it might give them, and to other interested parties.

If there is no objection, I shall include it in the record this morning as my opening statement and anyone not familiar with its contents can obtain a copy from the staff.

I would like to say that some time ago, when it became known that the National Academy of Sciences and National Science Foundation panels were recommending accelerated weather modification research work, I was joined by Senator George McGovern, of South Dakota, in a request to the Department of the Interior for assistance in developing an appropriate program to implement that report insofar as the Interior Department's mission is concerned. Such a program was developed and supplied to us. It became the basis of S. 2875, which was drafted by a member of our staff.

The program and the bill were developed over a period of several weeks. We had the help of some mighty fine scientists in preparing the program and the bill. I believe the bill will require some perfecting amendments, but as these hearings open I would like to testify that I feel it is a solidly based point of beginning for the consideration of our next steps in what, to my personal knowledge, is at least a 15-year-old effort to speed up the search for ways to tap the water resources of the atmosphere.

A copy of S. 2875, the report thereof, and the statement of background and purpose, follow.

(The documents referred to follow:)

[S. 2875, 89th Cong., 2d sess.]

A BILL To authorize and direct the Secretary of the Interior to conduct a comprehensive program of scientific and engineering research, experiments, tests, and operations for increasing the yield of water from atmospheric sources

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. As one means of assuring supplies of water adequate in quantity and quality to meet the requirements of the Nation's growing population and economy, it is the policy of the Congress to provide for effective beneficial utilization of atmospheric water resources through a coordinated program of research and operations.

SEC. 2. As used in this Act, words and phrases are defined as follows:

(a) "Secretary" means the Secretary of the Interior;

(b) "Atmospheric water" means water in fluid, gaseous, crystalline, or other state, in clouds, vapors, or any other form, located at any distance above the surface of the earth;

(c) "Comprehensive program" means the program of research and operations for accomplishment of the purposes of this Act, and any revisions, supplements, or additions to it.

TITLE I—THE COMPREHENSIVE PROGRAM

SEC. 100. The Secretary of the Interior shall formulate and carry out a comprehensive program of scientific and engineering research, experiments, tests, and operations directed at increasing the yield of water from atmospheric sources for beneficial uses in all regions of the United States, giving due regard to the relation of anticipated specific and general benefits to the costs of securing such increased atmospheric water yields, to the legal rights of interests that may be affected, and to other relevant matters. The comprehensive program may include, without being limited to, tests for improvement of present systems of cloud seeding or other methods of inducing precipitation; mathematical or other scientific analyses of clouds and cloud systems, and of the general continental or hemispheric circulation; engineering and other technical work for designing and developing equipment for identifying and modifying atmospheric water processes; economic, legal, and other research needed for planning and executing atmospheric water operations; and the training of scientists and engineers in atmospheric water resources research and operations. The aim of the comprehensive program is to develop and utilize techniques for controlling precipitation so as to increase the Nation's total benefits from its atmospheric water resources, and the program shall take full advantage of all of the Nation's scientific and technical capability, public and private, governmental, academic, and industrial that can be brought to bear on the problem.

SEC. 101. In formulation and execution of the comprehensive program, the Secretary shall request the advice and participation of all Federal agencies that have scientific or engineering competence related to atmospheric water matters, and all such Federal agencies are directed to participate in said comprehensive program on the basis of agreements with the Secretary.

SEC. 102. The Secretary may provide by contracts, grants, or other arrangements that he determines to be suitable, for participation in the formulation and execution of the comprehensive program by educational institutions, private foundations and other institutions, private firms and individuals, and local and State government agencies, and such participation may include training in the

sciences related to atmospheric water resources and in engineering and other technological aspects of increasing the yield of water from atmospheric sources.

SEC. 103. The Secretary shall establish and operate, or arrange for the establishment and/or operation of (a) a scientific and engineering facility which shall be the central planning, analytic, and administrative center for the comprehensive program; (b) regional scientific and engineering research and operations centers; and (c) such other temporary, mobile, or special purpose facilities as may be necessary and proper for accomplishment of the comprehensive program.

SEC. 104. The Secretary may arrange for the performance of scientific, engineering, or other portions of the comprehensive program by other Federal agencies on the basis of agreements, as provided in section 101 of this Act; and such agreements may include, among other things, provision for transfer to such agencies of funds appropriated to the Secretary.

SEC. 105. Contracts, grant agreements, or other arrangements for participation in the comprehensive program by educational institutions, private foundations and other institutions, private firms and individuals, and local and State government agencies pursuant to section 102 of this Act may include provision for the right to use, with or without charge, real or personal property, or patents copyrights, processes, inventions, or interests therein: *Provided*, That such agreements or other arrangements with educational institutions may included transfer to such educational institutions of the title to ownership of property determined by the Secretary to be useful for research and the training of scientists and engineers in the fields of atmospheric water resources.

SEC. 106. Not later than the first day of March of each year beginning one year after enactment of this Act, the Secretary shall report to the Congress on the status of the comprehensive program, including (a) summaries of the results of research, experiments, test, and operations; and (b) plans for such activities during the remainder of the comprehensive program; and such annual report shall be accompanied by the comments of the Water Resources Council established pursuant to the Act of July 22, 1965 (79 Stat. 244).

TITLE II—AUTHORIZATIONS AND LIMITATIONS

SEC. 200. The Secretary may, for accomplishment of the comprehensive program, acquire by purchase, lease, gift, or by other means (including transfer of Federal property), real and personal property or interests therein, patents, copyrights, processes, devices, inventions, or rights, to use thereof: *Provided*, That he may dispose of such property, rights, or interests only as provide by section 105 of this Act unless otherwise authorized by Act of Congress.

SEC. 201. The United States will compensate for the taking of property or rights, or for damage, injury, or for other just claims arising out of execution of the comprehensive program in the manner provided in the Act of August 30, 1954, an Act to amend the Atomic Energy Act of 1946.

SEC. 202, Activities intended to affect, or determined by the Secretary to be likely to affect, the atmospheric water resources of the United States may be carried on only pursuant to license issued by the Secretary in the same manner as licenses issued pursuant to the Act of August 30, 1954.

SEC. 203. No part of any appropriated funds may be expended pursuant to authorization given by this Act for any scientific or technological research or development activity unless such expenditure is conditioned upon provisions determined by the Secretary of the Interior, with the approval of the Attorney General, to be effective to insure that all information, uses, products, processes, patents, and other developments resulting from that activity will (with such exceptions and limitations as the Secretary may determine, after consultation with the Secretary of Defense, to be necessary in the interest of the national defense) be made freely and fully available to the general public. Nothing contained in this section shall deprive the owner of any background patent relating to any such activity of any rights which that owner may have under that patent.

SEC. 204. Except as provided in section 202 of this Act, nothing in this Act is intended to give or shall be construed as giving the Secretary of the Interior any authority or surveillance over water resources research or meteorological or atmospheric research conducted by other agencies of the Federal Government under authorization other than this Act; or as repealing, superseding, or diminishing existing authorities of any agency of the Federal Government to plan, conduct, contract for, or assist research or operation in its areas of responsibility and concern.

SEC. 205. There is authorized to be appropriated for the purposes of this Act not to exceed $35,000,000 for the first year after enactment of this Act, not to exceed $50,000,000 for the second year, not to exceed $70,000,000 for the third year, and such sums thereafter as may be necessary.

U.S. DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D.C., March 18, 1966.

Hon. HENRY M. JACKSON,
Chairman, Committee on Interior and Insular Affairs,
U.S. Senate, Washington, D.C.

DEAR SENATOR JACKSON: This responds to your request for the views of this Department on S. 2875, a bill to authorize and direct the Secretary of the Interior to conduct a comprehensive program of scientific and engineering research, experiments, tests, and operations for increasing the yield of water from atmospheric sources.

S. 2875 authorizes and directs the Secretary of the Interior to formulate and carry out a comprehensive program of research and operations directed at increasing the yield of water from atmospheric sources for beneficial use in all regions of the United States. It is broad in scope, designed to provide this Department with authority for establishing programs dealing with all aspects of atmospheric water operations. The bill authorizes the Secretary to request and receive assistance from other Federal agencies, and authorizes contracts, grants, and other arrangements with other organizations and institutions, including academic training. It authorizes the establishment of an analytical and administrative center for the comprehensive program, and of regional scientific and engineering research and operations centers, together with other facilities necessary to carry out the program.

The bill authorizes annual reports to the Congress on the status of the comprehensive program, including summaries of research already completed and future plans, to be accompanied by the comments of the Water Resources Council.

Title II of the bill authorizes the Secretary to acquire property and to dispose of that property to educational institutions. It requires the United States to compensate for the taking of property, and for the payment of claims arising from the program in the manner provided in the amendments to the Atomic Energy Act dated August 30, 1954. It further requires that such activities shall take place only upon license in the same manner as licenses issued pursuant to the act of August 30, 1954, and limits the expenditure of funds for research or development to cases where results of such research and activity shall be made available to the general public.

The bill specifically states that it is not intended to give this Department increased authority over programs of other Federal agencies and does not limit those programs in any way.

The bill authorizes appropriations not to exceed $35 million for the first year after its enactment, not to exceed $50 million after the second year, not to exceed $70 million for the third year, and such sums thereafter as may be necessary.

The bill is ambitious in scope and indicates thoughtful consideration of the many issues involved in the establishment of an effective atmospheric water resources program. The recent reports of the National Academy of Sciences and the National Science Foundation on the feasibility of weather modification indicate that we are rapidly approaching a time when we can begin to employ effective techniques to use the atmosphere as a source of water supply.

The development of those techniques has been a matter of great interest to this Department, which has in fact played a substantial role in this activity. The Bureau of Reclamation instituted a program several years ago which has since been substantially augmented and increased. The appropriation this year is $2.98 million; the budget for next year's program is $3 million.

Concurrent with the development of more effective techniques of weather modification has come the realization that these techniques cannot and should not be confined by geographical limitations. There is a clear need to develop techniques of inducing and augmenting precipitation in the West. The need is no less clear as it applies to other parts of the country. One need only consider the situation of the drought stricken East last year to conclude that this Nation's

need for a dependable supply of usable water is in no sense confined to the arid West.

The Department of the Interior holds major national water resources responsibilities. The Water Resources Council, under the chairmanship of the Secretary of the Interior, has been given basic water resource planning responsibilities. This Department has recently greatly expanded its saline water program, and has major responsibilties in the development of water resources research centers throughout the country. The clean rivers restoration bill, recently introduced into the Congress, is yet another example of the responsibilities contemplated for this Department.

The executive branch is considering a reorganization plan that would transfer some responsibilities and functions in the weather modification field. Although the proposed reorganization plan would not transfer any of the functions of the Department of the Interior, it would assign responsibilities in a manner that may be inconsistent with some of the provisions of the present bill. An example is the relationship between the comprehensive program for increasing the yield of water from atmospheric sources mentioned in section 100 of the bill, to the general responsibilties that might be consolidated.

Another example is the relationship between regional research and operations centers contemplated by section 103 of the bill and the research activities of other agencies. We endorse the concept of section 103, but feel that the section may be somewhat broader in scope than is necessary for this Department to carry out its assigned responsibilties associated with its national water management role.

We therefore suggest that it would be appropriate to defer action on S. 2875 until after the reorganization plan is disposed of.

When legislation is enacted, we believe that it is important to indicate, as is done in section 100 of the bill, that this Department is expected to engage in atmospheric water resources activities for the purpose of water management throughout the United States without regard to geographical limitation. We would expect, of course, to work very closely with other Federal and non-Federal agencies in developing and operating our weather management program. The Environmental Science Services Administration in the Department of Commerce occupies an important role in weather modification, as do programs of other Federal agences such as the Departments of Defense and Agriculture. We contemplate that very close relations will be maintained with these organizations to facilitate the effective discharge of the responsibilities of each as directed by the Congress.

There is also a need, when legislation is enacted, to provide some form of liability protection for contractors who are engaged in weather modification activities under the Federal program.

The Bureau of the Budget has advised that there is no objection to the presentation of this report from the standpoint of the administration's program.

Sincerely yours,

STEWART UDALL,
Secretary of the Interior.

DEPARTMENT OF THE AIR FORCE,
OFFICE OF THE SECRETARY,
Washington, March 30, 1966.

Hon. HENRY M. JACKSON,
Chairman, Committee on Interior and Insular Affairs,
U.S. Senate.

DEAR MR. CHAIRMAN: Reference is made to your request for the views of the Department of Defense with respect to S. 2875, 89th Congress, a bill which would authorize and direct a comprehensive program aimed at solving the national problem of providing adequate water supplies. The Air Force has been delegated the responsibility for expressing the views of the Department of Defense.

The bill would authorize the Secretary of Interior to carry out a comprehensive, coordinated program of scientific and engineering research and operations for increasing the yield of water from atmospheric sources. To this end, it would provide for the establishment and operation of necessary facilities; direct the participation of other Federal agencies on the basis of agreements which may include the transfer of funds; and permit contracts, grant agreements, or other arrangements for participation by educational institutions, private foundations and others. The bill would also require that activities intended or likely to affect the atmospheric water resources of the United States be licensed by the

Secretary of Interior. In addition, S. 2875 would recognize existing authorities of other Federal agencies to perform water resources, meteorological or atmospheric research.

Currently, national responsibility for monitoring all weather modification rests with the National Science Foundation. The Department of Defense suggests that Federal regulatory responsibility for all weather modification activities should reside in one Federal agency. While this need not necessarily be the National Science Foudnation, such regulatory responsibility should not be given to an element of the Executive branch which is itself active in weather modification research and operations. Therefore, the Department of Defense recommends that section 202 of the bill be deleted in its entirety.

Since the bill recognizes the authorities of other Federal agencies to conduct research and operations in their areas of responsibility and concern, the Department of Defense would not be unduly restricted in its weather modification research and operational efforts to enhance the accomplishment of the Defense mission.

In view of the definition in section 2 of the bill, the phrase "of the Interior" should be deleted as surplusage in lines 14, 23, and 11 of pages 2, 6, and 7 respectively.

To accurately reflect the fact that the listed property interests are included in the preceding phrase, substitute "including" for the second "or" in line 4 of page 5, and insert "including" before "patents" in line 2 of page 6.

Subject to the recommendations set forth above, the Department of Defense interposes no objection to S. 2875.

This report has been coordinated within the Department of Defense in accordance with procedures prescribed by the Secretary of Defense.

The Bureau of the Budget advises that, from the standpoint of the Administration's program, there is no objection to the presentation of this report for the consideration of the Committee.

Sincerely,

ALEXANDER H. FLAX,
Assistant Secretary, Research and Development.

DEPARTMENT OF AGRICULTURE,
Washington, D.C., March 23, 1966.

Hon. HENRY M. JACKSON,
Chairman, Committee on Interior and Insular Affairs,
U.S. Senate.

DEAR MR. CHAIRMAN: In reply to your request of February 23, 1966, this is our report on S. 2875, a bill "To authorize and direct the Secretary of the Interior to conduct a comprehensive program of scientific and engineering research, experiments, tests, and operations for increasing the yield of water from atmospheric sources."

This Department endorses Federal support and leadership in research and development activities that will contribute to knowledge of the atmospheric water reservoir and enable man to control this water supply when and where the need arises. We are cooperating, and look forward to continuing cooperation, with the Department of the Interior in weather modification research and development as the state of funds and budget considerations warrant. We would be pleased to see the Department of the Interior undertake additional research and development programs with respect to regulating and enhancing water supply through weather modification. We believe, however, that the legislation proposed by S. 2875 is not needed or appropriate at this time to accomplish that purpose.

S. 2875 would create within the Department of the Interior a major new research and development program directed at increasing the yield of water from atmospheric sources in all regions of the United States. The program would include, without being limited to, tests for improvement of present systems of cloud seeding or other methods of inducing precipitation; mathematical or other scientific analyses of clouds and cloud systems, and of the general continental or hemispheric circulation; engineering and other technical work for designing and developing equipment for identifying and modifying atmospheric water processes; economic, legal, and other research needed for planning and executing atmospheric water operations; and the training of scientists and engineers in atmospheric water resources research and operations.

Section 101 directs the Secretary of the Interior to consult and cooperate with all Federal agencies that have scientific or engineering competence related to atmospheric water matters.

Section 102 authorizes contracts, grants, and other arrangements with educational institutions, private foundations and other institutions, private firms and individuals, and local and State government agencies for execution of the program.

Section 103 directs the Secretary to establish a central scientific, engineering and administrative facility, regional research centers, and such other special purpose facilities as may be necessary.

Section 104 authorizes arrangements between the Secretary of the Interior and other Federal agencies for the performance of portions of the program.

There are provisions in the bill for annual reporting, patents and copyrights, and authorizations and limitations affecting the program.

The final provision of the bill authorizes appropriations not to exceed $35,000,000 for the first year after enactment, not to exceed $50,000,000 for the second year, not to exceed $70,000,000 for the third year, and "such sums thereafter as may be necessary."

Weather modification is of major importance to agriculture. Our concept of weather modification extends far beyond increasing yield of water from the atmosphere. The production of food and fiber, the productivity of forest watersheds, the protection of crops and forests, the full utilization of agricultural and forest resources, and the well-being of rural communities are all strongly influenced by weather and climate.

We are making significant progress in weather modification research. Our major activity has been in the modification of lightning storms to reduce the occurrence and severity of lightning-caused forest fires. This research, known as Project Skyfire, is being performed by the Northern Forest Fire Laboratory of the Forest Service at Missoula, Montana. Some 10,000 lightning-caused fires occur annually in the United States, causing damages in the millions of dollars to forest resources and from fire control costs. Project Skyfire is determining whether special weather modification techniques can reduce these great losses and costs. While much of this work is of a pioneering nature involving heretofore unexplored fields of research, progress in this major weather modification research is farther advanced than other major weather modification research programs. New knowledge has been gained of the basic mechanisms of fire-igniting lightning strokes and of the action of ice-forming nuclei on cloud electrification processes. High output, ram-jet type silver iodide smoke generators and new technology have been developed for delivering large quantities of silver iodide nuclei to thunderstorm cloud systems and for measuring and evaluating the results. Data from three years of cloud seeding experiments in a specially instrumented test area show more than 30 percent reduction in cloud-to-ground lightning from treated storms. This work is providing the essential foundation for a strengthened research effort and for larger scale pilot tests of lightning modification.

Results already achieved by Project Skyfire in lightning modification provide some of the background for projected research in hail suppression, a second weather modification area of major interest to this Department. Hail affects production and quality of grain and forage crops in the Plains and Mountain States and fruit and vegetable crops in many regions of the United States. Hailstorms cause extensive damage to agricultural crops every year, wiping out entire crops in some cases. Project Skyfire scientists have found that a relationship exists between hail occurrence and frequency of lightning discharges, the flash rate, and storm duration. Results suggest that if cloud seeding reduces the size and amount of hail, it may also reduce the amount of lightning produced by the storm. For these and other reasons, the modification of lightning and suppression of hail have common interests.

A third area of activity by this Department in weather modification research deals with processes that so vitally affect exchange of heat, water vapor, and carbon dioxide in the earth-air interface and the modification of these processes by the management of vegetative cover on agricultural and forest lands. We have a particular responsibility and concern in regard to micro- and meso-scale weather modification in the earth-air boundary layer. Here is where solar energy is incorporated into plant materials and thus enters the food chain. Agricultural research is aimed at obtaining the most efficient energy exchange through modifications of various elements of the environment in this zone. Changes in albedo, surface roughness, the geometry of field crops and forest

stands, moisture relations, and other factors can have a significant effect upon production of food, fiber, and water. Studies underway include such things as wind movement, air turbulence, energy budget as related to evapotranspiration, snow accumulation and melt, and photosynthesis. The Department is directly concerned with weather modification research which modifies precipitation intensities and storm patterns over the forested watersheds which produce over one-half of the stream flow in the West.

The biological consequences of weather modification are of great concern to agriculture. The best presently available information in the field of plant and animal ecology indicates that any significant large-scale modification of weather would be likely to result in extinction of some natural plant and animal communities, and to increase weed species, insect and disease pests. Conversely, as indicated above, modification of vegetative cover on agricultural and forest lands may have a strong influence on the local atmospheric behavior over these lands.

This Department has a particularly strong background of competency and experience in the scientific disciplines that should be brought to bear in determining the biological effects of weather modification. An increased research program in this regard should be undertaken concomitant with the research directed at learning how to modify weather and climate.

This Department also has a long history of effective cooperative and coordinated work with the program of the land-grant colleges as established under the Morrill Act of 1862, including the cooperative work of the State agricultural experiment stations carried out under the Hatch Act of 1887, as amended, and other grant programs. The State stations conduct basic and applied research on micrometeorology and phenology, including cooperative regional research, to correlate weather information for agriculture and to analyze the relationships between climatic variables and plant response. We are determined to continue support of this program and to encourage its expansion in high priority areas.

The Bureau of the Budget advises that there is no objection to the presentation of this report from the standpoint of the Administration's program.

Sincerely yours,

ORVILLE L. FREEMAN, *Secretary.*

COMPTROLLER GENERAL OF THE UNITED STATES,
Washington, D.C., May 19, 1966.

B–149711.

Hon. HENRY M. JACKSON,
Chairman, Committee on Interior and Insular Affairs,
U.S. Senate.

DEAR MR. CHAIRMAN: This is in response to your request of March 24, 1966, for a report of our Office on S. 2875, a bill to authorize and direct the Secretary of the Interior to conduct a comprehensive program of scientific and engineering research, experiments, tests, and operations for increasing the yield of water from atmospheric sources.

S. 2875 provides that in the formulation and execution of the comprehensive program the Secretary of the Interior shall request the advice and participation of all Federal agencies that have scientific or engineering competence related to atmospheric water matters, and that such Federal agencies shall participate in the program on the basis of agreements with the Secretary. The Secretary would be authorized to establish and operate or arrange for the establishment and/or operation of (a) a scientific and engineering facility which would be the central planning, analytic, and administrative center for the comprehensive program; (b) regional scientific and engineering research and operations centers; and (c) such other temporary, mobile, or special purpose facilities as may be necessary and proper for accomplishment of the comprehensive program. The bill would also authorize the Secretary to provide by contracts, grants, or other arrangements determined suitable, for participation in the formulation and execution of the comprehensive program by educational institutions, private foundations and other institutions, private firms and individuals, and local and State government agencies.

We find we are not in a position to add to the information your committee has already received in its consideration of this bill, particularly with regard to the significant licensing and claims provisions of sections 202 and 201. We however wish to point out that the present bill does not contain a provision, as preventive of waste and improper use of Federal funds under the program, to

require the recipients of Federal funds under grants or other participation arrangements entered into pursuant to section 102 or section 103 to keep adequate cost records, and permit access thereto by the Secretary of the Interior or the Comtproller General for the purpose of audit and examination. We therefore suggest the bill be amended to include a records and audit provision similar perhaps to that contained in section 11 of Public Law 88–206, Clean Air Act. See, also, section 8(a)(3) of Public Law 89–220, an act to authorize a high-speed ground transportation study.

Sincerely yours,

FRANK H. WEITZEL,
Assistant Comptroller General of the United States.

ATOMIC ENERGY COMMISSION,
Washington, D.C., March 22, 1966.

Hon. HENRY M. JACKSON,
Chairman, Committee on Interior and Insular Affairs,
U.S. Senate.

DEAR SENATOR JACKSON: The Atomic Energy Commission is pleased to comment on S. 2875, a bill "[t]o authorize and direct the Secretary of the Interior to conduct a comprehensive program of scientific and engineering research, experiments, tests, and operations for increasing the yield of water from atmospheric sources."

The proposed legislation would direct the Secretary of the Interior to formulate and carry out this comprehensive program by means of contracts, grants, or other arrangements with various institutions, both public and private, including other Federal agencies which are directed to participate in the program.

The Secretary would further be directed to establish and operate a scientific and engineering facility to serve as the central planning, analytic, and administrative center for the program, as well as regional centers and such other facilities as may be necessary to accomplish the program.

AEC believes the objective of this bill is important. We also think it is time that the entire scope of beneficial weather modification, including such other features as lightning suppression and dispersal of hurricanes and other storms, is committed to Federal planning in depth. It seems to us that research and development pursuant to an extensive National plan, as well as Federal control of the manipulation of weather, are necessary because the interests of all the people in this country are involved; additionally the weather modification program will no doubt eventually have international ramifications.

As you are aware, S. 2916 a bill "[t]o provide for a weather modification program to be carried out by the Secretary of Commerce" was introduced on February 10, 1966. Its scope is somewhat broader than that of S. 2875, apparently encompassing a comprehensive program of weather change and climate control. As we understand both bills, the activities which would be carried out by the Secretary of the Interior under S. 2875 would, under S. 2916, be included as part of the program to be carried out by the Secretary of Commerce. The Commission is not in a position to recommend that the responsibility for such activities be assigned to any particular Department or agency.

Our own programmatic interests, including our interest in the general field of atmospheric sciences and our development of nuclear energy devices for use in unattended weather stations at sea and in space, do not at this time include any direct participation in controlled weather modification efforts. As the weather program develops, it is very possible, in our view, that we may be able to contribute.

We would like to comment briefly on two features of S. 2875 that appear to us to serve particularly worthwhile purposes. These are the recognition that "legal rights of interests" may be affected by weather control efforts, and the requirement that a Federal license must be obtained before any activities can be conducted which may affect the atmospheric water resources of the United States. By explicit direction in the bill, both features are to be patterned after concepts built into the Atomic Energy Act of 1954, as amended. These have been employed by the AEC with considerable successful consequence for its programs. Whether or not AEC's Price-Anderson indemnification provisions should be wholly or substantially embodied in this initial full-scale research and development assault on the problems affecting weather control, or whether other protective approaches should be utilized, we cannot really say with any

certainty at this time. However, we firmly believe it is realistic and wise to provide for the protection of the public and those involved in the program, in relation to injuries, losses and damage that individuals may suffer while progress for the many is being pursued. Similarly, we are convinced that whether or not the concept parallels AEC's, appropriate Federal licensing control of weather manipulation would be highly desirable. Incidentally, we recommend that section 201 of the bill spell out the intended coverage for compensation for damage, injury, or other claims, and for the taking of property or rights; section 202 should also set forth the details of the intended licensing procedure.

Section 203 provides for public availability of all information, uses, products, processes, patents, and other developments resulting from activities covered by the bill which are carried on by the Secretary of the Interior, with such exceptions and limitations as the Secretary of the Interior may determine necessary in the interest of national defense after consultation with the Secretary of Defense. We strongly believe that in lieu of the requirement in the bill as written with respect to security-classified information, section 203 should provide for coordination between the Secretary of the Interior and the particular agency responsible for classified information to assure appropriate protection of the information in accordance with the judgment of the particular agency. As you know, the Atomic Energy Act of 1954, as amended, permits access to Restricted Data and formerly Restricted Data only in accordance with its stated provisions. We urge that the bill clearly reflect the fact that this body of security-classified information, and the release of such information, will be governed by the provisions of the Atomic Energy Act.

We note that in section 200, the Secretary of the Interior is given the right to dispose of the property only as provided by section 105 of the bill. It seems to us that this may be unnecessarily restrictive since it would apparently preclude the right to abandon relatively valueless property or to dispose of surplus property by routine Federal means unless authorized by Congress.

The Bureau of the Budget has advised that there is no objection to the presentation of this report from the standpoint of the Administration's program.

Cordially,

GLENN T. SEABORG, *Chairman.*

EXECUTIVE OFFICE OF THE PRESIDENT,
BUREAU OF THE BUDGET,
Washington, D.C., April 8, 1966.

Hon. HENRY M. JACKSON,
Chairman, Committee on Interior and Insular Affairs, U.S. Senate, New Senate Office Building, Washington, D.C.

DEAR SENATOR JACKSON: This is in response to your request for the views of the Bureau of the Budget on S. 2875, a bill "To authorize and direct the Secretary of the Interior to conduct a comprehensive program of scientific and engineering research, experiments, tests, and operations for increasing the yield of water from atmospheric sources."

S. 2875 would direct the Secretary of the Interior to conduct a comprehensive program to increase the yield of water from atmospheric sources for beneficial uses in all regions of the United States. In the conduct of this comprehensive program, the advice and participation of other Federal agencies would be required. A central scientific and engineering facility, and regional research and operations centers, would be established to accomplish the program. General contract and grant authority would be provided, and the Secretary would be required to make an annual status report on the program to the Congress. Compensation for damages and licensing authority over all activities affecting United States atmospheric water resources would be provided in the same manner as in the (Atomic Energy) Act of August 30, 1954. S. 2875 would also provide that, except for licensing authority, the bill is not intended to give the Secretary authority over research conducted by other Federal agencies under other authority. Finally, necessary appropriations, with the maximums stipulated for each of the first three years, would be authorized.

The Bureau of the Budget strongly supports those research and development activities of Federal agencies in weather modification which are required for the effective discharge of their responsibilities. These activities are directed toward many objectives, such as rainfall augmentation, lightning suppression, fog dissipation, pollution abatement, and severe storm suppression. In each case, however, the efforts involve the same medium, the atmosphere. This common char-

acteristic of weather modification efforts results in the possibility of conflicts and in the necessity for leadership and coordination.

S. 2875 deals with these problems by granting the Secretary of the Interior broad leadership responsibilities in the field of weather modification generally in order to advance the nation's capability to use modification techniques in one, albeit critical, field. Thus, in formulating and conducting a comprehensive program of research, experiments, test, and operations to increase atmospheric water yields, the Secretary is authorized to sponsor, among other things, scientific analyses of cloud systems and general continental or hemispheric circulation; economic, legal and other research; and the training of scientists and engineers. Other Federal agencies are directed to participate in the comprehensive program and any activities affecting the program can be carried on only pursuant to license issued by the Secretary. Due to the breadth of national interest and Federal effort in weather modification, it would appear unwise to subordinate all Federal weather modification activities exclusively to the water resources problem. In addition, the regulatory and the indemnification matters dealt with in the bill are of great importance and complexity, and most of the issues involved should be thoroughly studied before comprehensive legislation is enacted.

In view of the above, the Bureau of the Budget recommends against enactment of this bill. However, we would have no objection to legislation, if needed, clarifying the Department's authority to sponsor weather modification activities required to fulfill its water resources responsibilities throughout the United States.

Sincerely yours,

WILFRED H. ROMMEL,
Acting Assistant Director for Legislative Reference.

EXPANSION OF ATMOSPHERIC WATER RESOURCES PROGRAM OF THE DEPARTMENT OF THE INTERIOR

BACKGROUND AND STATEMENT OF PURPOSE OF HEARINGS ON S. 2875

The Subcommittee on Water and Power Resources of the Senate Interior Committee will conduct public hearings in Washington, D.C., March 21, 22, and 23; in Rapid City, S. Dak., on April 11; and in Albuquerque, N. Mex., on April 14, on Senate bill 2875, introduced February 4, to expand the atmospheric water resources responsibilities of the Department of the Interior. Twenty-one Senators joined in the bill.

This subject is not new to the Senate Interior Committee. As early as 1951 the late Senator Francis Case, of South Dakota, the late Senator Joseph O'Mahoney, of Wyoming, and I introduced and conducted hearings on three bills on behalf of three Senate committees (Agriculture, Commerce, and Interior) that led to the establishment in 1953 of the National Advisory Committee on Weather Control.

We now look forward to hearings on a new bill. Committee consideration of S. 2875 necessarily includes examination of recent developments and assessment of the prospects for the future in one of the most important, if not the most important, fields of weather modification—augmenting water supply.

Atmospheric water resources should become one of the essential programs used by the Secretary of the Interior in the wise management of all of the Nation's water resources. In order to accomplish this objective in the most efficient manner, the Secretary of the Interior will need the active support and help of all other Federal agencies that can contribute talent and resources in the field of weather modification. At the same time, the other mission-oriented agencies will necessarily need to carry on expanding programs in such other areas of weather modification as hail suppression, for dispersal, lightning suppression to prevent forest fires, hurricane research, and severe storm research. Senate bill 2875 makes clear that the programs of the other mission-oriented agencies should be continued and that the other Federal agencies should be prepared to be called upon by the Secretary of the Interior to participate in the atmospheric water resources program of the Department of the Interior.

The proposed bill would authorize and direct the Secretary of the Interior to carry out a comprehensive program of scientific and engineering research, experiments, tests, and operations for increasing the yield of water from atmospheric resources. The overall objective of the proposed legislation would be to comprehend within the Department of the Interior the full range of ac-

tivities in water resources. The Department of the Interior already has underway programs in the field of saline water, water resources research, and the development of water projects for various water uses. For many years the Department has conducted fundamental research in the Geological Survey on natural resources of which land and water are most significant. Research and administration in water pollution abatement have been recommended as additional Interior responsibilities by President Johnson. The significant omission at the present time, and the omission that the proposed legislation is intended to fill, is the responsibility of the Department of the Interior to develop atmospheric water sources on a national basis and to provide for its coordinated use with other water supplies.

The purpose of the scheduled hearings is to provide the Interior Committee with the full facts, information, and informed judgment on this promising new field of scientific and engineering research and development. That is why the subcommittee plans to give much of its time to the testimony of highly qualified scientists and engineers. We also seek the views of men of high professional standards who, as early pioneers, have clearly demonstrated their practical capability in weather modification. Some of the witnesses to be invited include the early pioners in weather modification who, in spite of frequent serious obstacles, held doggedly to their convictions while weather modification developed scientific support.

The Senate Interior Committee in recent years has supported a well-considered program of legislation aimed at strengthening the water resources responsibilities of the Secretary of the Interior. Action on S. 2875 by the Congress this year would add to the distinguished record of the 89th Congress in the enactment of legislation to meet critical natural resources problems of national concern.

Recent expansion of existing programs or the addition of new programs in water resources clearly demonstrate that the Department of the Interior with the active support of the Congress is seeking to comprehend the full range of water resources programs throughout the Nation. For example:

(*a*) The greatly expanded saline water program of the Department of the Interior is showing great promise. This supplemental source of water supply should eventually provide an economic and competitive source of fresh water for integrated use along with other sources of water supplies.

(*b*) The Water Resources Planning Act authorized the Secretary of the Interior to undertake comprehensive Federal-State planning as a basis for coordinated conservation and development of the surface and subsurface waters of the Nation's streams, rivers, lakes, and underground water aquifers. That significant legislation, strongly endorsed by President Johnson, will enable the people of this country through their State and Federal Governments to plan wisely for optimum beneficial multipurpose use of the Nation's water resources.

(*c*) The Water Resources Research Act authorized the Secretary of the Interior to work with the States in establishing water resources research centers designed to meet the problems of State and local interests.

(*d*) The Water Resources Planning Act established the Cabinet-level Water Resources Council to plan the most efficient use of our portion of this planet's water. President Johnson has designated Interior Secretary Udall as the Chairman of the Council, the other members being the Secretaries of Agriculture, Defense, and Health, Education, and Welfare, and the Chairman of the Federal Power Commission.

(*e*) The Senate Interior Committee in 1964 held general hearings on weather modification as a basis for increased appropriations to the Bureau of Reclamation for undertaking engineering and applied research in atmospheric water resources. The practical program of the Bureau of Reclamation gives great promise on operational levels and is designed to determine the economic feasibility of increasing the water supply available to reclamation projects, through the application of weather modification techniques, for the purpose of increasing the precipitation in the headwaters of drainage basins providing the inflow to reclamation reservoirs.

Other areas of water resources where the Department of the Interior is receiving added assignments include the Federal Water Project Recreation Act which places outdoor recreation and fish and wildlife on an equal basis with other major purposes in Federal water resources projects. Interior's Bureau of Outdoor Recreation will direct the planning of these projects together with its former task of river basin planning.

President Johnson's message to the Congress on February 23, 1966, relating to the pollution of our waters and proposing a clean-rivers demonstration program,

will add substantially to the nationwide responsibilities of the Department of the Interior. The President stated that he would shortly submit to the Congress a reorganization plan to transfer to the Department of the Interior the Water Pollution Control Administration now housed in the Department of Health, Education, and Welfare. The President then emphasized that the logic of good government requires the integration of water resources efforts and responsibilities. He stated:

"Today the Department's water management programs range from saline water research to irrigation. It is responsible for wildlife preservation, and for administering the national park system. Its Secretary serves as Chairman of the Water Resources Council. Thus its present task, and the logic of good government, requires that it be entrusted with an important new effort to clean and preserve entire river systems."

The proposed legislation to authorize the Secretary of the Interior to carry out a comprehensive program for increasing the yield of water from atmospheric sources would be in keeping with "the logic of good government" stressed by the President. It is in the light of this philosophy that the Senate Subcommittee on Water and Power Resources proposes to undertake its comprehensive hearings.

The Select Committee on National Water Resources reported to the Senate in 1961 that large areas of the United States face increasingly critical water shortages. Water supply limitations for a large part of the Nation may in fact curtail economic opportunities for economic and population growth by 1980. These include the south Pacific area in California, the Colorado River Basin, the San Juan Pecos, the Great Basin, and the Upper Missouri River Basin.

Other areas will be short by the year 2000. In recent years the Great Lakes have been plagued with falling water levels with serious domestic as well as international effects. The aging of the lakes has become extremely serious. And the unprecedented drought in the Northeast during the past 5 years has demonstrated that other parts of the Nation are not immune to damaging droughts and serious water supply problems.

Great projects on an international scale like the North American Water and Power Alliance (NAWAPA) are being proposed to meet part of these pressing problems. Scientific reports now indicate that effective utilization of our atmospheric water resources should be considered as another component in developing overall plans for the sound use of al water resources.

The proposed legislation would also move forward on recommendations contained in two comprehensive scientific reports recently released, one titled "Water and Climate Modification, Problems and Prospects" by a panel of distinguished scientists assembled by the National Academy of Science-National Research Council, and a second report titled "Weather and Climate Modification" by a Special Commission on Weather Modification established by the National Science Foundation. These two reports call for great expansion in the engineering and research efforts in all phases of weather modification.

These important reports have been widely reported in scientific and popular journals. The January 28, 1966, issue of Science states:

"The lack of a scientific consensus on the value of cloud-seeding experiments has had a discouraging effect on proposals for greater Government involvement in weather modification. The missing consensus may now be taking shape, however, as a result of a report issued last week by a prestigious panel appointed more than 2 years ago by the National Academy of Sciences.

"The NAS panel, chaired by Gordon J. F. MacDonald, professor in the Institute of Geophysics and Planetary Physics at the University of California, Los Angeles, has substantially revised its own previous views about cloud seeding."

The January 31, 1966, issue of Newsweek states:

"The change in the climate was rather precipitous, to say the least. Just last May, President Johnson had complained of the 'slow pace' in attempts to modify the weather to man's benefit, and last week, the scientific group that has been so skeptical about rainmaking and other techniques suddenly announced weather modification is possible after all."

In the words of the National Academy of Sciences-National Research Council report, volume 1, page 22:

"The available evidence, though not conclusive, indicates that artificial nucleation techniques, under certain meteorological conditions, may be used to modify the space or time distribution of precipitation. Specifically, we find some evidence for precipitation increases of as much as 10 or 20 percent over areas as large as 1,000 square miles over periods ranging from weeks to years."

It is believed that these reports, prepared after several years' work by distinguished scientists, provide a valid basis for confidence that an atmospheric water resources program can be effective and beneficial. To illustrate, the report of the Special Commission on Weather Modification of the National Science Foundation states:

"With respect to the scientific prospects for the future, the commission finds that attractive opportunities exist. Advanced experimental techniques and application of sophisticated concepts in statistical design promise to reduce the present uncertainty in the interpretation of field experiments. The scientific exploration of weather and climate modification is passing from a speculative phase to the rational phase. Within reach are mathematical and laboratory modeling techniques that permit the simulation of atmospheric processes. By these means it should become possible to assess in advance the probable consequences deliberate intervention. An expanded program of basic and applied research is needed to take advantage of these scientific opportunities."

With respect to the size of the program, the report states on page 129:

"The Commission recommends that the total current fiscal year 1966 budget for climate and weather modification research of approximately $7.2 million be increased by 1970 to $20 to $30 million, or approximately 5 percent of the total current fiscal year 1966 budget of $500.6 million, for both atmospheric sciences and meteorological services. Additional increases of the same order are needed for basic research and for large computing facilities, making a total increase of $40 to $50 million per year by 1970."

The report of the Panel on Weather and Climate Modification of the National Academy of Sciences previously referred to makes a comparable recommendation on page 22:

"We recommend that immediate steps be taken by the agencies to raise the support from the 1965 level of $5 million to at least $30 million by 1970.

"This recommendation is based on a rough estimate of the cost of needed research with emphasis on field research programs. Further progress in weather modification will depend in a critical way on progress in understanding the atmosphere, and in extending our capability for predicting atmospheric phenomenon both in time and on a local scale. Increased funding in weather modification should, therefore, be accompanied by a commensurate increase in funding for the supporting atmospheric sciences and for the development and operation of supporting research facilities and systems, including new computers and observational networks for stimulating atmospheric circulation."

The NSF Commission report further states on pages 29–30:

"There should be a concerted effort directed specifically at the development of what may be called the technology of weather and climate modification. This is a sector in which a conspicuous gap is becoming evident. The objectives should be early development and testing of techniques by which deliberate intervention in atmospheric processes can be accomplished and consideration of the likely consequences of human activity in inadvertent intervention. Large-scale undertakings with substantial logistical support will be required and close liaison will be desirable with the social, biological, and other related studies.

"There should be provision for operational application by both the public and the private sectors as the feasibility and efficacy of modification techniques are validated.

"There should be such regulation as may be required to protect the public interest and advance the state of the art. Admittedly, it is difficult to arrive at a judgment on such matters as the timing and necessary scope of regulation and the form of administration. In the opinion of the Commission, however, it is not too soon to deal with this matter of providing flexibility for adaptation to changing needs.

"In the light of the above program, the following considerations with respect to funding appear to be relevant:

"Federal financial support for research and development activities in weather and climate modification need to be increased substantially above present levels."

A year ago President Johnson advised the Congress that substantial progress had been made in weather modification "but the pace has been slow. To advance the rate of progress, an effort of larger scope and direction is needed both in conducting basic research and in developing means to put the knowledge to work." Success in weather modification will inure to the credit of the interest, initiative, and understanding of the Congress in offering encouragement and support to this worthy and important research.

In this connection, the National Science Foundation is playing an important role in supporting fundamental or basic research in weather modification. The programs carried out by the Foundation over the years are responsible for the scientific progress that is now finally being widely recognized. These programs have established a solid foundation for the challenging opportunities of drawing on atmospheric water resources for the benefit of all mankind. In major respects, the basic scientific support of the National Science Foundation and the engineering and applied research and development of the Bureau of Reclamation are complementary—not competitive—programs. For these reasons, the legislation proposed by Senator Anderson and 20 other Senators would in no way alter the existing responsibilities of the National Science Foundation in the field of weather modification. In the years ahead, there will be even greater justification to support substantial increases in the basic research and scientific training programs in weather modification of the National Science Foundation.

While it should be clearly understood that the engineering and scientific research should be supported on a sustained basis over a period of years, in the final analysis the objective must be to provide for the economical and coordinated use of atmospheric water resources in the wise management of the Nation's total water supplies. In other words, the end objective is the development of operational systems that can be installed where needed not only in the United States but also throughout the world where improved water supplies are needed.

It should be empasized that an expanded atmospheric water resources program in the Interior Department will require the help and cooperation of other Federal agencies such as the Weather Bureau and other organizations of the Environmental Science Services Administration, the Department of Agriculture, and the Defense Establishment.

The new look of weather modification today will surely result in a number of other legislative proposals. Many other Federal agencies will, of necessity, be conducting expanding programs in the field of weather modification. Accordingly, one can expect that the other mission-oriented agencies will be before other House and Senate committees for legislative authorization and program support. But the field of atmospheric water resources is ideally suited for research and development by the Department of the Interior. The field of weather modification represents an essential part of the Department's responsibilities in water resources and as such is properly the concern of the Senate Interior Committee.

The late Senator Robert S. Kerr, chairman of the Select Committee on National Water Resources, said in 1960 that "It is clear that a water resource development task of great magnitude lies ahead of the Nation." The wise development and use of atmospheric water resources represents an important segment of that task.

In considering what proper use of atmospheric water resources could mean to this Nation, one can reflect on the wise comments of the scientists of Interior's Geological Survey that "most resources are practically as limitless as man's imagination, ingenuity, skill, and knowledge permit. Resources used by man are created largely by human inquiry—by research that finds new uses for previously valueless materials, that finds resources that could not be found before, and that provides ways to extract and refine materials that formerly could not be exploited profitably * * *. The quest for knowledge about our resources must be a never-ending one. And, because our population and per capita consumption of raw materials and energy are growing, we must increase our research to meet the Nation's aims of economic growth."

S. 2875 has been drafted to carry out the rainfall augmentation recommendations of the National Science Foundation Special Commission and the Panel of National Academy of Sciences. The bill also provides for two other requirements recommended in the reports for NSF and NAS: First, protection from liability, and second, regulation of atmospheric water resources activities. These two needs are provided for in the bill, although perhaps not in the detail or with the specificity that they should have after hearings and committee consideration.

Through this proposed legislation, the Senate is opening up tremendous opportunities for meeting the water needs of the Nation for economic growth and the well-being of its people. The Government's management structure in water resources will be strengthened and shaped to meet the challenges ahead.

Senator ANDERSON. Senator Bible has a statement for the record.

STATEMENT OF HON. ALAN BIBLE, A U.S. SENATOR FROM THE STATE OF NEVADA

Senator BIBLE. Mr. Chairman, I have given continuous and active support to weather modification programs to increase water resources throughout my more than 10 years in the U.S. Senate. I continue to believe that man can solve many of his water supply problems through weather modification techniques. The rewards, we all know, can more than justify the investment.

Despite many advances in this field, I must agree with President Lyndon Johnson's recent statement that "the pace has been slow." We need to speed up the pace—speed it up dramatically. I hope this legislation which is now before this committee will help achieve that goal.

Certainly one effective means of speeding up our efforts to bolster water resources through weather modification is to establish one central point of direction and coordination. We must control our various efforts even as we hope to control the climate.

It seems obvious to me that the Department of the Interior is the logical point of direction and coordination for the broad atmospheric water resources program. This is the Department that is so deeply involved in water resources research, reclamation, and conservation. Within it, the Bureau of Reclamation is currently pursuing an active program to increase Colorado River streamflow through "rainmaking" activities in the upper basin. Other agencies within the Department of the Interior are actively engaged in allied work. President Johnson, in a recent message to Congress, gave further recognition of the Department's eminence in water resources responsibilities by recommending the transfer of the Water Pollution Control Administration from the Department of Health, Education, and Welfare to the Department of the Interior.

As you know, I was instrumental in securing additional appropriations to accelerate Bureau of Reclamation atmospheric work in the Colorado River Basin. This is because I feel this effort is an extremely valuable pioneering project and because I know that even a small measure of success can bring tremendous benefits to this chronically water short region.

As I stated at weather modification hearings in 1964, data supplied by the Bureau of Reclamation indicate the benefits of increased rainfall through "rainmaking" could be amazing. One additional inch of precipitation above Glen Canyon Dam would produce a runoff of 575,000 acre-feet. This extra amount of flow through Federal powerplants could boost income, on established power rates, by $2.5 million. Naturally, this additional water would be available for agricultural, municipal, and industrial uses. Allowing for losses in runoff, this added inch of precipitation would still supply 500,000 acre-feet for irrigation which, based on a 1962 water-crop-benefit formula, would produce a gross crop income of $25.7 million. Municipal and industrial uses would raise the total value even more to a grand total of something approaching $30 million.

To date our efforts in the field of weather modification has been as diverse as the subject itself. This diversity is underscored and the need for coordination emphasized in the National Science Founda-

tion's Seventh Annual Report on Weather Modification. I would like to have the portion of the opening chapter subtitled "A Broad-Based National Program" included for the record at this point:

A BROAD-BASED NATIONAL PROGRAM

The term "weather modification," of course, covers a broad range of possible activities, with varying probabilities of success and varying time scales for the essential preliminary research and development. It includes the dispersion of supercooled fogs, which, on a pilot basis, has already been accomplished at airports. It includes cloud seeding of most air masses as they are lifted by mountain ranges, a technique which appears to produce at least modest increases in winter snowfall, despite the fact that we do not yet sufficiently understand why. It includes the suppression of hail, a field in which a national program of research and development is now being planned. It includes an attempt to modify hurricanes, for which there is as yet no evidence of feasibility. It includes attempts to increase precipitation from summer showers and thunderstorms, which have been tried with thus far equivocal results, but in which recent evaluations present more optimistic prospects than previously. It includes attempts to influence the paths of storm tracks to help alleviate drought—a field of inquiry in which the path toward applications is sufficiently long, and the possibilities are so diffuse, that a decade or more may be required to determine whether or not such large-scale efforts are economically feasible. It includes determining the extent of inadvertent modification that is now in process through the exhausting of fossil fuel gases into the atmosphere, the conversion of large rural areas to cities and suburbs, and the injection of jet aircraft exhausts into the atmosphere at jet-stream altitudes.

At the present time a realistic weather modification program must therefore be evolved from a whole range of potentialities, each of which must be approached individually in terms of scientific planning and research; technical development; the odds for, and value of, ultimate successful application; and the time, effort, money, and manpower required.

In designing a national program built on these diverse potentialities, the critical task is to preserve the proper balance among them, utilizing the proper proportions of scarce manpower and dollars in (1) making the best use of current knowledge; (2) continuing the vigorous acquisition of basic knowledge and engineering capabilities that will lead to subsequent applications; (3) continuing the expansion of the reservoir of trained manpower upon which, a decade or two hence, the execution of a major national effort will depend; (4) foreseeing and finding ways to avoid or solve the social and economic problems, both national and international, that successful weather modification techniques can create.

Too much emphasis on short-range objectives would make it more difficult to reach such longer range objectives as determining the feasibility of large-scale climate modification that may prove to be of far greater value. Too little emphasis on such short-range objectives as improving methods of orographic cloud seeding would delay the beneficial application of current knowledge.

The existing national effort in weather modificaiton has emerged piecemeal from the interests of various groups within the scientific community, various commercial operators, and various Federal agencies. Nonetheless, a rough, healthy balance, such as described above, has emerged. In the national interest, therefore, the future task should be to build on this modest but sound beginning by increasing coordination among Federal agencies (through such instrumentalities as the Interdepartmental Committee for Atmospheric Sciences, a subgroup of the Federal Council on Science and Technology), and by improving interactions among the scientific community (especially the universities), private industry, the Federal agencies that must play the leading role of sponsorship, and all the economic and political bodies which will be the users of weather modification techniques as they are developed.

As a further example of the diversity—and often the confusion—involved in weather modification, I should like to submit for the record a recent memorandum from my legislative assistant that highlights the difficulty of appropriating for the various programs with any degree of efficiency and coordination; and I ask that it be inserted at the close of my statement.

In summary, Mr. Chairman, I wish to underscore three major points: Clearly, the water resource potential of weather modification is worth heavy investment.

Clearly, the Congress must provide for effective direction and coordination of the many activities in this broad field.

And clearly, legislation along the lines of the bill before this committee is essential to implement these policies.

The memorandum follows:

MEMORANDUM

SEPTEMBER 13, 1965.

To: Senator Bible.
From: Joe T. McDonnell.
Subject: Weather modification.

I. BACKGROUND

The term "weather modification," unless adequately defined, creates the same confusion as does the term "small business." With regards to the latter, everyone is for small business, the difficulty arises when one uses this term without first defining what it means. To one person it means the small store; to others it means anything short of General Motors.

The term "weather modification" is subject to the same confusion if not more so. On the one hand it must be emphasized that this term cannot be narrowly defined; this for the reason that the successful achievement of true weather modification depends upon scientific knowledge that man has not acquired knowledge about atmospheric processes ranging from the interactions of minute water droplets to the behavior of global circulations. Further, in acquiring the needed techniques, almost every field of scientific endeavor will continue to make important contributions so that we may literally change our physical environment.

The goal of weather modification research is perhaps most succinctly stated in the "Sixth Annual Report of the National Science Foundation Relative to Weather Modification" (House Doc. No. 188, 89th Cong., 1st sess.) as follows:

"Indeed, it is well to make clear the significance of the goal that is sought and which may (no more certain word can yet be used) be within man's reach. This is the ability to alter the weather and the climate in which men live, to diminish the incidence of violent storms, and to change large-scale air circulations in ways that will bring adequate precipitation to areas that are now semiarid or desert. In brief, it may be possible, with imaginative, long-term effort, to change the face of the earth itself by altering the large-scale features of the weather.

"This is an undertaking whose rewards to mankind and whose scientific and engineering challenges rank with those of developing peaceful uses of nuclear energy or placing a man on the moon. But weather modification is several steps behind atomic energy and the exploration of space. The scientific principles of nuclear reactors and space travel are well in hand; the problems we now face in these pursuits are—though of high complexity—mainly engineering. But the achievement of large-scale weather modification depends upon scientific knowledge we have not acquired, knowledge about atmospheric processes ranging from the interactions of minute water droplets to the behavior of global circulations.

"The atomic age is now in its third decade; however, atomic power is still without widespread peacetime applications. Space exploration will be well into its second decade before man sets foot on the moon. Such efforts consume the energies of a generation. It is not surprising that the achievement of the full potential of weather modification will probably take a similarly long time.

"While substantial progress has been made, both in acquiring fundamental knowledge of the atmosphere and in developing engineering applications, the pace has necessarily been slow. If we are to evaluate and exploit the potential of weather modification in our lifetimes in order to help solve problems of resource management and world population before they become critical, the effort in atmospheric research, both fundamental and applied, must be accelerated. To achieve this acceleration means placing a higher national priority on the goal of weather modification than has yet been done."

In lay language, some of the goals of weather modification research may be categorized as follows:

(1) Determining the basic underlying mechanisms of why a cloud or clouds or a particular storm or storm system results in rain or snow under given environmental conditions, both natural or man made.

(2) Creating more moisture from rain or snow in a specific area under controlled conditions and the prediction with reasonable accuracy of the projected results.

(3) Changing the physical characteristics of cloud formations and storm systems so as to minimize or eliminate the harmful aspects such as lightning, hail, over condensation of moisture in areas that have ample water so as to pass the moisture inland to areas that suffer from an undersupply or a shortage.

(4) Altering the physical characteristics of violent storms (e.g., hurricanes) so as to dissipate and/or steer such storms so as to minimize damage.

(5) Ultimately, achieving the ability to control or beneficially modify global weather systems. This will require a degree of international cooperation that cannot now be visualized as, in addition to scientific cooperation, political cooperation will be vital.

The vital need to fully understand what is mean to be embraced in the term "weather modification" is illustrated by the following excerpt from the very recent hearings before the Senate Subcommittee of the Committee on Appropriations for the Departments of State, Justice, and Commerce, the Judiciary, and related agencies, 1966:

"Senator McCLELLAN. All right. Come around, Mr. Secretary. How many agencies or departments are reporting on weather?

"Dr. HOLLOMON. The total number of agencies that do some work on the weather—that is, either research, or observations, or spend some money having to do with the weather—are 13.

"Senator McCLELLAN. Thirteen?

"Dr. HOLLOMON. Yes, sir.

"Senator McCLELLAN. They are what different departments?

"Dr. HOLLOMON. I don't know that I can name them all.

"Senator McCLELLAN. You have so many that you can't name them?

"Dr. HOLLOMON. I will give a try at it to see if I get up to 13. The Department of Commerce, the Federal Aviation Administration, the Atomic Energy Commission, the Navy, the Army, the Air Force, Interior, National Science Foundation, Department of Agriculture, at least, and there are several more.

"Senator SMITH. Mr. Chairman, I have before me a copy of Parade magazine for May 30, which has a story that list 17 agencies spending on weather a total of $431.5 million. Would that come pretty near it?

"Dr. HOLLOMON. I think, Senator Smith, that there is a little bit of confusion in that article. It includes also some basic research having to do with the upper atmosphere and so on that is not usually included in the weather operation. If you would like, I will have submitted for the record exactly how much the total amount of money that is spent throughout the Government on the weather if you would like that.

"Senator SMITH. Are you referring to the NASA account?

"Dr. HOLLOMON. I am referring to some of the basic research that is done in NASA that is not normally considered, for example, as part of the weather.

"Senator SMITH. One of the reasons I have been a great supporter of the NASA program is that I had hoped out of it would come better and more improved, more correct weather reporting.

"Dr. HOLLOMON. Right.

"Senator SMITH. So I would say that is very definitely a weather service, Mr. Chairman.

"Senator McCLELLAN. Let this article or table at least be printed in the record with proper identification of it so that the record will reflect what we are talking about. Do you want the whole article in the record?

"Senator SMITH. I have not read the article through, Mr. Chairman.

"Senator McCLELLAN. Let the table, at least, be printed in the record, and identify it so that we will know what the witness is testifying about.

"(The table referred to follows:)

"Table on weather expenses by agencies, as reported by Fred Blumenthal in Parade magazine of May 30, 1965

Agency spending on weather	*Millions*
1. Air Force	$128.4
2. Weather Bureau	103.8
3. NASA	75.4
4. Navy	35.5
5. Federal Aviation Agency	21.0
6. National Science Foundation	20.7
7. Army	16.0
8. Atomic Energy Commission	8.5
9. Defense Advance Research Projects Agency	5.2
10. Treasury	4.5
11. National Bureau of Standards	4.0
12. Defense Atomic Support Agency	3.0
13. Health, Education, and Welfare	2.0
14. Interior	1.9
15. Defense Communications Agency	.8
16. Agriculture	.5
17. State	.3
Total	431.5

"COORDINATING GOVERNMENT ACTIVITIES ON WEATHER OPERATIONS

"Dr. HOLLOMON. Mr. Chairman, also I think it should be brought to the attention of the committee that about a year or so ago the President and the Bureau of the Budget assigned to the Department of Commerce the responsibility of trying to make some improvement in coordinating the activities throughout the Government in the case of weather operations. We have gotten together. This activity is now underway. There is a man called the Federal Meteorological Coordinator with a small staff who has made some real progress in this direction and his first report has been submitted to the Congress indicating some improvements in the coordination of the activity and hopefully some very real reductions in the cost of some of these activities. There is an attempt to coordinate all the activities of the 13 or 17 agencies that work in this field.

"Senator MCCLELLAN. We are spending over $400 million in the field of weather. A sum like that is a tremendous amount.

"Dr. HOLLOMON. It is.

"MERGER OF FUNCTIONS ON WEATHER OPERATIONS

"Senator MCCLELLAN. There are 13 or 17, whatever the number is, different agencies. It does occur to me that there could be a consolidation, a merger of these functions, reorganized in 2 or 3 areas, in 2 or 3 localities, instead of 13 or 17, and we would get better service and get a little economy in it as well as greater efficiency. You say some study was started a few years ago?

"Dr. HOLLOMON. A year or so ago.

"Senator MCCLELLAN. What progress has been made?

"STUDY BY FEDERAL METEOROLOGICAL COORDINATOR

"Dr. HOLLOMON. Some very real progress has been made. We can submit for the record the progress.

"Senator MCCLELLAN. I think you should. Because I think it is sprawling and getting out of hand. We ought to eliminate the duplication and provide even better reporting for less than all of this is costing. I know some of this is research and some research is desirable. We ought not to discontinue research. We should enlarge the research program some.

"(Letter from Assistant Secretary Hollomon on weather modification:)

" 'THE ASSISTANT SECRETARY OF COMMERCE,
Washington, D.C., June 18, 1965.

" 'Hon. JOHN L. MCCLELLAN,
Senate Appropriations Committee,
U.S. Senate, Washington, D.C.

" 'DEAR SENATOR MCCLELLAN: At the appropriations hearings this week, I was asked to submit for the record information as to the current programs supported by the Government agencies in weather modification.

" 'I am very happy to supply the following program information (the fiscal year 1966 data represents the submissions to the Congress):

" '[In thousands of dollars]

	Fiscal year 1965	Fiscal year 1966
Department of Agriculture—Project Skyfire to modify thunderstorms in ways that will decrease the number and intensity of cloud-to-ground lightning	120	180
Department of Defense—The modification of warm fog, the study of the basic mechanisms of precipitation particularly in convective clouds, modification of the electrical field of thunderstorms, development of efficient pyrotechnic type nuclei dispensers for seeding convective type clouds and joint operations with the Weather Bureau in Project Stormfury	1,330	1,200
Bureau of Reclamation—Engineering research to develop techniques for enhancing precipitation in orographic storm situations and convective clouds	1,100	1,230
Weather Bureau—Project Stormfury, a joint project with the Navy for modifying some characteristics of hurricanes and tropical cumulus clouds through seeding, and the development and modification of mathematical models of atmospheric processes	115	750
National Science Foundation—Basic investigation into the effects of various techniques of seeding with various types of nuclei, the development of an adequate theory of turbulence, the study of the behavior of various aerosols including the development of adequate analysis techniques, the study of various aspects of droplet coalescence processes including electrical and shock effects	2,010	2,000

" 'Sincerely yours,

J. HERBERT HOLLOMON.'

"WEATHER MODIFICATION

"Senator BIBLE. Might I ask one question, Mr. Chairman, as long as you are on this subject? I have spent some time in this field of weather modification which is within this overall weather problem. I know the Department of the Interior this year is spending something like $1,200,000, and I think in close cooperation with the Weather Bureau and National Science Foundation and other agencies, but I see you have an item on page 10 asking for additional funds of $700,000 for weather modification studies. I wish either you or someone else within the Weather Bureau might indicate exactly what you are going to do with that $700,000. Possibly you are the right witness. Maybe somebody who follows you is the better witness; I don't know.

"Dr. HOLLOMON. I think I can give a very brief statement and when Dr. White from the Weather Bureau is here, he can elaborate on it, but briefly, the Interior Department is primarily concerned with making more water. We are concerned in this program primarily with the elimination of storms, how to modify storms, hurricanes, tornadoes, hailstorms that cause great damage. That, in a nutshell, is the major difference in the programs.

"Senator BIBLE. I wonder, Mr. Chairman, if it is not possible to pursuance of the request you made of the Secretary, to have him furnish the same information on the more narrow subject of weather modification, how many are actually working in weather modification."

It should be noted in the above extract that Dr. Holloman and both Senators McClellan and Smith, until you raised the specific subject of weather modification, were speaking of weather observations, weather forecasting, weather operations, and so forth. Further, compare the table inserted in the record by Senator Smith from the May 30, 1965, issue of Parade magazine on "Weather Expenses

by Agencies" showing a total of $431.5 million being spent on "weather" by 17 agencies. However, note that as a result of your questioning, Dr. Holloman submitted for the record a table showing those agencies engaged specifically in weather modification. This latter table shows 5 agencies instead of 17 and for fiscal year 1965 a total of $4,675,000, instead of $431.5 million for modification research.

II. ATMOSPHERIC WATER RESOURCES RESEARCH—BUREAU OF RECLAMATION

For this activity for fiscal year 1966, the budget estimate was $1,230,000. The House increased this amount by $1 million for a total of $2,230,000. The Senate approved an increase of an additional $1,500,000 over the House for a total of $3,730,000. Of the amount allowed by the Senate, $500,000 was earmarked in the committee's report "for the application of existing weather modification methods for the actual production of water." During the hearings on this item, the following testimony was elicited from the officials of the Bureau of Reclamation as a result of questions posed by you and Senator Mundt in support of the additional million dollars added by the subcommittee. (The additional $500,000 was not added until the full committee markup on a motion of Senator Allott on behalf of Senator Dominick and himself.)

"FISCAL YEAR 1966 FUND REQUIREMENTS

"Senator BIBLE. I think you testified a year ago that in this present fiscal year 1966 you anticipated a funding of something in the neighborhood of $2,230,000.

"Mr. DOMINY. That is correct, sir. If we were to carry on the work in fiscal 1966 at levels already underway in 1965, we would need $2,230,000. In launching a plan under this program the first year we did not have 12 months—we had about 7 or 8 months of effectiveness at the maximum and we had to staff up and get all of our contracts negotiated in that short period.

"EFFECT OF REDUCED BUDGET

"Senator BIBLE. Is there an existing capability to expend $2,230,000?

"Mr. DOMINY. Yes, sir. As a matter of fact, if we have a budget of less than $2,230,000, we will have to eliminate some of the work that is projected under existing contracts.

"Senator BIBLE. That was the next question that I was going to get to, because we, out in Nevada, are very proud of the Desert Research Institute. They have surrounded themselves with a staff of men very knowledgeable in this field. And as I understand it, they hold a contract with the Bureau for something in the neighborhood of $300,000 for fiscal 1966. Obviously, if this is funded at $1,230,000 rather than $2,230,000, there will have to be a cutback in that contract which, in turn, means that when you get down into the field that the Institute will be required to let a certain number of their highly specialized employees out in the Desert Research Institute, and I know that will be detrimental to their program.

"Mr. DOMINY. I agree that where we staff up with trained people and program over a period of years, it is very unfortunate if we are not permitted to carry through. For example, in the case that you cite under the budget this year before you at $1,230,000, we would have to reduce the expenditures to the University of Nevada from the projected $300,000 down to $140,000 and, as you say, this would mean that they would have to be laying off the very staff that they have just recruited and got organized to do a bigger job.

"Senator BIBLE. I could not agree with you more. And I emphasize, Mr. Chairman, that I think that if it is at all possible we will have to hit some fair amount of funding for a period of years, so that the universities that gear themselves to a project are not going to be required or compelled to leave some of their very valuable staff go. I know that you are going to develop what we have done for this $1.1 million. You have done that. But are we getting closer to breakthroughs? Where do we stand in this overall weather modification atmospheric research?

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"FISCAL YEAR 1966 CAPABILITY

"Senator BIBLE. Might I ask, can you beneficially spend another $1 million?

"Mr. GARSTKA. We could spend more than that. We could use up to $3.5 million if we are going to move rapidly, because we have an unusual group of people who are enthusiastic and are at a very high temperature in their enthusiasm throughout our system; they are working around the clock. This is an activity in which anything that we do is going to cost money, and it is cheaper to spend sufficient money now and do it right, than to stretch it out over a period of time, thus spending more in the end and still not getting even near the results.

"LONG-RANGE PROJECTION

"Senator BIBLE. You put a 10-year period on it. I know that this is a tough question, but we will be asked how many years we are going to spend $2.5 million a year of $3 or $3.5 million; 10 years, 20 years?

"Senator MUNDT. Until you solve the problem.

"Mr. GARSTKA. Until you are satisfied that we are getting our money's worth for the investment. In the end the decision is one of economics. Is the activity worth what it costs? This is what we are out to determine. There is no doubt now that we can make it snow. We do not know how to make it rain in a warm convective system. We do not know enough about storm paths. What we want to do is to pursue it aggressively, now, to get some of these answers and then we will make the decision as to whether we continue or not. Ten years is a reasonable estimate. We may attain it much sooner in some cases if we are lucky and have sufficient finances to keep the group working without letdown.

"LEVEL OF FINANCING REQUIRED

"Mr. DOMINY. You will remember that last year, Senator Bible, I indicated that a 10-year period was minimal, and that it ought to be financed in the range of $2.5 to $5 million a year, depending on what we began to uncover and what our capabilities were demonstrating to be in terms of manpower and advances in the research project. We are prepared to push this program at whatever level the Congress determines to be desirable. We need a minimum of $2,230,000 to continue it at the level we are presently launched on. If you want to expand, for example, into other areas for additional research, or to try to push the research a little faster in the existing areas, then we need more than $2,230,000 for fiscal year 1966.

* * * * * * *

"Senator MUNDT. Like Senator Bible, with whom I have been associated closely in trying to move this program forward, I was disappointed at the budget request of $1,230,000. This would represent a cutback, and I understand that for the present staff to do what we are attempting to do would require $2,230,000 as the minimum.

"Mr. DOMINY. That is correct.

"Senator MUNDT. Suppose that we added $1 million to that minimum. What would you be able to do in addition in this area of activity?

"Mr. DOMINY. If we were to go up to a program level in fiscal year 1966 of about $3,350,000; for example, we would increase the work of South Dakota, we would increase the southern Sierra program—we would increase the participation of the U.S. Geological Survey, and of other Federal agencies such as the Navy, the Forest Service, the Soil Conservation Service, and the Weather Bureau. The State of Washington activity, would be broadened to make a further advance as the Pacific Northwest investigation in Washington and Oregon. We would increase substantially the Wasatch Mountain program, and we would step up the Arizona and the Rio Grande and San Juan activities. These are the principal areas that we felt we could expand and in which we would have capabilities to expand with good prospects of making quicker progress.

"Senator MUNDT. I took that figure of $1 million off the top of my head. Do you have a capability beyond and in addition to $1 million.

"Mr. DOMINY. I think we could produce the capability but I would not want to attempt to step the program up more than about $1 million above the $2,230,000 which we had originally projected for 1966."

EXHIBIT 1

ATMOSPHERIC WATER RESOURCES PROGRAM FISCAL YEAR 1966 FUNDING AT VARIOUS LEVELS

1. Estimated utilization of proposed fiscal year 1966 by funds at various levels:

State	$1,230,000	$2,230,000	$3,230,000
Arizona	$60,000	$140,000	$200,000
California	110,000	160,000	300,000
Colorado	307,000	467,000	477,000
District of Columbia (Weather Bureau)	50,000	125,000	150,000
Nevada	140,000	300,000	420,000
New Mexico (anticipated)	0	10,000	50,000
Oregon, Oklahoma, Nebraska, and Montana (anticipated)	5,000	10,000	55,000
South Dakota	175,000	300,000	420,000
Utah	40,000	70,000	300,000
Washington	20,000	50,000	150,000
Wyoming	150,000	407,000	407,000
Neutron activation analysis, Denver	0	0	50,000
Program support and administration, Denver	173,000	191,000	251,000
Total	1,230,000	2,230,000	3,230,000

NOTE.—Entries are estimates subject to change upon passage of appropriation act and execution of mutually acceptable amendments to existing contracts and successful negotiations on activities not yet formalized.

EXHIBIT 2

SEPTEMBER 1, 1965.

STATEMENT ON GOVERNMENT-WIDE WEATHER MODIFICATION COORDINATION

The Bureau of the Budget, as part of its regulatory duties, reviews various Federal agencies' proposals for program funding.

Coordination was first initiated by the National Science Foundation under Public Law 85–510. NSF has held annual Federal interagency conferences on weather modification as reported in its annual reports. The next meeting of this conference is scheduled for September 30-October 1, 1965, in the vicinity of Washington, D.C. Dr. A. M. Kahan, of the Bureau of Reclamation, is a member of NSF Advisory Panel on Weather Modification, which deals with the NSF funded program.

The Department of the Interior has established an Advisory Committee on Atmospheric Water Resources consisting of outstanding scientists primarily connected with other Federal agencies, for the purpose of maintaining intimate liaison with the program funding by other Federal agencies.

The Federal Council for Science and Technology has appointed an Interagency Committee on Atmospheric Sciences (ICAS) which meets frequently for the purpose of gathering information for use by the Science Adviser to the President.

The Office of Water Resources Research of the Department of the Interior maintains liaison with the Bureau of Reclamation and with universities and industrial research activities through the Science Information Exchange and through the directors of its institutes. The American Society of Civil Engineers has recently established a weather modification committee in its irrigation and drainage division. The American Meteorological Society and the American Geophysical Union have from time to time used committees on weather modification, and their national and regional meetings, as a rule, contain programs and symposia on weather modification. Various State and local authorities are in communication with Federal agencies on weather modification activities of mutual interest.

Scientists and engineers in the Federal and State governments, educational institutions, and private industry fields are in continuous personal communication with each other, as is to be expected in a rapidly evolving and challenging activity potentially of great importance to the Nation.

EXHIBIT 3

AUGUST 31, 1965.

ATMOSPHERIC WATER RESOURCES PROGRAM FOR FISCAL YEAR 1966

Any effort to combine operational seeding with the engineering and scientific research experiments at this time would obscure or nullify research results. The Bureau of Reclamation in the short period of 1 year of its expanded program simply has not had enough time to develop or test operational seeding activities. Representatives of the Bureau have stated on a number of occasions that one or two decades of well-supported research may be necessary to the full development of economical methods of operational seeding. Within this period, however, the Bureau would expect to make recommendations to the Congress for operational seeding funds whenever discoveries or developments warranted.

However, if the Congress should provide funds for operational seeding at this time, the Bureau would establish a separate pilot-plant type of operation, prepare specifications for a seeding program, and employ by competitive contract an agency or contractor to carry out this additional program. Careful instrumentation would be necessary if the Government is to have ways and means of determining the effect of operational seeding on available moisture.

EXHIBIT 4

WEATHER MODIFICATION: NAS PANEL REPORT AND NEW PROGRAM APPROVED BY CONGRESS REVEAL SPLIT ON POLICY

(By John Walsh)

After World War II it was widely assumed that a great time of beating scientific swords into technological plowshares was beginning. Perhaps the most dramatic prospects of all were proclaimed for the peaceful atom and weather modification. But while men have taken giant steps toward mastering their environment, the two prodigies have hardly fulfilled the great expectations.

Now nuclear plants producing electric power have begun to operate in the black, the uses of nuclear materials in industry and medicine are increasingly impressive, and the civilian atom seems to be coming of age. Weather modification, however, remains in the research and development stage.

High hopes, nevertheless, continue to be held for doing something about the weather. Last year Congress, by special resolution, appropriated $1 million intended for use in the most ambitious "operational" weather modification program so far. But, at the same time, a National Academy of Sciences panel was completing a survey of research activities in the field and an estimate of the potential and the limitations of future research, and late last fall it issued a report[1] which put a damper on expectations of major triumphs in modifying the weather very soon.

The resolution and the report present a contrast which reflects a controversy over the pace and direction of the national weather modification program. This controversy could become increasingly significant, since it ranges a group of influential legislators on one side, some distinguished atmospheric scientists on the other, and several science-oriented Federal agencies in the middle.

The differences grow directly out of the modern history of weather modification, which began in the later 1940's with the well-known work of Langmuir and Schaefer on cloud modification. The Department of Defense financed sizable projects in 1947, and since then the Federal Government has been involved as a patron of research in this field.

From the outset, public interest in weather modification centered on rainmaking. By the early 1950's some of the early enthusiasm had waned, because of claims of success and refutations were about equally vociferous. But the armed services and the Departments of Agriculture, Interior, and Health, Education, and Welfare continued to sponsor or conduct research in atmospheric sciences

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[1] "Scientific Problems of Weather Modification," available from the Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Ave. NW., Washington, D.C., 20418.

related to weather modification. Conspicuously absent from the field was the Weather Bureau in the Department of Commerce, which under its former chief, Francis W. Reichelderfer, displayed a studied lack of interest in weather modification research.

In 1958 the National Science Foundation was designated by Congress to promote and coordinate projects in the necessary fields to insure an effective national weather modification program. Other agencies continued to support applied and basic research; NSF primarily supported studies designed to provide basic data.

(In fiscal 1963, total Federal expenditures for weather modification projects were $2.75 million, with some $1.3 million of that accounted for by NSF. For fiscal 1964, the total figure was $3.35 million, and the NSF figure, $1.57 million. NSF in fiscal 1963 spent slightly more than $16 million on its overall atmospheric sciences program, of which weather modification is a part.)

During recent years impatience has been growing in Congress, and particularly among a group of Western Senators who have felt that a sizable and long-term research program was not producing an adequate practical payoff.

Bills have been repeatedly introduced to launch "operational" programs in weather modification, usually aimed directly at cloud seeding. Last year Senator Clinton Anderson, Democrat, of New Mexico, introduced a bill authorizing the Secretary of the Interior to "conduct a program in five areas of the United States to increase the usable precipitation and for other purposes." Cosponsors were Senators Bennett and Moss (Utah), Bible and Cannon (Nevada), Engle and Kuchel (California), McGee (Wyoming), and McGovern (South Dakota).

Under the criteria governing the assignment of bills in the Senate, the bill was sent to the Commerce Committee, where it languished.

An effort to shift the initiative to the Interior Committee, which is dominated by westerners from dry States, was successful when the sponsors backed a resolution providing for an increase of $1 million in appropriations for the Interior Department for "exploration, research, and application of weather modification methods for the purpose of increasing precipitation in the Colorado River Basin."

Hearings were held last May before the Interior Committee's Irrigation and Reclamation Subcommittee, headed by Senator Moss, and the resolution was passed and then shepherded through the Senate Appropriations Committee by Senators Bible of Nevada and Mundt of South Dakota. The measure was added to the Interior Appropriations bill and accepted by the House.

The Colorado Basin was probably picked first for the scaled-down program for the reason that two very dry years had made the always difficult water problem there potentially desperate. But also the Senators and their advisers were convinced that the Colorado Basin provided promising conditions for a major test program aimed at increasing precipitation.

Encouraging reports have been coming in about results from seeding supercooled clouds, and the idea took hold that the so-called orographic storms over the Colorado Basin could be exploited. (Orographic cloud systems are found in areas where mountains in the path of moisture-laden air force the air to rise and cool.)

The hope was that precipitation from winter storms over the basin could be increased. If the program succeeded, the effect on the supply of usable water would be particularly favorable because of the extraordinary storage facilities in the basin. According to testimony at the hearings, an estimated 56 million acre-feet can be stored, about four times the average annual runoff.

While the National Academy's panel [2] on weather and climate modification did did not deal directly in any way with the new Colorado Basin program, its report amounts to a big wet blanket.

OPERATIONAL OBJECTIVES

The panel accepted the objective of promoting effective weather modification at the earliest possible date, but in the introduction to the report it summed up its outlook on weather modification this way:

"The striking development during the past 10 years of a number of new tools that produce intensely interesting effects, often involving the triggering of large

[2] Chairman of the panel is Gordon J. F. MacDonald of UCLA. Members are Julian H. Bigelow, Jule G. Charney, Francis S. Johnson, Edward N. Lorenz, Joanne S. Malkus, Joseph Smagorinsky, Verner E. Suomi, Edward Teller, Helmut K. Weickmann, and J. Workman.

releases of energy in clouds, in the atmosphere near the surface, and in the upper atmosphere, provides a basis for future efforts in weather modification. In the activities that have possible economic importance, our findings are as follows: it is possible to disperse stable clouds, such as supercooled fog and stratus, by seeding; it has not been demonstrated that precipitation from winter orographic storms can be increased significantly by seeding; it has not been demonstrated that hurricanes can be "steered" or diminished by seeding; it has not been demonstrated that asphalt coverings, black dust, or any other surface modifications increase precipitation. On the basis of these findings, we conclude that the initiation of large-scale oporeational weather-modification programs would be premature. Many fundamental problems must be answered first. It is unlikely that these problems will be solved by the expansion of present efforts which emphasize the *a posteriori* evaluation of largely uncontrolled experiments. We believe that the patient investigation of atmospheric processes coupled with an exploration of the technological applications will eventually lead to useful weather modification, but we must emphasize that the time-scale required for success may be measured in decades."

The panelists make the general observation that despite advances made in the last two decades, scientists at present do not have "an adequate physical description of the precipitation process."

The body of the report is divided into four main sections, headed "Problems of Cloud Modification," "Surface Modification as a Means of Stimulating Convection," "The General Circulation of the Atmosphere," and "Contamination or Modification of the Upper Atmosphere." The discussions in these sections touch on such potentially practical aspects of weather modification as mitigation of hail by seeding, lightning suppression, hurricane suppression, and fog dissipation, as well as rainmaking. Only in the case of supercooled stratocumulus and fog, where cloud modification processes are reasonably well understood, are operational studies recommended. The report is a preliminary one, and the panel, which was appointed by the Atmosphere Sciences Committee of the Academy, plans to issue a final report by summer. This final report is expected to include recommendations on long-range policies and objectives for the national weather modification program.

Meanwhile, the Colorado Basin program is obviously making some scientists who are concerned with weather modification apprehensive.

The program is being administered by the Department of Interior's Bureau of Reclamation, which deals with conservation, development, and utilization of water and related land resources in the West. Its scientific program in the past has focused mainly on various phases of reclamation engineering, and in the early 1960's it was estimated that about 7 percent of the scientific work supported by the agency was in basic research.

The Colorado Basin program is still in the planning phase, and it is not yet clear whether the Bureau will mount a test program designed to improve evaluative techniques or will go directly to a larger operational program, which presumably would involve extensive seeding of clouds.

The Bureau has set up a Committee on Atmospheric Water Resources, which draws members from the National Science Foundation, the Weather Bureau, and other Federal agencies, to consult on the program. Relations between the Bureau and other agencies at the moment are said not to be at their best. It is thought likely that the Bureau will look to outside institutions with which it has already developed ties, such as the University of Nevada, the University of Wyoming, and the South Dakota School of Mines & Technology.

On the other hand, the Bureau has a record of very substantial achievement in applying science and technology to the chief problem of the "reclamation States" of the West, and it is this record which has won the agency the Senators' confidence.

Advocates of an operational program also point to scientific backing from inside and outside the Government. In the hearing before the Moss subcommittee, for example, John C. Calhoun, science adviser to the Secretary of Interior, said in his statement on behalf of the Department, "in summary at this point, our evaluation shows that the time has arrived for larger scale, well planned field experiements."

Calhoun went on to say that part of the Department's role in weather modification should be sponsorship of a "continuing program primarily directed toward improving precipitation from winter storms." He added, however, that this program should be conducted in a "research atmosphere," and he later made

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the following cautionary observation. "To proceed into operational phases now without completely understanding the processes involved could lead to undesirable effects. These might range from decreases rather than increases in precipitation, to gross atmospheric contaminations leading to adverse weather and to possible handicaps to future research. So we believe it is essential that any new effort in weather modification be approached as carefully planned development research, which will take into account probable environmental consequences of experimental actions each step of the way."

A reading of the hearings produces the clear impression that the Senators believe the "well planned experiments" (in Calhoun's phrase) are likely to produce results that can be counted in acre-feet in Colorado Basin reservoirs and ponds. The legislators candidly state that a gamble is involved, but they appear convinced by the evidence that the gamble is worth taking.

The Moss hearings were short and to the point. Only representatives from the Interior Department and its Bureau of Reclamation testified. No nongovernmental authorities were brought in, and nobody from other Federal agencies engaged in weather modification research—including NSF—appeared.

SENATORIAL DISPLEASURE

Among those most closely concerned with weather modification on Capitol Hill, the attitude toward NSF in this context seems to be expressed by one observer who said the legislators and their staffmen feel that NSF has been "wishy-washy" on the subject of weather modification, because the agency kept recommending more research and the training of more weather modification researchers when the Senators wanted action.

While there has been no showdown, it is fair to say that a significant split on weather modification policy has developed. On one side are scientists who are sanguine about the eventual development of effective techniques to modify the weather but are opposed to large-scale "engineering" programs now, since they feel that there is no sound way to design such programs at this time. They oppose proceeding on a trial-and-error basis because of possible unfavorable effects such as those mentioned by Calhoun, and because it would disrupt an orderly program of research in atmospheric sciences. Some feel that this, ironically, could turn out to be a year of unusual high precipitation in the Colorado Basin and that the apparent success of a seeding program could lead to misleading conclusions.

On the other hand, the legislators and their advisers feel that a lot of time and money has been spent on weather modification research without important practical results or signs of an approaching breakthrough. The States in the Colorado Basin area have exploited the last water sources available to them now, and the advocates of the new program believe that there are sound scientific reasons for gambling on finding a shortcut.

Among at least some of these advocates, it should be noted, there is also a feeling that research scientists—one salty veteran staff member called them "the Cosmos Club crowd"—are more interested in producing more scientific papers, while the Senators are interested in producing more water.

Unfair as this may be, it nontheless reflects an attitude which lies beneath the surface of relations between Congress and the research establishment but may come into play when friction develops, as it has over weather modification.

Aware of the storm signals, NSF has a commission on weather modification, composed half of scientists and half of members distinguished in other fields, to survey the broad aspects of weather modification—legal, economic, biological, and sociological as well as scientific. The commission will make recommendations on long-range policy to the agency. The Weather Bureau is seriously reappraising its stand on weather modification. And the NAS panel hopes, next summer, to follow up its final report with an educational effort designed to make the status and prospects of weather modification research more widely understood.

While it should not be exaggerated, the current split on weather modification falls into the area of the problem of science advice for Congress. It represents, not a breakdown, but, rather, evidence that no adequate conduit between Congress and the community represented by the Academy and NSF has ever been soundly established.

EXHIBIT 5

[From the Nevada State Journal, Aug. 21, 1965]

WET NEVADA WEATHER HELPS DRY UP EAST

(By Don Murtha)

Abnormally wet weather in Nevada and the rest of the West is directly related to the worsening drought in the Northeast, a University of Nevada scientist said last night.

Meteorologist Charles Stidd, of the Desert Research Institute, noted that while the normally moist Northeast is parched, the normally arid West can't seem to dry out this summer.

The situation is simply a matter of all the water being dropped on the Western States and the remaining dry air driving rain-producing conditions off the eastern coastline into the Atlantic Ocean.

Meterologists have many views on what causes freak weather conditions over a period of years and years of statistics to study, Stidd explains.

But facts are vague and inconclusive.

"We cannot forecast the weather accurately for more than 1 month, and we aren't always sure about tomorrow," Stidd said.

But, the reason for the wet West and dry East seems to be pretty clear, the atmosphere expert says.

"It is a very unusual and persistent pressure pattern," Stidd said.

He explained: Normally the prevailing winds and weather are from the west to the east across California and Nevada.

A low pressure center, however, is causing the winds to loop around to lower California into the Gulf of Mexico.

The air picks up moisture in the gulf and sweeps it on up into Nevada in a current. In Nevada, clouds form and storms erupt.

The current meanders up and down across the Western States to the Rocky Mountains.

East of the Rockies the now-dry air becomes a high pressure system that movest eastward toward the Atlantic Ocean.

The prevailing weather for the Northeast comes up from the Gulf of Mexico and in from the Atlantic Ocean.

But the eastward moving high pressure system drives rainmaking conditions out into the Atlantic Ocean, leaving the East dehydrated.

Does this type of thing come in 7-year cycles as the Bible tells us?

"There is no general agreement on cycles," Stidd said.

There are many ways of looking at statistics but they "herald nothing about the future and offer nothing conclusive about such things as cycles," the environmental scientist said.

He did speculate that the wet summer could mean a wet and perhaps early fall, but offered no certainty of that.

"Over the centuries there has been some trends in climate changes," Stidd said, "such as the ice age."

There has been a general warming trend recorded since before the middle of the last century, but again there is "nothing conclusive about that."

"It depends on what statistics you use," the meteorologist said.

"The weather over a long period," Stidd said, "is no more predictable than the roulette wheel."

Perhaps science will perfect a means for planning next summer's vacation in years to come, the weather scientist allowed.

By the way, the local weather bureau predicts generally fair weather for most of the State with scattered thunder showers in the northern border area and in the vicinity of Las Vegas—maybe.

EXHIBIT 6

[From the Nevada State Journal, Aug. 22, 1965]

EGYPTAIN ENGINEER STUDIES: HOW TO GET RID OF EXCESS WATER IN ARID NEVADA?

(By Wendy Miller)

Nevadans hear a lot about conserving water. They live in an arid State.

But an Egyptian engineer is currently studying how to get rid of water in the Silver State.

Dr. Abdel-Aziz Ismail Kashef, on appointment by the University of Nevada Desert Research Institute, is spending 2 months traveling tip to toe over the State's terrain.

The State has little worry now in the realm of excess water, but "20–40 years from now the problem could become serious" if preparations are not made.

"We engineers plan far ahead," said the foreign specialist in soil and drainage.

EVAPORATES NOW

Nevada, he says, does not lie along the coast where the ocean provides an unlimited waste depository. At present, most unused water in the State is eliminated by evaporation.

But in the future, with the plans for increasing Nevada's water supply from the reserves of wetter States, the mechanics of evaporation will not work fast enough, said Dr. Kashef.

CLOSED BASIN PROBLEM

"Closed basins provide a special problem for Nevada," claimed the civil engineer.

He cited Diamond Valley in central Nevada as an example of the closed basin. There, he said, irrigation takes place to a broad extent. Year by year as irrigation continues, the water table rises.

As ground water reaches plant roots, the crops begin to die off by suffocation explained Dr. Kashef.

The specialist said he has no answer for the problems as yet. He is merely gathering date for DRI Water Research Center.

STATEWIDE DRAINAGE MAP

"I'm thinking of drawing a drainage map for the entire State—of the natural gullies and valleys."

Dr. Kashef was called to Nevada because of his extensive research in other dry regions of the world, said Dr. George B. Maxey, professor of hydrology and geology for DRI.

TWICE PRESENT SUPPLY

Dr. Maxey said available water will sometime in the future be "in excess of twice the present supply" in Nevada—or 5 million acre-feet.

Where the water comes from, and how, is now the problem of the Western States Water Conference.

The Water Research Center was in need of consultation with an expert in the drainage problems of an arid, landlocked region, said Dr. Maxey.

"We had no one in our department with wide experience in drainage and irrigation both," he explained.

Dr. Kashef was their man. With a Ph. D. in soil mechanics and groundwater hydrology, he has held a number of Egyptian Government positions including one of preliminary work on the high Aswan Dam of the Nile River.

MANY SIMILARITIES

The engineer sees many similarities between Nevada terrain and that of the Middle East countries where he has worked.

"The State's closed basins resemble those of Saudi Arabia," he said.

The climate of the Nile Valley is also akin to that of Nevada, says the professor, though with less rain. The Egyptian valley receives less than 3 inches precipitation annually, while Nevada averages 10.

Dr. Kashef received his B.S. and M.S. degrees from the Cairo University and Ph. D. from Purdue. He has taught in various universities in Egypt, and for 4 years was with the American University in Beirut, Lebanon.

Since 1962, Dr. Kashef has been visiting professor at the North Carolina State University. He is the author of numerous technical papers both in English and Arabic, and is a member of the American Society of Civil Engineers, the American Concrete Institute, and the American Geophysical Union.

Senator ANDERSON. Senator Moss, do you have anything at this time?

STATEMENT OF HON. FRANK E. MOSS, A U.S. SENATOR FROM THE STATE OF UTAH

Senator Moss. I am proud to be a cosponsor, with Senator Anderson, of this important bill. We westerners cannot overlook any opportunity of increasing our water supply.

The great demand for water, as evidenced by the chronic water shortage in the West, as well as the recent shortage in the East, makes active research designed to assure adequate water supplies a necessity. Free and easy years of surplus water in such river basins as the Colorado are over. As the population of our country grows, our water problems will increase.

My service on the Senate Select Committee on National Water Resources several years ago convinced me that weather modification is one of the most promising methods of increasing our water supply. The National Academy of Sciences, in their report of January 1966, stated:

> We find some evidence for precipitation increases of as much as 10 or even 20 percent over areas as large as 1,000 square miles over periods ranging from weeks to years.

The time has come when a vigorous applied research program can be mounted to curb the growing water shortage in many sections of the country. Increased precipitation through clouds seeding is an established fact. A program is needed to exploit this fact.

As President Johnson stated last spring:

> The development of methods for altering weather and climate to the benefit of mankind is a subject of quickening interest in the Congress and executive branch of the Government of the United States—as, indeed, it is to all of the human race. We recognize that achievement of such a capability would mean vast economic and social gains for human life on this earth. * * * To advance the rate of progress, an effort or larger scope and direction is needed both in conducting basic research and in developing means to put the knowledge to work.

The National Academy of Sciences report indicated several problem areas related to weather modification, including the question of acceptable design and evaluation of atmospheric experiments, the inadequate design, development, and testing of instrumentation and equipment, the insufficient knowledge of atmospheric water budgets, and the difficulty in assessing the seedability of the variety of storm types. A carefully designed, but vigorously executed, program is necessary to solve these problems.

The solution to many of these problems is being sought at this moment. In my own State of Utah, for example, a research program developing automatic precipitation measuring and reporting networks

is underway as a part of a scientifically designed seeding experiment in the Wasatch Mountains. A worthwhile program could also be initiated in the Uinta Mountains, in which are located the headwaters of four of the major rivers in Utah.

A program to solve this national water problem will require the expenditure of sizable sums of money. The Federal support of weather modification in fiscal year 1965 totaled $4.97 million. Both the National Science Foundation and the National Academy of Sciences urge a greatly increased budget—at least $30 million by 1970. This is a great deal of money to be spent for a commodity we have long taken for granted. But the recent shortages in the East raise many questions. How much is a quart of water worth to a man dying of thirst? We must take action so that this question never need be answered.

How best can this situation be avoided? By recognizing that water, including atmospheric water, is a natural resource. The Department of the Interior is the natural resource agency of the Federal Government. The Office of Saline Water, within the Interior Department, is making great strides toward making economical fresh water from salt water. One aim of weather modification is also directed at increasing the supply of fresh water. The Department of the Interior's position was recognized by Congress in 1961 when the Bureau of Reclamation was given a modest appropriation to study the feasibility of increasing inflow to its reservoirs through the application of weather modification techniques.

The National Science Foundation Special Commission on Weather Modification points out:

(*a*) The phase of weather modification now most nearly ready for aggressive applied research, development, and actual operational activity—the augmentation of precipitation—is vitally linked to the water management program of the Bureau of Reclamation.

(*b*) Weather modification activities, including basic and applied research, relate closely to those economic and political interests that are concerned with the overall mission and programs of the Interior Department. This would go far to assure priority attention and adequate funding of the weather and climate modification program.

(*c*) Weather modification activities are highly compatible with the basic long-range mission of the Interior Department—the conservation, development, and use of scarce natural resources.

The present work being done by the Bureau of Reclamation brings to bear on the problem much of the talent available in universities and private meteorological firms, as well as its own group of scientists and support from other Government agencies, including the Forest Service, Geological Survey, and the Weather Bureau. In addition, the work being done is creating a climate of learning where new talents can be developed.

The atmosphere recognizes no political boundaries; neither does the problem of water supply. The present research effort of the Interior Department's Bureau of Reclamation is limited to programs in the Western States. Many of the results obtained in Utah or California or South Dakota will be applicable to Florida or Illinois or New York. But many of the questions can be answered only in these areas. An expanded program, based upon the experience developed in the West,

will lead to nationwide utilization of this most important of natural resources.

S. 2875 takes nothing from any other Federal program. It emphasizes and retains in its proper place the duty of the Department of the Interior to conserve the natural resources of the Nation.

Senator ANDERSON. The first witness this morning is Secretary of the Interior Stewart Udall. Mr. Secretary, we are pleased to have you back with us again.

STATEMENT OF HON. STEWART L. UDALL, SECRETARY OF THE INTERIOR

Secretary UDALL. Thank you, Mr. Chairman. I have a prepared statement. It is such a good statement I think I will read almost all of it. There may be a few ad libs if that is all right, Mr. Chairman. However, first, I should like to say, Mr. Chairman, that we sense in our Department with all of our wide-ranging water interests the development of a whole new wave of interest in water resources of which atmospheric water resources are of strategic importance.

I should like to say, too, that the Senator from New Mexico, who is presiding here today—probably more than any one man in the Congress—has over the past two decades done more to push research programs that might lead to significant accomplishments. I think your efforts and the effort of others on this committee have brought us to the point where we are today.

I welcome this opportunity to be here on the first day of spring to present the views of the Department of the Interior on atmospheric water resources, and to give our strong support for the long-range objectives underlying S. 2875 as introduced by Senator Anderson and on behalf of 21 other Senators.

The long and shining list of sponsors of S. 2875 reminds me of what John Ruskin once said about the weather:

> Sunshine is delicious,
> Rain is refreshing,
> Wind braces up,
> Snow is exhilarating.
> There is no such thing as bad weather
> Only different kinds of good weather.

Two months ago, I spoke of the challenging horizons in atmospheric water resources in addressing the annual meeting in Denver of the American Meteorological Society. It was thoughtful of Senator Anderson to insert these remarks in the Congressional Record. I would also like to make the address a part of the record of these important historic hearings.

Senator ANDERSON. Without objection, it may be done, sir. It was a very fine address.

(The document referred to follows:)

WATER RESOURCES IN THE SKY

(By Secretary of the Interior Stewart L. Udall)

Tonight I should like to approach the subject of weather modification by a somewhat circuitous route beginning, as does the whole hydrologic cycle, with air and water. You and I don't need to read the newspapers to know that air and water are our two most precious natural resources. While we can do with-

out food for weeks we can live no more than 5 minutes without air. Yet as basic as this knowledge is, air and water continue to make newspaper headlines and the reason is obvious. We are experiencing a great dislocation. When weather is behaving it gets no more than a small box of type on the front page and 60 seconds on television. When weather starts making banner headlines we can be sure the clouds are deep or dark. The stories under headlines about air and water are important reading. So are the comprehensive accounts of floods and drought which appear in news and science magazines. So also are such documents as the excellent report, "Restoring the Quality of the Environment," released by the White House in November. It is only through the communication media that we are made fully aware of the dangerous position to which we have come through maltreatment of these precious life-sustaining necessities.

It does not require critical analysis—only plain, garden-variety horsesense—to tell the thinking American that the Connecticut, the Hudson, the Potomac, the Ohio, and the Willamette must again run free and clear; that the Great Lakes, Long Island Sound, Raritan, and San Francisco Bays were not intended as garbage disposals; that the presence of a great American city should not be announced to airline passengers by the pall of smut and smog that enshrouds it.

The mistakes, carelessness, and neglect of the past century will, of course, not be corrected in a fortnight. The first step is to intimately know the problem and accord it national attention. President Johnson has lucidly described the situation as he has spoken across the Nation. With regard to water, President Johnson told those in attendance at the dedication of Rayburn Dam on May 8, 1965:

"No single resource is more important to us than water. Our management of America's water resources is basic to the many obligations and many opportunities of our growing population."

Since our involvement with air here is mainly as mover and distributor of water vapor. I shall confine my appraisal of it to this role. However, with regard to this necessary and abused resource, I have many other concerns which I shall not bring up tonight.

After proper definition and expression of any problems, there must come action toward a solution. In response to the President's challenge, the 89th Congress has been exceedingly alert. We have the Water Quality Act, requiring the setting up of standards and providing Federal aid for construction of sewage treatment plants, demonstration plants, and research. The Water Resources Planning Act established the Cabinet-level Water Resources Council to plan the most efficient use of our portion of this planet's water. The Federal Water Project Recreation Act puts outdoor recreation, fish, and wildlife on an equal basis with other major purposes in Federal water resources projects. Interior's Bureau of Outdoor Recreation will direct the planning of these projects together with its former task of comprehensive river basin planning.

Other water-related efforts in which the Department of the Interior has been proud to share include the plans for a proposed Wild Rivers System and an exciting new plan encompassing the entire Potomac River Basin. A sadder but related task has been the continuing study of the Northeast drought.

Essentially, the Department of the Interior is an action agency. After I have taken a few moments to define certain problems. I will ask you to consider with me the action I believe has now become essential in areas where you and I have mutual interests and responsibility.

Despite all the progress, some of which I have mentioned and much of which I have not, the large question of daily concern remains: How do we assure for ourselves, our children, and our grandchildren, adequate and properly distributed supplies of clean, fresh water for all our varied needs? This huge question involves a subsidiary problem upon which I intend to focus tonight: How can we and how should we make the most effective use of our water resources in the sky to help meet our water needs on the ground?

To place this latter question in context, let us look briefly at the larger problem first. Three years ago a National Academy of Sciences report stated that "limited pure-water resources of the arid West are almost at an end," and that Arizona, for example, was drawing "60 percent of its water supply from overpumped wells." Those of you from New York City and other parts of the Northeast know what we went through last summer during the fourth in a series of below-average rainfall years. The Water Resources Council, in its 1966 reappraisal of the Northeast drought, told President Johnson that not only is the crisis the most intense in history, but that the drought is creeping steadily southward. The situation is now entering its 5th year. The average monthly precipitation

for more than 50 months now has been 1 full inch below normal in an area from northern Delaware to northern New Jersey , southeastern New York, western Connecticut, and southwestern Massachusetts. We cannot afford the luxury of assuming that things will be better this year.

The marked southward thrust of the drought has now involved all of Maryland, Delaware, and the northern half of Virginia as well as New Jersey, eastern Pennsylvania, southeastern New York, and southern New England. Almost all stations reported intensification of the situation during December.

The tone of this drought reappraisal is reminiscent of certain science-fiction programs, where visitations from outer space or incomprehensible changes in environment occur so quickly that the voice of the announcer simply cannot instill the message with any sense of reality. Obviously such abrupt changes are fake and corny. One is aware that one is listening to fiction. But this is not a Ray Bradbury short story or a Thornton Wilder play. It is happening here, now in, the United States. The chorus in these areas is strictly a sober "How dry I am," and by the end of this century there will be twice as many Americans to swell the chorus.

But there is another tune, just as geographically out of joint with recent weather history, coming from other parts of the Nation. Our Denver hosts can give us personal commentaries on the floods that recently caused in excess of $200 million in damage in the Denver area alone, and millions more to the rich farmlands along the Platte and Arkansas Rivers. The rains in Arizona last month were unprecedented and would have caused flood damages twice as large as those which did occur had it not been for the irrigation storage reservoirs of the Salt River project. We all remember the Mississippi floods of late spring and the rampaging rivers which turned the Pacific Northwest into a soggy sponge a year ago.

One side of the weather coin is augmentation of moisture to fight scarcity; the other side is controls to combat excess. Put them together and the total problem facing the Nation is one of control and distribution of the water.

It is at this point where our two paths converge—weather modification on the one hand and water storage and distribution systems on the other.

The matter of control and distribution of water resources is not new to the Nation and most particularly is this true of the 17 western States.

For the past 63 years, the Bureau of Reclamation—a part of the Department of the Interior—has made irrigation facilities available and provided water service to more than 9 million acres of land suitable for sustained irrigation. The value of crops and forage produced on these lands over the water controlled years now stands at $21.7 billion. This fantastic figure represents the return from irrigation alone, and it is roughly five times the entire Federal cost of plant, property, and equipment, including even those projects now under construction.

While irrigation was the initiating factor in reclamation work and remains its biggest single reason for being, other water users are making increasingly insistent demands on the systems. Provision of municipal and industrial water supplies, generation of hydropower, prevention of floods, regulation of river levels, and enhancement of recreation, fish and wildlife habitant all are claiming their share of consideration in our on-the-ground pooling and dispensing of this important resource.

Yet with all our planning and building and looking ahead to try to outguess the future, we find ourselves still at the mercy of the weather. Diminishing water supplies in some places, destructive floods in others, show that all the massive efforts of past and present still do not add up to that magic word "enough."

In New York our pitchers are dry. In Denver, our cup briefly runneth over. If we are to achieve some sort of nationwide distribution which will correct this condition then we must make progress in order of magnitude greater than we are now making. Many ways of hastening this progress are open to us and we cannot afford to neglect any of them. But to my mind the most logical and challenging is the one which most stirs the imagination. This is worthwhile utilization of the water resources of the sky.

I am not a scientist and I will not be so presumptious as to lecture this group on the scientific aspects of the hydrologic cycle. What does appear to me, because of its potential for a mankind, is the idea of enormous rivers of water flowing over us in the atmosphere; of huge pools of moisture poised above our heads; of enormous reservoirs in vaporous state sailing majestically over mountains, or bumping into them and dropping their precious burdens too soon. We toil here, on the thin skin of our planet, "making do" with the fresh water which moves and puddles up here

and there on the surface of the land, and engage in expensive efforts to make this water walk, not run, to the nearest gravitational exit. In some ways this could be called a downhill fight.

We have concentrated our efforts on the thin layer of planetary surface which is sandwiched between the water-saturated rocks that extend for miles beneath our feet and the moisture-laden air which reaches miles above our heads. We strain to store, to channel, to use and reuse the surface water that nature accords us, before it gravitates away and becomes salted in the oceans. It is time we turned our concerted attention to the time-space continuum of the skies. Where do these overhead rivers flow? What are the fluctuations in their water content? Where, when and why do they puddle up into airborne lakes that overflow, usually in moderation but sometimes in excess?

To know, to understand, and control our surface water resources, how much detail must we use in mapping the moisture of the sky? What of the nature and distribution of particulate matter and how about air-land interaction over desert and forest, lake and farm? Perhaps Langmuir was right when he said, "It may be easier to make the weather than to predict its behavior." But as he would be the first to point out, in order to make something the first requirement is to know your ingredients.

Both the American Meteorological Society and the U.S. Weather Bureau are of critical importance in this effort. Your presence here tonight testifies to your resolve that your record shall be an ongoing one. As someone once noted, there is no more prickly place to rest than on your laurels.

Along with these tremendous achievements we can count the results of the research and development projects going on in my own Department and elsewhere in Government and the scientific community—projects aimed at understanding the weather.

However, let's look for a moment at the Federal funds spent last year in research alone on the major units of our environment. Seventy-two and a half million dollars went into studies of the oceans, $212 million into the lands, and $1,555 million into the space program. Similar research in the atmospheric sciences, exclusive of the space portions, amounted to $94 million. Of this, only one-twentieth—$4.1 million—went into weather modification research by all Federal agencies.

I make no brief that these sums should be comparable. I do, however, believe it reasonable to conclude that there is a gap to be filled and that it is in the national interest to greatly expand our studies of the atmosphere so that we may learn to harness its water resources.

It is true that a start has been made—a good start. Almost 20 years ago, in 1947, the Bureau of Reclamation, became interested in weather modification as a possible means of assisting in the accomplishment of its mission; namely to provide the water to reclaim the arid and semiarid lands of the West.

This effort culminated in fiscal year 1962, when $100,000 was provided to start such a program. Finally, in 1965, the Bureau was funded with $1,100,000 by the Congress for the specific purpose of weather modification research. The Senate Appropriations Committee instructed that this amount was to be divided between research and orographic and convective weather systems. The committee directed that "emphasis is to be placed on actual water production and the exploration and research is to include application of existing weather modification methods."

The principal justification for this major step was the fact that you and your colleagues in associated sciences, with the generous support of the National Science Foundation, the U.S. Air Force, the Office of Naval Research, the U.S. Weather Bureau, NASA, and other agencies had advanced the science to the point where engineering research and development activities were in order.

The fiscal year 1966 budget of the Bureau of Reclamation, increased by the Congress to $2.98 million, involves research and development contracts to scientists and engineers in universities and consulting firms. Interior's whole weather modification program is headquartered here in Denver.

To touch lightly on the present program, it encompasses practical engineering research on winter storms in the Rockies, cap clouds in Wyoming, summer cumulus cloud studies in the Dakotas and in Arizona, and potential transmountain diversions in the Pacific Northwest. Other activities include work in the Great Basin and on the Wasatch front near Salt Lake City and Ogden.

Right here in Colorado a major physical experiment in the Park Range near Steamboat Springs is underway.

I am proud of this entire program. If it succeeds, and we hope it will, all of us will benefit. The scientists and engineers who are participating are eager,

enthusiastic and talented. Each operation involves the solution of complex logistic problems, often including pioneering efforts under arduous physical conditions. The Forest Service, the Weather Bureau, the Geological Survey, the National Center for Atmospheric Research in nearby Boulder, all are taking essential roles as are State institutions and private contractors. This is the kind of cooperation and team effort which will get a big job done on the double—which is exactly how we need it.

All these fine activities are encouraging. On cursory inspection they might seem to represent a sufficiently strenuous effort. However, I cannot agree. Nor, I am sure, will most of you. The present reclamation atmospheric water resources program and all other such programs can operate only in terms of "the present state of the art." As Secretary of the Department of the Interior and as Chairman of the President's Water Resources Council, I salute the workers who have brought us this far along the road. But I think that as scientists you must agree with me that the progress so far represents only a drop in the bucket and that this drop may disappear by evapotranspiration (to borrow one of your terms) if the spigot is not opened much further.

Perhaps the most encouraging signal to go ahead with this program came last week in Washington, D.C., from two of the most highly respected scientific organizations in the country * * * the National Science Foundation and the National Academy of Sciences. Weather modification reports, released independently by an NSF Commission and an NAS Panel give strong endorsement to expanding programs in weather modification. The National Academy pointed out that "to be successful, the national program recommended by the Panel must represent a fine balance between unwarranted optimism and undue skepticism. There is an unparalleled opportunity for our scientific community and our Federal Goverment to demonstrate imagination, perception, and wisdom in the management of a program having both intrinsic scientific interest and potentially far-ranging socioeconomic and political consequences."

The Special Commission for the Science Foundation likewise indicated that activities in this field should progress at a rapidly expanding rate. The Commission recommended that by 1970 annual Federal Funds for all weather modification activities should be in the order of $50 million a year. The report urges that Federal agencies undertake those operational activities required for effective discharge of their particular missions—suppression of lightning by the Forest Service, fog dispersion by the Federal Aviation Agency, and rainfall augmentation in reservoir systems areas by the Department of the Interior. Such agencies, the report went on, should be free to continue and support such research and development as may be required to discharge these missions.

If we are to make a success of precipitation control, as I believe we must, we have no alternative but to be knowledgeable of the water budget of the atmosphere, day in and day out, over any part of the United States, over the Nation as a whole, over this entire continent and the oceans which bound it. In planning development of the water resources of the Colorado River Basin, we are taking into account all the water components of that sorely beset region—its reservoirs, irrigation needs, ground water levels, desalting plants, recreation uses, effect on fish and wildlife, reclamation of sewage effluent, urban demands, industrial recycling, economics, and legal questions, to name a few. How long can we continue to neglect the water flowing overhead? The increasing number of scientists and engineers conducting weather modification experiments in the region tells us the time is not long. I hope you agree.

We have spent decades building a gigantic plumbing system for the water we can catch here on the ground. We have built canals, aqueducts, transmountain diversion tunnels, dams and reservoirs. We have turned rivers upside down and made them flow backward to suit our purposes. All this, I might add, has been at some expense to the management. Is it not time, then, that we began to plan also for aerial distribution via the rivers in the sky as part of this total system? Such gigantic international water distribution systems as that proposed under the title "NAWAPA"—North American Water and Power Alliance—may one day come to pass. But one must ask: What would be the feasibility and expense of providing for some or all of this redistribution by using waterways in the air in addition to or rather than pipes on the ground?

We know enough about man's ability in problem solving to ask not "Can we do it?" but rather, "How soon can we do it?"

This challenge I throw directly to you. You are atmospheric scientists and engineers. It is your responsibility, indeed it is your obligation, to provide the necessary information. We in Washington are part of your Government; we

must look to you. You must provide the leadership to make this weather management feasible; as citizens you must provide the pressures that move a great Nation forward.

Let me say, in closing, that the Department of the Interior welcomes the major responsibility it has been given for engineering research and development in the field of weather modification, a program which long has interested President Johnson. We consider the challenge one of utmost seriousness and anticipate even greater emphasis on these efforts. Certainly on some future day we will achieve worthwhile control of the vast water resources of the sky.

Secretary UDALL. Perhaps no single factor in man's environment exerts a more profound control on the well being of the American people than does the distribution of rainfall.

Our ability to provide food and fiber in abundance sets us apart in the world. Yet this ability depends heavily upon the continued supply of atmospheric water, our one vital replenishable, but extremely variable resource. As the margin between famine and plenty is narrowed by the world's population growth, and as the demand for an increased share of food by those already here becomes more insistent, the strength of our Nation in a competitive world will in large part be determined by our ability to manage our water resources, including precipitation.

This step in water management is a large one. However, the chances of success and the potential payoff are so great that we must attempt it. In spite of the large gaps still remaining in our scientific knowledge, 15 years of careful study have revealed enough areas where a payoff is visible as to warrant an effort sufficiently bold to be equal to the task.

The Nation has shown through other scientific programs that it is willing to pay the price to cross new frontiers. When we cross this one the material benefits will exceed the investment a thousandfold. The complexity of the problem demands imaginative planning and forceful backing by government, universities, and industries. The program will demand that atmospheric studies be extended to the measurement of all parameters which are known to be important, that artificial alterations be applied where the best physical concepts dictate they should be applied, and that the operations be conducted within the framework of good scientific and engineering design in order that proper evaluations can be made.

There will be logistic problems beyond the capability of meteorologists and atmospheric scientists; therefore development in operations and observational capability will have to depend upon utilization of similar talents in national industry and aerospace science.

It will require bringing together diverse groups under strong, imaginative central direction and discipline. However, any significant advancement in man's ability to make use of atmospheric water resources will benefically affect a vast number of human problems ranging from relief of individual suffering to relief of international tensions.

And let me hasten to add that management of precipitation is but one of many benefits that may be expected from increased knowledge and experience in weather modification. If we are to make the most of the opportunities now before us, it is most important that all Federal agencies make proper use of weather modification wherever research, development, and operations in this area would speed accomplishment of their missions.

The water needs of our Nation are common knowledge to this committee and I need not take your time to cite examples of over and under supply of water that are painfully familiar to all of us. Recognizing the peril we face either through lack of sufficient fresh water or proper management of that which we do possess, this committee, other Members of the Congress, and the President have done yeoman service in meeting the challenge.

For long years we have striven to make increasingly effective use of our underground and surface waters. Beginning with the Reclamation Act of 1902, and even before, we could cite action after action taken by one Congress after another culminating in the Water Resources Research Act, of 2 years ago, under which water resource centers have been established in the 50 States and Puerto Rico; the Federal Water Projects Recreation Act which places fish and wildlife and outdoor recreation on an equal basis with other major purposes is another step forward; and establishment of the Water Resources Council, of which I am chairman, to coordinate river basin planning; the passage of the Water Quality Act of 1965.

With growing recognition by the Congress that reliance on surface and ground water supplies would not always be sufficient, the Congress turned our attention to the sea as a source of fresh water by desalination. Now with improved technology and the farsighted vision of President Johnson, and the late President Kennedy, we are moving rapidly forward to make the waters of the sea directly available and to provide fresh water in areas where it is rarely found and to supplement supplies where pressures of industry and population require it.

With all this emphasis and effort to recover and use and conserve the waters of our lands and seas, one might hope our greatest needs might be met. And perhaps they would be were it not for men's insatiable desires contantly to improve his lot and in doing so to place ever increasing demands on his natural resources.

In the case of our water resources, our needs for fresh, unlimited supplies multiply drastically each year while at the same time we busily contaminate that very resource we so desperately seek.

As a result, three pressures converge upon us: (1) to get more fresh water; (2) to distribute it more efficiently; (3) to manage and use it more wisely.

For over 15 years the Congress has recognized an opportunity to make more effective use of the major source of all our fresh water, the atmosphere. Then 4 years ago support was provided by the Congress for the Bureau of Reclamation to push forward the engineering research necessary eventually to provide more water from the clouds.

Two specific panels have now demonstrated the wisdom of that action, and we are now that much closer to our goal of effective use of atmospheric water. The scientists now give us a clear go ahead signal, the traffic light has changed from yellow to green to pursue sharply stepped up programs of engineering research, and we can look realistically not only to the land and the sea, but to the sky both for additional supplies of fresh water and to help with the distribution problem.

As I said when I spoke to the meteorologists in Denver:

> We have spent decades building a gigantic plumbing system for the water we can catch here on the ground. We have built canals, aqueducts, transmountain tunnels, dams, and reservoirs. We have turned rivers upside down and made

them flow backwards to suit our purposes * * * is it not time, then, that we began to plan also for aerial distribution via the rivers in the sky as part of this total system?

And it is this "total system" aspect of the problems that I want to emphasize today. No matter how excited we can get, and should get, about the vast potential benefits of weather modification, our plans for use of atmospheric water must be fitted into the total planning for all of our water resources.

It is because of scientific research that we now can add this new component to our water resource system; and this scientific work must continue in order constantly to advance our knowledge and capabilities. But now increased emphasis must be placed on engineering and research and design, on operating procedures and on system analyses of entire regions and river basins, and on the multitude of economic, social, and legal problems that relate to proper management of our total water resources.

Because the Department of the Interior is deeply involved and committed to a wide variety of programs designed to define and solve our water problems, I am deeply concerned that efforts to recover and make use of additional atmospheric water be completely integrated with those now in progress relating to the fresh water of our lands and from our oceans.

The water management program of the Bureau of Reclamation has been making conservation history for more than 60 years in the western United States. Because of this wise husbandry, the arid and semiarid regions of the West have continued to operate normally, on what in many highly populated areas amounts to only half the rainfall which the "drought stricken" Northeast has recently received.

Management of water resources has, historically, been a primary concern of the Department of Interior ever since the Federal Government began to take an interest in this area. As the legislative tempo picked up, Interior has continued to maintain the lead—whether the effort be aimed at desalting ocean water, setting up effective water quality controls, or coordinating river basin planning. The Department has enthusiastically accepted the technical challenge of extending our control and management of water to the rivers of vapor which flow over our heads. Man's interaction with his environment—most specifically with air and water—can only become increasingly critical to all mankind.

The bill with which we are concerned this morning is consequently of great interest to me. Serious consideration of such legislation is certainly necessary in response to the statement made last spring by the President when he said of weather modification:

> The scientific and engineering obstacles that must be overcome rank in magnitude with those encountered in developing peaceful uses of nuclear power and compare with those now being encountered in our attempts to place a man on the moon. * * * Substantial progress has been made * * * but the pace has been slow. To advance the rate of progress, an effort of larger scope and direction is needed both in conducting basic research and in developing means to put the knowledge to work.

S. 2875 quite properly seeks to deal with that part of the science of weather modification relating only to atmospheric water resources. In keeping with this concept, the proposed legislation specifically provides that the weather modification programs of the other Federal

mission oriented agencies are not to be affected in any way. This is a very important point, Mr. Chairman, except as provided in section 202.

In view of the conclusions and recommendations of the recent reports released by the National Academy of Sciences and the National Science Foundation, it is logical to expect that the other mission-oriented agencies will be proposing expanding programs in such other areas of weather modification as lightning suppression to prevent forest fires, hail suppression, fog dispersal, and severe storm and hurricane research. All of these are very vital facets of weather modification.

It is to be observed that the proposed legislation would not alter the weather modification activities of the National Science Foundation. A great deal of the recent progress of the Bureau of Reclamation in establishing expanding engineering and applied research programs to augment precipitation is due to the basic research and training supported by the National Science Foundation. This program will need to be expanded.

Weather modification responsibilities assigned to NSF by the Congress complement the programs of the Department of the Interior.

The proposal to authorize substantially increased funds to carry out the atmospheric water resources program over the next 10 years is also in keeping with the recent reports I have just mentioned. I understand the committee later today will have the benefit of statements from the chairmen who headed the task groups that produced the reports.

The testimony of these and other witnesses to follow will shed light on the nature and extent of financing required to support an aggressive yet sound program of applied engineering and scientific research and operations over the next 10 years.

In carrying out a comprehensive program, careful attention will also need to be given to a number of closely related matters. Among these is the question of the legal right of interests that may be affected by the proposed scientific research, development, and operational programs.

We would propose that legal talents be put to work to assess these problems so that they can be taken into account in the development of the comprehensive program.

This obviously, Mr. Chairman, is a very basic and crucial question. I think very early in the game, before our research and operations have reached the point where we go into large-scale projects, we will need to assess and to define these problems.

We are considering some actions that we propose to take now to get some of the finest legal minds of the country at work identifying these problems for the benefit of the Congress and the country.

We also agree that biological, social, ecological, and economic and other research studies will be needed for planning and executing a comprehensive program.

I have just returned from Europe where air and water pollution problems and programs were carefully surveyed. It would be well to mention here that air pollution is a potent force affecting the atmospheric process. The wise husbandry of nature's resources is a strong tradition in many countries over there. The water charter prepared by the Council of Europe establishes the kinds of goals that our own Nation should be able to improve upon.

This conclusion is clear. Programs for water pollution abatement and for effective use of our atmospheric water resources cannot be considered alone. They are part and parcel of the broad-scale coordinated attack required to meet the Nation's growing water requirements. In other words, water resources are not divisible in our judgment in any way.

To sum up, I wish to compliment the Interior Committee for its wisdom and forethought in arranging these hearings. They are truly of significance. Testimony of leading scientists and engineers, reports from the practical observers, operators, advice of governmental agencies, all these facts and informed opinions should provide a basis for devising a sound national program for atmospheric water resources. The Department of the Interior is eager to join in this endeavor.

The water legislation that has been adopted in recent years, and the various water resource proposals now before the Congress are aimed at meeting the President's challenge in water resources that "the Government's management structure must be strengthened and reshaped to meet the challenges that lie ahead."

That concludes my prepared statement, Mr. Chairman. I will be delighted to answer any questions you may have.

Senator ANDERSON. I want to note the presence of the Senator from South Dakota, Mr. McGovern, who shared in preparation of this bill.

Senator MCGOVERN. Thank you, Mr. Chairman.

Senator ANDERSON. This is a fine statement, Mr. Secretary. I recall when Dr. Von Neumann became a member of the Atomic Energy Commission. He had one of the finest minds in this country. He said the ultimate weapon is not the hydrogen bomb or atomic bomb but weather control.

It may not have direct application to the war effort but it has some interesting applications.

We will start the questions with Senator Moss.

Senator Moss. Thank you, Mr. Chairman. I compliment you, Mr. Secretary, on this very fine statement on the challenge that is presented.

I think the latter part of your statement, where you say the water problem is not divisible, is one that we have to concentrate on. We have tended, as we applied ourselves at various times to providing more water or cleaning up water, to consider it as compartmentalized, but we go right across the spectrum.

Since the source of all water is in the atmosphere, obviously we must press ahead in that area. I do not think I have any specific questions to ask. I want to compliment you and to point out that some feeble beginnings have been made and I consider them relatively feeble. We certainly must expand and accelerate our efforts in development of water resources.

Senator ANDERSON. Senator Allott.

Senator ALLOTT. I have only one remark to make, Mr. Chairman. You know of my own interest. I come from an area of the country, as you do, which is very slightly interested in this. I must say that I am a little bit concerned about the proliferation of efforts and I hope in this area we can gradually bring together at one point the major force to resolve this problem so that we come up with real answers.

As you know, we have had cloud seeding experiments in the West for many, many years. The reaction to them depends entirely on

whom you talk to at the moment. We have had them in my own part of the country in southeastern Colorado.

We have had them all over the States and all over the Midwest. I would hope that then it develops into a very hard program from the viewpoint of scientific approach because otherwise the legal problems that you spoke of briefly in your statement, I think, can become overwhelming.

I do think that starting on the possible legal aspects of this now is very important, because certainly along the way the solution to the legal problems is going to become of considerable significance.

That is all I have to say.

Secretary UDALL. Mr. Chairman, if I may I would like to comment in a general way on an observation that both Senator Allott and Senator Moss have made—that is the need to provide a sharper, more centralized nationwide focus in terms of our water management, and particularly with respect to water as a resource that is usable by man.

This is what we are talking about in the phase of weather modification that the Bureau of Reclamation and my own department are interested in. To show the thought that the two Senators have expressed is in complete harmony with the whole direction and tenor of actions taken by the administration, I point out two steps that the President, himself, has taken within the last 8 months when this committee voted out and the Congress passed the Water Resource Planning Act last year.

Under this act a Federal Water Resource Council has been established. The President was given the opportunity to designate the Chairman of that Council and he designated the Secretary of the Interior, intending thereby to give a sharper focus at the national level to the coordination of all of our overall water efforts in terms of conserving water as a resource usable by all mankind.

The second step, of course, occurred 3 weeks ago when the President proposed a major reorganization proposal to transfer the water pollution control program to the Department of the Interior. I said at the press conference that I considered this the most important step since I became Secretary over 5 years ago, in terms of adding to the role of the Department in managing the Nation's water resources. I want to emphasize that the objective of the administration is to centralize water resources functions, particularly in regard to the conservation and wise use of water as a resource that man relies upon for his own welfare.

Senator ANDERSON. I am sure the Secretary will not mind my quoting from his report on the bill:

> The bill specifically states that it is not intended to give this Department increased authority over programs of other Federal agencies and does not limit those programs in any way.

Senator Jordan.

Senator JORDAN. Thank you, Mr. Chairman.

Mr. Secretary, I should like to inquire if you know whether other nations are doing any atmospheric water resource research at this time?

Secretary UDALL. Senator, I will respond in a general way and then you may want to ask my science adviser or Dr. Kahan to answer the question later. I will say that other nations are interested. I know

that Australia has been doing some work. Of course, most of their continent is arid. There are other research efforts that are underway in Japan, Russia, Spain, France, Italy, and Switzerland.

But I think I can say to you that in terms of magnitude of effort that what the various agencies of the U.S. Government are doing is below the effort of the Soviet Union.

Senator JORDAN. Would the Secretary anticipate this might be an area that is going to call for a lot of study and exploration as the air currents carrying moisture are no respecters of international boundaries? Certainly there will be drift one way or another.

Of course, there is no body of international law bearing on this but it seems to me the kind of research you are doing would adapt itself very well to international cooperative effort.

Secretary UDALL. Senator, this is a very sound point. I think it certainly deserves to be underscored. There are two resources, interestingly enough, that the people of the world own basically, the ocean—when one gets beyond our tideland areas where the Nation's claims end—and the atmosphere overhead. These are two areas where, it seems to me in terms of conservation, in the next 50 years we are going to see developed whole new international mechanisms, and devices of international cooperative to manage them. Weather modification applies not only among nations but among States; even among the people in different river basins.

If you start intruding you immediately raise legal questions, questions of social policy. We may have to develop new laws and new legal concepts under which we can carry out programs of this kind.

The scientists tell us that they see hope on the horizon in weather modification. We don't have anything like all the answers, but we can see that research is fruitful. We need to move out ahead and get the answers to these legal and social and other problems so that we will have a system in which we can indeed modify the weather without creating all sorts of political and social and other problems among ourselves as well as among the other nations of the world.

When one begins to modify the atmosphere, since it is in motion all the time, one immediately affects the rights of other peoples and of other nations.

Senator JORDAN. Others have spoken, as you have yourself, of the legal problems that will arise between river basins and States and communities and among various types of users. I have not seen any mention of the international aspect of the problem, especially, it seems to me, with respect to this hemisphere, our neighbors on the north and south. They certainly would have an interest in anything we do as a nation here in this area.

Senator ALLOTT. Mr. Chairman, may I make this remark? At my instigation several years ago the National Science Foundation started a study of courses engaged in basic research of the atmosphere.

Of course, this would not interfere. Looking at this as a whole proposition I cosponsored by request this bill and I support it but atmospheric research or atmospheric weather modifications, in my opinion, is just one phase of the total problem.

We have a great problem, for example, in the agricultural use of water, the efficient use of water, actual farming operations, the lining of ditches. I am not sure but what that is one of the greatest sources

to cure pollution which, despite all of the Government's efforts to date, still goes on in many areas unabated and in fact in some areas it is actually increasing despite the fact that the Government is proposing to put all this money in it.

So I think, in order to keep this in context that while this bill is for this one purpose, the whole effort ties in with the total effort of use and reclaiming of water. I personally regard pollution of both air and water as one of the top challenges to our modern civilization.

While atmospheric pollution is related sometimes directly and sometimes indirectly to this problem, certainly water pollution is closely related to it. I would hope that out of all these investigations we start meeting these challenges and find some answers.

Secretary UDALL. I would like to agree completely with you on the point you have made. One of the reasons we have gotten ourselves in trouble in the past in many conservation problems is that we have taken the easy attitude that we could go ahead and do what we were doing and that somehow science would come and produce a trick answer later on that would save us from our mistakes.

Certainly weather modification, as we see it, is a rather promising new facet of an overall water conservation effort, to stretch and enhance the water supply that we already have. We should not take the attitude that we can go ahead polluting and following poor conservation practices in parts of our country where water is already dear in the hope that somehow later on by weather modification or other means we can suddenly produce a solution that will get us out of the mess we are in.

So we see this as some promising new facet of an overall problem, an opportunity of conserving and managing our supplies to enhance their usefulness for man in every way.

Senator ANDERSON. Senator McGovern.

Senator MCGOVERN. Mr. Chairman, since I am not a member of the subcommittee I want to thank you for the special welcome that you extended to me to sit in on these hearings.

I do have a great interest in this field which stems in part from the longtime interest of my predecessor, Senator Francis Case, who was especially concerned about weather modification. Also because of the leadership which has been provided in this field at our South Dakota School of Mines and Technology.

I want to express my appreciation to you, Mr. Secretary, not only for your statement this morning but for your leadership in the whole field of water resources. In view of your recent trip to Western Europe and earlier visits to the Soviet Union apropos Senator Jordan's question, I am wondering whether you can tell us in general terms whether any substantial effort is being made in this field by any countries in Europe or by the Soviet Union?

Secretary UDALL. Western Europe and the Soviet Union have quite extensive weather modification programs, with particular emphasis on hail suppression in the U.S.S.R. I believe Dr. Verner Suomi of the University of Wisconsin has reported there are three to five weather modification research centers in Russia of the order of magnitude of our one National Center for Atmospheric Research in Boulder, Colo. They are reported to be spending four or five times more than we are on these activities.

In the rural area in Germany 2 weeks ago we saw what is really a pioneering example of intensive water management in one of the most heavily industrialized areas of the world. They pass the water down from community to community and industry to industry for use and reuse. An intensive program of pollution abatement is in operation. They manage water in a much more intensive way than we are doing in this country.

On the other hand, the Soviet Union, for example, on the Caspian Sea, in an area that has practically no rainfall, is moving very rapidly in the direction of large desalination plants of the type that we are contemplating for use as an answer to the water shortage problem.

It seems to me that we can learn from these other countries by looking at what they are doing. They are aware of what water means to their future. They are taking those steps that are deemed necessary to insure adequate supplies of water.

But when one looks down the road 50 or 100 years as we always try to do in conservation, weather modification certainly can be one of the most exciting new tools to help us enhance the overall resources of our country.

Senator ANDERSON. Senator Jackson.

Senator JACKSON. Thank you, no questions, Mr. Chairman.

Senator ANDERSON. Thank you very much, Mr. Secretary. I know you have other problems so we will excuse you if you wish to leave.

I will call on Mr. Bates and Mr. Dominy.

STATEMENT OF DR. THOMAS F. BATES, SCIENCE ADVISER TO THE SECRETARY, DEPARTMENT OF THE INTERIOR

Dr. BATES. Mr. Chairman and members of the subcommittee, with your permission I would like to read the statement I have prepared. It is fairly short.

I consider it a privilege to have this opportunity to testify today on a matter I consider of major importance to our Nation.

In his statement before the committee, Secretary Udall has pointed up the urgent need to develop the capability of influencing precipitation in order that the effective use of atmospheric water resources may be included, where necessary, as an essential component of the total water resource management system. The possibility of a major forward step at this time for the use of atmospheric water resources arises from many considerations. Most of these have been thoroughly discussed in the two recent reports of the National Academy of Sciences and the National Science Foundation which have been referred to and quoted in your committee print which provides the background and statement of purpose of these hearings.

Suffice it for me to say that weather modification has now reached a high level of recognition among scientists as a vital subject deserving of much stronger research and development effort. On the basis of a long series of experimental efforts, together with an improved understanding of atmospheric structure in general, there is now the realization that man is definitely able to modify the characteristics of clouds in certain instances, and that many of these modifications could be of direct economic benefit.

These encouraging developments result from the work of a relatively small number of dedicated people operating with small budg-

ets. There are now more scientists interested in the work, more tools for appropriate field and laboratory studies, improved computers and improved understanding of how to use them to model meterological processes. All of these factors suggest that now is the time to move ahead more rapidly. While recognizing the important contributions to be made by various independent research teams, it has become clear that the scale and complexity of the important meterological phenomena are such that large-scale coordinated effort is required for the accomplishment of the mission.

The time has now arrived when it is scientifically appropriate, technically feasible, and economically and socially desirable to marshal the required talent and know-how—in universities, industry, and Government—behind a concentrated effort. If properly planned and supported, this could have a significant beneficial effect on the economy of the Nation and, indeed, of the world.

A variety of factors dictate that efforts directed toward the control of precipitation be rather different from existing programs in other fields. One factor is the complexity of the logistic and engineering problems, which involve many different disciplines; another is the vastness of the atmosphere and the range of aspects to be considered, which extends from molecular physics to planetary circulation; another, and perhaps most important, is the daily impact of weather on the individuals of the country, and the attendant need for understanding the legal and social implications that the Secretary has just talked about.

There are other aspects of the total weather modification problem that will require direct examination and suitable programs. However, the nature and potential importance of precipitation control requires that special attention be given to this subject. Thus, the effort must be national in scope, yet responsive to regional needs; it must be strong in its own right, yet keyed in tightly with other major activities, that taken together, constitiue the water resource program of the Nation; it must take advantage rapidly of advances in our basic knowledge and measured characteristics of the atmosphere, yet it should be a major contributor to that same store of knowledge thereby providing essential information for related porgrams and activities.

A national program designed to make use of our atmospheric water resources should draw upon the coordinated strengths of several agencies, each doing the job that it knows best. The present program of the Office of Atmospheric Water Resources of the Bureau of Reclamation is based on this concept. Its eventual success is dependent on careful measurement and analysis of the atmosphere, precipitation, and streamflow. We are drawing heavily on the services of the Weather Bureau, the Soil Conservation Service, the U.S. Geological Survey, and the Forest Service to obtain these necessary elements of our program. Further, we recognize a continuing need for the research efforts of these and other agencies, public and private, if our prototype operating systems are to progress from present levels of efficiency to becoming highly effective atmospheric management tools.

If the objectives set forth in S. 2875 are to be attained, there will be immediate need for more projects which investigate the natural system by analyzing quantitative data on modified and unmodified clouds and cloud systems against data produced in computer-gen-

erated, physical models of such systems. Several such projects are already going on in a limited fashion and these must be amplified and additional ones added as required. Similar projects will engage in quantitative physical modeling and its experimental verification for the larger and more complex storm systems which provide the much larger portion of the total water supply.

The spectrum of activity will range—as, indeed, it does right now—all the way from such basic and applied research studies sponsored or conducted by the various Federal agencies to commercial cloud seeding aimed at giving increased participation in a particular watershed utilizing the latest engineering methods. The development of operational programs will vary considerably, but will generally begin with the period of experimental research in a particular geographical area. The project will then evolve naturally into an experimental prototype of any operational program—somewhat in the nature of pilot plant operation. Finally, the techniques developed will be refined in the economic sense for continuing operational programs. Operational programs must include careful monitoring of precipitation characteristics so that modification methods can be tailored to the situation provided by nature.

Within a few years after the initiation of such a national effort, a careful look at the total program would reveal a large number of activities at various stages of progress with research and development underway here, operations proceeding there, and intermediate stages represented elsewhere. All projects, whether large or small in atmospheric scale, size, and support would be conducted in the common objective of increasing and distributing precipitation to provide maximum benefit to the Nation.

The attainment of a major objective such as this obviously requires careful and continued planning conducted by responsible and experienced people and integrated with similar planning for the entire water resource system of the Nation. Such planning has long been in progress in the Department of the Interior.

In order to conduct the sort of projects outlined above, it would be desirable to have facilities such as those proposed in S. 2875. As pointed out in the Department's report, however, the scope of this part of the bill may be broader than needed.

A central headquarters would certainly be needed to provide the overall program management, to handle those items which affect all the regional groups, and to coordinate interregional operations. Such a central facility would need a unique library and information-communications setup, since the subject of information dissemination is of critical importance to the success of this extremely complex field which is fast moving and involves so many different disciplines. Experts at the center would give special attention to the legal, economic, and social aspects of the program, although special studies in these subjects might also be undertaken at regional facilities. Where extremely large facilities are required for some special research effort, facilities from several regions may be pooled.

Each region would logically have a regional headquarters which would manage the conduct of research and application operations within the region.

Responsibilities given to regional centers would cover a span of missions covering exploratory, experimental, and operational projects.

Reasonable autonomy would have to be given to each region because programs and specific objectives will vary from one region to the next as the result of varying atmospheric conditions and characteristics from one region to the next. In each area, the appropriate data from the whole region, especially radar information and information on wind temperature and moisture distributions which affect the seedability of the particular air mass, would be gathered into the regional headquarters. The tools most effective for the tasks of research and seeding would be determined by the personnel of the regions with the aid of advice from central headquarters scientists and engineers. Certainly radar and instrumented aircraft would play an important role in all projects, many of which would be carried out at varying locations within or even outside of the given region where task force operations utilizing large concentrations of mobile equipment would concentrate, for varying lengths of time on specific aspects of regional or interregional problems.

Increased emphasis, of the type envisioned, in an atmospheric water resources effort would require talents, skills and facilities obtained from all possible sources. Thus government laboratories and service organizations, educational institutions, and private profit and nonprofit research and development organizations would all be involved—as, indeed, they are in the present atmospheric water resources program of the Bureau of Reclamation. A major part of the effort over the near future would include the introduction of the most advanced techniques in engineering, instrumentation, systems, management, and operations research which have developed in the last decade in the aerospace industries and elsewhere. Heavy reliance will also be placed on the organizations already involved in weather modification projects.

The major new items and those which involve the largest costs of the program would be the equipment items which are required to permit the monitoring of large volumes of the atmosphere in the detail required for the program, and items for the handling and final assimilation of the vast quantities of data developed by the data systems. The equipment aspects of the program would benefit greatly from the development of new techniques by appropriate scientists and engineers whose backgrounds are from other fields.

The manpower requirements would eventually exceed the supply of people now participating in or being trained for research and development tasks in the atmospheric sciences. In addition the major growth aspects of the program would involve the subjects of engineering, systems analysis, and operations research: fields in which talented and well trained people are already in demand. It appears evident, therefore, that manpower needs which would increase with the growth of the program would have to be met, at least in part, by training projects and traineeships set up and implemented as part of the program. Since much of the total effort would be university based, graduate student training on research grants and contracts would be heavily relied upon to attract new talent to each of the many disciplines in engineering, the physical sciences, and the social sciences involved in the effort.

Finally, one of the most essential components of the entire atmospheric water resource effort must be an aggressive information program which will constantly interpret the plans, projects and progress

to the American citizen. Considerable education is necessary on the general character of atmospheric forces and events and ignorance in this area has already stirred fears and mistrusts of atmospheric scientists. A program of this magnitude would need broad public support which would come only through understanding and, in many cases, active participation in efforts designed to produce maximum benefit for all.

In summary, Mr. Chairman, let me reemphasize the points that I consider most essential for your committee's consideration.

First, atmospheric water is the most vital component in the total water resource system. Decisions as to the need for, recovery, and use of the water over our heads must be made as part of the planning for the entire system. Additional water from the sky may well be the solution to a particular drought situation, but the decision to try to get it should be made only as the result of a decisionmaking process that takes into account all the components of the total system and their interactions—dam storage, interbasin transfer, desalting, leaky water pipes, pollution problems, and so on.

Second, management of at least a portion of our atmospheric water resources is now in sight. The studies of the Academy of Sciences and National Science Foundation panels, and results being obtained in both government and privately sponsored programs corroborate this.

Third, variability in climatic conditions, ground and surface water supply water needs, and economics in various regions of the country make it essential that problems be faced on a regional basis under an umbrella—if I may use that term—of national surveillance, responsibility, and direction.

Fourth, the atmospheric water resources program of the Department of the Interior—whether we speak of the one in effect for the last 4 years, or of one of greater size and scope—is dependent, for maximum success, on continued advances in the state of knowledge about our atmosphere. It is therefore essential that research such as supported over the past 15 years by the National Science Foundation be markedly increased.

Fifth, an atmospheric water resources program is just one, though a most important one, of a large number of programs which can and should be pushed forward at an accelerated pace because of the possibilities and potential for using weather modification for the benefit of all mankind. Interior's efforts to make proper use of weather modification for precipitation control purposes cannot be conducted with full efficiency unless adequate support is provided to the total national effort.

Sixth, we are on the threshold of a step capable of providing a major advance in human welfare. I should like to congratulate the committee for its interest and effort toward this end.

Nevertheless, as indicated in the Department's report, the Department recommends that action on the pending bill be deferred for the time being.

Senator ANDERSON. Dr. Bates, I think most of us are agreed that the possibility of modifying and perhaps one day even controlling the weather opens up awesome prospects and will involve cooperative efforts of many Federal agencies in addition, of course, to those of universities and industry. What roles do you see for agencies other than the Department of Interior in this total picture?

Dr. BATES. I would like to make very clear to the committee that I feel that this entire area of weather modification is, as the Secretary has indicated, one of the most challenging that faces us, and therefore we must have the full cooperation, coordination, and active participation of all the Federal agencies that have responsibilities and missions to accomplish in this area. I frankly believe that if Interior is to do its job properly, we must depend on a tremendous amount of data on the general circulation in the atmosphere, on detailed measurements of nuclei counts in areas in which we are working as well as in areas in which we are not working; that there is a major role and responsibility here for the Weather Bureau; for the National Science Foundation; the university scientists; the Department of Agriculture concerned with the lightning suppression and hail suppression; the Navy, Air Force, and the FAA from the standpoint of fog at airports, and all thees activities.

I think we have a pattern here which has been developing for a number of years with regard to the related efforts of these various responsible agencies of the Government. I think this pattern should be continued. We must have a greatly expanded national program in all aspects of learning about the atmosphere involving all these agencies.

Senator ANDERSON. Since a number of different Federal agencies are very deeply involved in weather modification activities, how can we insure the necessary cooperation on the Federal level without risk of domination?

Dr. BATES. I think this is a very important aspect of the total problem. I consider it necessary that we have referees—if you want to call them that—people who are not actually involved in the operating programs themselves, who will essentially serve to coach and coordinate the activities of the various agencies as they relate to this total aspect of weather modification.

Senator ANDERSON. In addition to coordination, there will certainly be some aspects of regulation. What are your thoughts on regulation?

That was the toughest problem we had 15 years ago. Everybody is in favor of doing something but wants to be sure that his particular pet hobby is let alone.

Dr. BATES. This certainly is on the horizon. We will soon arrive at a point—I don't believe that we are there now—when regulation will be absolutely necessary. This will need to be taken care of by a regulating body set up for the purpose. That body should be completely independent of any of the individual operating agencies that are in the business of using the atmosphere in one way or another.

Senator ANDERSON. Dr. Bates, consideration is being given to greatly increasing the level of support for research and development in weather modification. Do you see problems in marshalling the manpower to carry out in the near future programs of the magnitude being discussed? Where would the additional people come from?

Dr. BATES. I believe, as I said in my statement, that as the program grows and increases in size, as I believe it must, there are going to be increasing manpower needs. I think we can forestall some of these by beginning training programs at an appropriate time, through the appropriate agencies, to bring more people into this field. At present and in the immediate future we may experience somewhat the same situation that we have had in other programs which have a strong

national image; namely, many scientists in other fields may wish to move into this particular area. Since we will need a great many physicists, chemists, and engineers in this program, I don't anticipate an immediate short supply of manpower. I do think we must look forward to a short supply later on if we don't get prepared for it.

Senator ANDERSON. At about the time the reports of the panels for the National Academy of Sciences and the National Science Foundation were released, Senator McGovern, acting for himself and in my behalf, write the Secretary of the Interior asking him for the assistance of some of you people in the Department in developing a program to implement the two reports.

It is my understanding that you worked with a member of our staff, that several scientists with competence in the field were consulted, and you developed what the group regarded as an accelerated, but practical and feasible, program of weather modification research, development, testing, and operations the group felt might wisely be undertaken. Can you tell me how these scientists were recruited and how they worked?

Dr. BATES. Yes, sir. After receiving the request from you and Senator McGovern, I invited to come into my office, for a 2-day session which was then followed up by several others, a number of people that I consider to be among the leading experts with knowledge in this area. I will be glad to provide you with a list of the names for the record.

Senator ANDERSON. It would be well to do so for the record.

(The list referred to follows:)

CONSULTANTS ON ATMOSPHERIC WATER RESOURCES PROGRAM

Dr. Julian H. Bigelow, School of Mathematics, Institute for Advanced Study, Princeton, N.J.; applied mathematics, member, NAS Panel.

Dr. John C. Calhoun, Jr., Texas A. & M. University, College Station, Tex.; petroleum engineer, former science adviser to Secretary of the Interior.

Dr. Charles L. Hosler, dean, College of Mineral Industries, Pennsylvania State University, University Park, Pa.; meteorology.

Dr. Yale Mintz, Department of Meteorology, University of California, Los Angeles, Calif., meteorology.

Dr. Paul B. MacCready, Jr., president, Meteorology Research, Inc., 2420 North Lake Avenue, Altadena, Calif.; meteorology.

Dr. Vincent J. Schaefer, director of research, Atmospheric Sciences Research Center, State University of New York, Schenectady, N.Y.; physics.

Dr. BATES. We considered the state of the art, not only as represented by the reports which had just come out, but in terms of the personal experience of these experts. We put together a general preliminary draft of a plan that we felt might be used in expanding toward a national effort.

We gave careful consideration to the problems that would have to be faced with regard to logistics, manpower, material, and probable funding. We have subsequently receved from consultants two other preliminary plans that will be useful in preparing for the total national effort. We have been working very hard at this matter and we think that we have the basis for moving ahead when the time is right.

Senator ANDERSON. I want to ask you that question, because I asked several Senators to join as cosponsors on the bill. I wanted assurance that the bill was not a sort of shot in the dark, but did represent a lot of study on the part of scientists who knew the field and what could and should be done.

Dr. BATES. I will be very glad to give you these statements as well as the plans of the consultants.

Senator ANDERSON. I have a copy of the memorandum on how the reports might be implemented and, without objection, will make it a part of the record. It comes from your shop.

(The memorandum referred to follows:)

A PROPOSED NATIONAL PROGRAM FOR UTILIZATION OF ATMOSPHERIC WATER RESOURCES

January 31, 1966

INTRODUCTION

No single factor in man's environment exerts a more profound control on the internal security and well-being of the American people than does the distribution of rainfall. Our ability to provide food and fiber in abundance sets us apart in the world. Yet, this ability depends entirely upon the continued supply of atmospheric water, our one vital replenishable, but extremely variable, resource. As the margin between famine and plenty is narrowed by the world's population growth, and as the demand for an increased share of food by those already here becomes more insistent, the strength of our Nation in a competitive world will in large part be determined by our ability to manage our atmospheric water resources.

This step in water management is a large one. However, the chance of success and the potential payoff is so great that we must attempt it. In spite of large gaps still remaining in our scientific knowledge, 15 years of careful study have revealed enough areas where a payoff is visible as to warrant an effort sufficiently bold to be equal to the task. The Nation has shown through other scientific programs that it is willing to pay the price to cross new frontiers. When we cross this one the material benefits will exceed the investment a thousandfold. The complexity of the problem demands imaginative planning and forceful backing by government, universities, and industry. The program will demand that atmospheric studies be extended to the measurement of all parameters which are known to be important, that artificial alterations be applied where the best physical concepts dictate they should be applied, and that the operations be conducted within the framework of good scientific design in order that proper evaluations can be made. There will be logistic problems beyond the capability of meteorologists and atmospheric scientists; therefore, development in operations and observational capability will have to depend upon utilization of similar talents in national industry and aerospace science. It will require bringing together diverse groups under strong, imaginative central direction and discipline. However, even a minor breakthrough in man's ability to forecast and control elements of the atmosphere will beneficially affect a vast number of human problems ranging from relief of individual suffering to relief of international tensions.

BACKGROUND

The basis for the recommendation, at this time, for the exploitation of atmospheric water resources on a nationwide level arises from many considerations. Encouraging results have been found from certain small-scale projects aimed at increasing precipitation. A recent report by the Weather and Climate Modification Panel of the National Academy of Sciences describes the results of a 2-year study as follows: "There is increasing, but still somewhat ambiguous statistical evidence that precipitation from some types of cloud and storm systems can be modestly increased or redistributed by seeding techniques. The implications are manifold and of immediate national concern."

Weather modification has now reached a high level of acceptance among scientists as a vital subject deserving of strong research and development effort. This level of acceptance is due to a series of research-oriented experiments as well as long-term commercial experiments which have improved the physical understanding of precipitation and method of alternation. On the basis of these advances in cloud physics, cloud modification, and atmospheric structure in general, there is now the realization that man is definitely able to modify the characteristics of clouds in certain instances, and that many of these modifications are of direct economic benefit.

These encouraging developments result from the work of a relatively small number of dedicated people operating with small budgets. Now that there are more scientists interested in the work, more tools for appropriate field and laboratory studies, improved computer and improved understanding of how to

use them to model meteorological processes, and since all of these factors have the potential for a significant development to even greater competence in the near future, it is appropriate to harness the Nation's capabilities for this program. Small, uncoordinated groups cannot effectively cope with the management and technical complexity of the important meteorological phenomena. The appropriate strength must be concentrated and must be increased in order to reach the critical mass where the economic payoff of the program for precipitation control can be quickly established and can, thus, help assure continuation of the optimun future program.

There is a variety of factors which dictate that a program for the controlled increase of precipitation be rather different from any existing programs in any field. One factor is the complexity of the logistic and engineering problems, which cover many different disciplines; another, is the vastness of the atmosphere and the range of aspects to be considered which extends from molecular physics to planetary circulation; another, and perhaps most important, is the daily impact of weather on all individuals of the country, and the attendant need for understanding the legal and social implications. Related programs in atmospheric modification are also necessary to decrease hail, eliminate tornadoes, modify hurricanes, open holes in clouds around airports, protect crops from freezing, etc., and the precipitation control program will have to be most effectively coordinated with these other efforts. However, the nature of precipitation control requires that a special commitment be made to this subject, and that the program be large, permanent, flexible, and imaginative.

PROGRAM GOALS

The proposed program is aimed at the increase and redistribution of atmospheric water in a manner to provide benefit to the people of the whole country. By pressing operational developments forwarded at a rate consonant with the ever-advancing state of the art, this program will try to get as close to this goal as possible and do it in as short a time as is consistent with the complexity of the problem and the strength of the commitment in terms of dunding and manpower. The program goal also includes the exploitation of any techniques which show a potential for significant economic benefits as soon as the developments warrant.

Whereas a successful program of the type proposed represents an essential order-of-magnitude step forward resulting in benefits to mankind difficult to conceive, it should be borne in mind, of course, that managerial control of the total atmosphere is an ideal goal which may not be attainable within any time limit now practicable.

GENERAL NATURE OF THE PROGRAM

The program must be extremely broad in scope because of the complexity of the total effort. Thus a large amount of research is still necessary as a basis for future developmental and operational efforts. There will be immediate need for more projects which investigate the natural system by analyzing quantitative data on modified and unmodified clouds and cloud systems against data produced in computer-generated, physical models of such systems. Several such projects are already going on in a limited fashion and these must be amplified and additional ones added as required. Similar projects will engage in quantitative physical modeling and its experimental verification for the larger and more complex storm systems which provide the much larger portion of the total water supply. Operational projects such as those underway in the Bureau of Reclamation must be greatly expanded as, for example (1) optimizing the seeding of orographic and cap clouds and (2) randomized seeding of individual supercooled cumulus clouds.

In addition to specific studies such as these, there must be other efforts aimed at detailed measurement and understanding of atmospheric circulation over considerable areas (300–500 miles).

Thus, there will be a spectrum of projects ranging all the way from such basic studies as those of nuclei distributions of the natural atmosphere to commercial or commercial-type cloud seeding projects aimed at giving maximum precipitation in a particular watershed utilizing the latest engineering methods.

The development of operational programs will vary considerably but may often involve a sequence of efforts beginning with the type of project mentioned above where the need is to compare the calculations of physical computer models with events in the real atmosphere in natural and modified conditions. As the

specific seeding techniques are engineered through such a program to be more and more efficient, it will hopefully become possible to direct increased precipitation to a particular local region such as a portion of a watershed.

At this stage the project evolves naturally into an experimental prototype of an operational program, somewhat in the nature of a pilot plant operation. Finally, the techniques developed would then be refined in the economic sense for the final continuing operation program. Since the latter will of necessity include careful monitoring of storm characteristics so that the seeding method can be continually tailored to the situations provided by nature, each operational project will involve research and development components resembling those characteristic of earlier stages in the sequence of efforts.

All projects, whether large or small in atmospheric scale, size, and funding, will be joined in the common objective of increasing and distributing precipitation to provide maximum benefit to the Nation.

PROGRAM MANAGEMENT AND ORGANIZATION

The proposed program must be the responsibility of a single, mission-oriented agency if the aforementioned goals are to be achieved in the most direct and efficient manner. At the same time it must be recognized that precipitation processes constitute by far the most important short time-scale energy exchange in the atmosphere. Therefore, any group responsible for the modification and possible control of any atmospheric phenomena (lightning, hail, fog, etc.) must of necessity participate in a program set up to investigate and modify the precipitation process. It is thus essential that when one agency is singled out for major responsibility for the proposed program the assignment of collaborative tasks and participation by other agencies becomes a necessity if a true national program of weather modification for maximum benefit is to be realized.

In order to conduct the sort of projects outlined above, it is recommended that a central headquarters and 8 to 10 regional centers be established. The regions will cover the entire Nation. The role of the central operation is to provide the overall program management, to handle those items which affect all the regional groups, and to manage operations which involve weather on a scale beyond that appropriate for treatment on a regional basis. The central facility must have a unique library and information-communications setup, since the subject of information dissemination is of critical importance to the success of this extremely complex field which is fast moving and involves so many different disciplines. The center will pay special attention to the legal, economic, and social aspects of the program, although special studies in these subjects will also be performed in relation to the regional facilities. Where extremely large facilities are required for some special research effort, facilities from several regions may be pooled.

Each region can be expected to have as its focus a regional headquarters which manages the conduct of research and application operations within the region.

Responsibilities given to regional centers will cover a span of missions covering exploratory, experimental, and operational projects. It is essential that reasonable autonomy be given to each region because programs and specific objectives will vary from one region to the next as the result of varying atmospheric conditions and characteristics from one region to the next. In each area, the appropriate data from the whole region, especially radar information and information on wind temperature and moisture distributions which affect the seedability of the particular airmass, will be gathered into the regional headquarters. The exact tools which are most effective for the tasks of research and seeding must be determined by the personnel of the regions with the aid of advice from central headquarters scientists and engineers. Certainly radar and instrumented aircraft will play an important role in all of the projects many of which will be carried out at varying locations within or even outside of the given region where task force operations utilizing large concentration of mobile equipment will concentrate, for varying lengths of time on specific aspects of regional or interregional problems.

SPECIAL PROGRAM NEEDS

Public relations

In view of the breadth of the spectrum of views as to what constitutes an improvement in weather, a public relations program must constantly interpret the progress of this effort. Considerable education is necessary on the general character of atmospheric forces and events. Ignorance in this area has already

stirred fears and mistrust of atmospheric scientists. A program of this magnitude needs a broad public support which will come only through understanding.

Manpower

The manpower requirements exceed the supply of people now participating in or being trained for research and development tasks in the atmospheric sciences. In addition the major growth aspects of the program involve the subjects of engineering, systems analysis, and operations research: fields in which talented and well-trained people are already in demand. It appears evident, therefore, that manpower needs which will increase with the growth of the program will have to be met, at least in part, by training projects and traineeships set up and implemented as part of the program. Since much of the total effort will be university based, graduate student training on research grants and contracts will be heavily relied upon to attract new talent to each of the many disciplines in engineering, the physical sciences, and the social sciences involved in the program.

Skills and facilities

The program must stimulate and use talents and facilities from whatever sources are available: government laboratories and service organizations, educational institutions, and private profit and nonprofit research and development organizations. A major part of the program over the near future must involve the introduction of the most advanced techniques in engineering, instrumentation systems management, and operations research which have developed in the last decade in the aerospace industries and elsewhere. A vital factor will also be reliance on the organizations already involved in weather modification projects.

The major new items and those which involve the largest costs of the program are the equipment items which are required to permit the monitoring of large volumes of the atmosphere in the detail required for the program, and items for the handling and final assimilation of the vast quantities of data developed by the data systems. The equipment aspects of the program will benefit greatly from the development of new techniques by appropriate scientists and engineers whose backgrounds are from other fields.

Especially during the early stages of the program, there must be strong emphasis on systems analyses so as to make reasonable decisions concerning the large expenditures for equipment items. The largest single tool will be the high-speed computer. This is needed especially for the all-important general circulation work, and no present computer has sufficient capacity. The appropriate computer is within the present advanced state of the art.

FUNDING REQUIREMENTS

The table following gives a breakdown of possible cost distributions leading toward the sort of $1 to $2 billion program for 10 years which seems warranted now. The scheduling of the costs during the first several years for this specific $1,300 million program is predicated on being able to spend $2 million during fiscal year 1967 for operations research and systems design:

TABLE I

[In millions of dollars]

Facility operation	Fiscal year									
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Control facility (plant, administration, information, dissemination)	3	3	4	5	6	7	9	10	11	13
Regional facilities (research, operations)	8	12	18	25	36	45	65	80	100	130
Systems analysis, operations research, and legal-social-economic studies	3	5	6	4	4	4	3	3	3	3
New equipment and techniques development	9	13	17	23	31	40	40	40	35	30
Capital procurement	10	13	18	26	36	42	46	50	48	40
General circulation studies	1	2	3	3	4	4	4	4	5	6
Educational training	1	2	4	4	3	3	3	3	3	3
Total [1]	35	50	70	90	120	145	170	190	205	225

[1] 10-year total: $1,300,000,000.

NOTE.—The last 5 items will be handled by either the Central Facility or appropriate Regional Facilities, or combinations of each.

Senator ANDERSON. Now let me ask you. If S. 2875 were enacted, would not the Interior Department have a program pretty well in mind for moving ahead with accelerated weather modification work?

Dr. BATES. Yes, indeed. We already have, of course, the experience of the 4 years of the Bureau of Reclamation with regard to the problem, in approaching this matter. It involves, first, a critical evaluation of the water resource needs of a particular region as part of the analysis of the total system that I mentioned in my report, and that the Secretary indicated in his.

It is not a matter of automatically throwing atmospheric water in where there happens to be dry ground. It is a matter of analyzing why are are dry, and of critically evaluating whether or not atmospheric water needs to be provided. Perhaps we could take care of the situation through other means, desalting, or proper reclamation, or storage facilities, and so on.

It is the responsibility of the Department of Interior to make such decisions. However, having established that such a need exists, as it does in some of the areas in your State and elsewhere in the West, then one must establish whether climate conditions make it possible to meet the need by using atmospheric water in that particular area. We may find in some situations that it will not be feasible. We can't simply pull the plug in the clouds, particularly if the clouds aren't there.

By putting these two aspects together, the need and the feasibility, of using atmospheric water to meet the need, we can make appropriate decisions as to the desirability of taking further action to provide water either there or in an adjacent area.

Senator ANDERSON. Thank you very much. I do appreciate very much the help you have given us.

Dr. BATES. You are welcome.

Senator ANDERSON. Senator Jackson.

Senator JACKSON. Dr. Bates, one cannot help but be impressed, in listening to the testimony this morning, by the fact that there are so many scientific disciplines, that are involved in this effort plus many different interests within the Federal structure, let alone all of the public and private sectors of our national society.

I want to ask you, are you satisfied that the present arrangement will do the job as far as the coordination of effort that needs to be done in order to do what you have in mind?

Dr. BATES. No, I am not, Senator Jackson. I believe that the coordination effort should be the responsibility of an organization, such as the Office of Science and Technology, that is not involved in the operations.

Senator ANDERSON. You think it should be in the President's Office?

Dr. BATES. I believe so; yes, sir. This is a very complicated situation where agencies could be treading on each others toes, and, therefore, we need, as I said before, a referee that is not a participant in the program.

Senator ANDERSON. Do you think this interim arrangement will work? In other words, with your Department, the Department of the Interior carrying out a certain responsibility, and Commerce carrying out other responsibilities?

Dr. BATES. I believe it has been working up to this point. Obviously, as we grow we must take care to make sure it still works.

Senator JACKSON. I notice that section 202 of the bill on page 6 provides that activities intended to affect, or determined by the Secretary to be likely to affect, the atmospheric water resources in the United States may be carried on only pursuant to license issued by the Secretary in the same manner as licenses issued pursuant to the act of August 30, 1954. Now I have a feeling that maybe this particular section may raise a question within the departments.

Dr. BATES. I have no doubt that there will be considerable discussion with regard to some of these specific points in the bill.

Senator JACKSON. I notice that the Secretary in his letter in reporting on the bill stated:

> The bill specifically states that it is not intended to give this Department increased authority over programs of other Federal agencies and does not limit those programs in any way.

I do believe that some of this will certainly need clarification in order to get, Mr. Chairman, a kind of coordination we all want to achieve. Certainly the Department of Interior has long been active in this area. Other departments of Government have been active in research such as the National Science Foundation for the past 15 years. I must say that this particular topic challenges all the scientific disciplines and it challenges all the best means by which we can bring about the kind of governmental coordination that it is necessary to achieve in order to take advantage of the limited, qualified talent that you have available.

Dr. BATES. I agree 100 percent.

Senator JACKSON. I know that many years ago an old friend of mine and Senator Anderson's, the late John Von Neumann, while on his deathbed, stated that in his judgment the control of the weather was the next great challenge before the scientists of the world. As I recall, he had an article or two in Fortune magazine on the subject. As we all know, Dr. Von Neumann was without a doubt the world's greatest mathematician in this century and his contributions to science are well known.

I want to commend the chariman of the subcommittee for pushing this program. I hope that we can help you by endeavoring to resolve some of the coordination problems, both on the political side and on the scientific side.

Dr. BATES. Thank you, Senator Jackson.

Senator ANDERSON. We recognized that some people would have different viewpoints, but we put section 202 in so that we could examine the licensing problem.

Senator Allott.

Senator ALLOTT. I have no questions.

Senator ANDERSON. Senator Moss.

Senator Moss. I have no questions. I do commend Dr. Bates for his very fine statement. I agree that we must press into this area of utilizing all the talents we have without getting spun off into corners and without duplication.

Senator ANDERSON. Senator Jordon.

Senator JORDAN. I have one question, Doctor. Do you calculate only to reshuffle the existing supplies of water in the atmosphere, or do you expect that we will be able to increase the supply of atmospheric moisture?

Dr. BATES. We are talking about existing supplies in the atmosphere which are very tremendous relative to those that get on the ground in the right place at the right time.

I suggest that, if you wish, Dr. Kahan might speak to this point. As I understand it, there are tons and tons of water going over our heads which, if we were able to bring them all down, might completely submerge us. Therefore, we are talking about existing supplies in the atmosphere, hoping that we can get a greater proportion out of the atmosphere rather than leaving it there, but not taking out too much.

Senator JORDAN. Do you think there is enough up there to satisfy everyone?

Dr. BATES. There certainly is; yes, sir.

Senator JACKSON. Right on that point, won't it be necessary to get some kind of international understanding on this, treatywise?

Dr. BATES. It certainly will; yes, sir, particularly relative to our neighbors to the north and south.

Senator JACKSON. That is right, and conceivably we all know that depending on how far you go, there are tremendous military implications involved in the control of the weather.

Dr. BATES. That is correct.

Senator JACKSON. I would assume that all of those considerations are being followed closely in connection with any proposed program that might be submitted.

Dr. BATES. That is right.

Senator ANDERSON. Does Mr. Dominy have a statement?

STATEMENT OF HON. FLOYD E. DOMINY, COMMISSIONER, BUREAU OF RECLAMATION, U.S. DEPARTMENT OF THE INTERIOR

Mr. DOMINY. Yes, Mr. Chairman.

I appreciate the opportunity to appear before this committee to testify concerning the Bureau of Reclamation's investigations on increasing the yield of water from atmospheric sources. As you may remember, this is not the first time I have been before you for this purpose.

You gentlemen will recall my enthusiasm for this subject at a time when it was not quite as fashionable as it is today to advocate learning

In the past few months there have been gratifying developments. The need for well-designed field experiments to test weather modification procedures is now widely recognized. Large expenditures are being advocated by responsible groups in the scientific community. This improving environment is satisfying to observe.

Not only is it a clear validation of the judgments made by the Bureau of Reclamation and this committee when the Congress first assigned to us weather modification research duties 4 years ago, but also the new attitudes will encourage more rapid progress toward the goal of intelligent management of our atmospheric water resources.

I believe that the vigorous development of our program over the years since fiscal year 1962 has contributed materially to this constructive change of attitude about weather modification.

Our program continues along the course mapped out when we began. We aim to determine if it is feasible to increase inflow into the Bureau

of Reclamation reservoirs, above what would naturally be provided by nature. To do this reliably requires substituting facts for assumptions at a rate determined in large part by the learning opportunities provided by nature.

To learn what we need to know to discharge our assigned mission, we have undertaken field studies in Arizona, California, Colorado, Nevada, South Dakota, Utah, Washington, and Wyoming. Others are planned for New Mexico, Oklahoma, Oregon, and Montana when funding and availability of trained staff permit. The selection of the sites for experimentation is made with expediting learning in mind.

In each case, however, it has been necessary to invest time and money in the installation of instrumentation and the acquisition of previously unavailable knowledge of the cloud, storm, precipitation, and streamflow characteristics of the area.

There is no one place where one can learn all that needs to be known. Some of the gaps in knowledge involve questions for which answers must be found at each location where experimentation and possible subsequent operation is to be carried out. Other questions can be answered at one place in a manner that is applicable elsewhere.

For example, the characteristics and frequency of occurrence of seeding situations must be learned. Those for north central Colorado may have significant differences from those from central Washington or western Nevada. A technique for detecting silver iodide in snow, on the other hand, could again be applied to samples taken from all areas.

In assigning responsibilities to the various groups which are involved in our program, it has seemed good sense to fit, to the extent possible, the work assigned to the skills and interests of the group. Work which, hopefully, will produce one or more answers of general applicability was, in several cases, combined with investigation of locally pertinent problems.

Our task is not something that can be accomplished overnight. Speaking before you in 1964, I stated that 10 years was an absolute minimum time requirement and two decades would be much better. Our experience since that time, while encouraging, has strengthened my conviction that a long-term program is involved.

The Bureau of Reclamation's atmospheric water resources program came into being as a result of an insertion in the 1962 public works appropriation bill by the conference committee which read as follows:

> Increased rainfall by cloud seeding, $100,000. The committee recommends an allowance of $100,000 to be used for research on increasing rainfall by cloud seeding. This amount would be utilized in cooperation with the National Science Foundation and the Weather Bureau, which are expected to contribute funds and participate in this research.

Funding of the program continued at the $100,000 level in fiscal year 1963. In fiscal year 1964 funding was increased to $175,000. The appropriation for fiscal year 1965 was $1.1 million and $2.98 million in fiscal year 1966.

Experience has shown that this latter amount, which is about three-sevenths of the current annual Federal expenditure for weather modification research and development, is sufficient to pay for only a beginning on the work and facilities required. The importance of the problem under attack justifies higher funding levels.

More money and more manpower will permit some more rapid progress toward understanding the myriad complexities, some of which differ from region to region, but no matter how much money is made available there will remain a considerable time requirement.

It would be a mistake to expect too much learning too soon. Too much money too soon could result in waste unless great wisdom is applied in selection of areas and methods in which to expand.

The Bureau of Reclamation is conducting an operationally oriented program of engineering research aimed initially at learning the circumstances under which it is feasible to use weather modification techniques to increase inflow into its reservoirs. The end products of its research program will be practical operating systems which will include (1) decisionmaking based on physical and economic evaluation as to whether or not to attempt the use of weather modification techniques; (2) the means of recognizing suitable opportunities; (3) means of treating those opportunities; and (4) procedures for evaluating accomplishment.

While some of what remains to be accomplished to make these systems a reality involves meteorologists acquiring new knowledge of the behavior of the atmosphere, a major portion of the total job requires the application of available skills, knowledge, and experience of engineers, hydrologists, social scientists, economists, and technicians who may not have been previously concerned with weather modification.

The Bureau of Reclamation has demonstrated, I believe, as an important asset, its past experience in bringing a variety of disciplines to bear on the solution of complex water resource problems as it tackles the problem of developing atmospheric water resources.

Our approach has been to staff primarily for planning and monitoring. Once we are able to identify requirements, we contract for their fulfillment with private industry, research organizations, consultants, universities, and other governmental agencies. We thus are free to seek answers where they can best be found.

While there will be a need for continuing improvement in these operating systems, early application of available and nearly available knowledge is the goal of the Bureau of Reclamation. That there is a need for considerable empiricism—to learn by doing—in discovering what needs to be known is a basic concept of our program.

It is in the country's best interests to learn by doing rather than to postpone action awaiting the development of complete understanding of all aspects of this complex problem.

The program requirements necessary for the creation of practical operating systems include—

(1) Better observational facilities;

(2) Improved knowledge of local storm precipitation and streamflow climatology;

(3) Improved seeding equipment;

(4) Improved operational know-how; and

(5) Better evaluation procedures.

The Bureau of Reclamation has in effect contracts or subcontracts with seven educational institutions, five private meteorological organizations, and one State agency. In addition to these contracts, memorandums of understanding have been completed with the Geological Survey, the Soil Conservation Service, the Forest Service, the Weather

Bureau, and the U.S. Naval Ordnance Test Station, China Lake, Calif. The Bureau is also receiving cooperation from the National Science Foundation and the National Center for Atmospheric Research.

At the University of Wyoming, the Natural Resource Institute is studying cap clouds at their Elk Mountain Observatory, an isolated peak located 50 miles north of Laramie. This site presents an ideal location for the study of cap clouds. These clouds, which do not precipitate naturally, only rarely, are rather common occurence on the high mountains of Wyoming.

In addition to the usual instrumentation required by atmospheric research programs, the University of Wyoming has installed an observation facility atop Elk Mountain to permit personnel to make observations within the cap clouds during nucleation events.

It has been found that cap clouds are susceptible to manipulation to a much greater extent than other types of clouds. Intermittent operation of a silver iodide generator has produced similarly intermittent precipitation from the clouds.

Movement of the generator in a direction perpendicular to the windflow has resulted in similar movement of the precipitation plume.

Studies have indicated that these nonprecipitating cap clouds may become an important source of additional moisture. A surplus M–33 radar is used at Elk Mountain to track constant level balloons and upon occasion to detect precipitation echoes.

Research into convective cloud systems is being conducted at the South Dakota School of Mines and Technology. Convective clouds are an important source of water in the northern Great Plains. Two randomized field experiments are being conducted by the school. One is in an area located near Rapid City and the other field site is near Shadehill, S. Dak.

Aircraft are used to introduce artificial nuclei into the clouds. The nuclei are produced by generators mounted on aircraft.

A Nike-Ajax radar has been installed near Rapid City and a second Nike-Ajax system is being prepared for use during the summer of 1966. These are typical of the approximately $11 million worth of surplus radars which, though obsolete for their original mission, are being used with benefit throughout our field programs. A specially instrumented aircraft has made a number of cloud penetrations in the northern Great Plains region. Preliminary analyses of the data obtained during these penetrations indicate that ice crystals are not normally present in the majority of the supercooled clouds investigated.

In the Park Range area of Colorado, E. Bollay Associates, Inc., is conducting an experimental program for the Bureau of Reclamation. An important aspect of this program is the use of power spectrum analyses of precipitation rate data to detect changes in the natural storm pattern caused by artificial nucleation.

In connection with this program, the Soil Conservation Service has installed a dense network of snow survey stations, some of which are equipped with snow pillows which can telemeter water content data to an office located in Steamboat Springs.

The Geological Survey is also installing several stream gaging stations in the Park Range area. These stations would have an accuracy

much higher than ordinarily required. They will assist in detecting increases in runoff caused by artificially induced nucleation. The Forest Service is conducting watershed management studies for the Bureau to determine how such practices influence runoff.

At Colorado State University, a program is in progress to apply statistical analysis to streamflow data to aid in the evaluation of weather modification programs.

The five organizations whose programs are directed exclusively or primarily to the Park Range program are excellent examples of the interdisciplinary approach which is required for fruitful attainments in programs of this type.

In the southern Sierra area of California, the U.S. Naval Ordnance Test Station is conducting research into the use of various nucleating agents which can be introduced into the atmosphere by pyrotechnic devices.

This program searches for materials which can be used to nucleate warm clouds as well as additional substances for nucleation of supercooled clouds.

At Taft College in Taft, Calif., a program is underway to develop statistical methods for the evaluation of precipitation data. Fresno State College, under a contract with the Bureau, is developing a program which will coordinate the activities of commercial cloud seeding operations with the Bureau's activities in the southern Sierra area to permit more research information to be obtained from all activities.

Utah State University is developing a program in the Wasatch Mountain areas which features a dense network of precipitation gages which can telemeter their information to a central location. Remote controlled silver iodide generators located at both valley and mountaintop sites are another important aspect of this program. Three radars acquired from surplus military supplies will be used in this program to study precipitation echoes and track balloons and research aircraft in the area.

The Desert Research Institute of the University of Nevada is continuing its randomized cloud nucleation program in Elko, Nev., area and is developing a thoroughly instrumented natural laboratory area in the Lake Tahoe-Mount Rose area near Reno.

Three surplus M–33 radars are used in the vicinity of Lake Tahoe to track balloons as well as track and control seeding aircraft and instrumented research planes operating in the area.

In the vicinity of the San Francisco Peaks near Flagstaff, Ariz., Meteorology Research, Inc., is conducting a program which studies orographically induced convective clouds which appear downwind from the San Francisco Peaks. This program is being expanded to include winter studies of the orographic uplift provided by the Mogollon Rim, further to the north.

The Weather Modification Board of the State of Washington is initiating a program to study the feasibility of shifting precipitation from coastal areas with excessive rainfall to areas further inland where water is at a premium.

It is anticipated that the various programs presently underway will be expanded as funds permit. The program in South Dakota, operating under the concept of a regional center, will include all South Dakota and portions of North Dakota, Nebraska, eastern Wyoming,

and eastern Montana in its research activities. The University of Wyoming will develop a research activity on the cap clouds in the remote and rugged Wind River Mountains.

The Colorado Continental Divide program will include areas other than the existing park range activity which will continue for several years. The Utah activity will enlarge its target area to include most of the mountainous country of the Wasatch and Uinta Mountains.

More induced development of both the summer and winter activities in Arizona is anticipated. The southern Sierra activity will be enlarged as funds permit as will the program in the State of Washington.

Additional programs are foreseen in Idaho, Montana, Oregon, Oklahoma, and possibly Texas.

In addition to these activities which are directly related to the manipulation of precipitation processes, it is highly desirable if not urgent, that programs be developed to investigate the legal, social, economic, and biological implications of weather modification.

The Bureau of Reclamation looks forward with anticipation to continuing its developing program in atmospheric water resources, for this field of activity offers much promise.

Much of what we are doing will be applicable beyond the geographical area of the 17 Western States. The know-how we have acquired should be used wherever it is needed.

Thank you, Mr. Chairman.

Senator ANDERSON. I would like to ask Dr. Kahan a question. That is, how extensive did cloud seeding get in the early days when nearly everyone with a shortage of rainfall tried seeding the clouds?

STATEMENT OF ARCHIE M. KAHAN, CHIEF, OFFICE OF ATMOSPHERIC WATER RESOURCES, CHIEF ENGINEER'S OFFICE, BUREAU OF RECLAMATION, DENVER, COLO.

Dr. KAHAN. There was a time when all of the semiarid States had some kind of cloud seeding going on in them and in some cases entire States were under contract. That, in general, has decreased at the present time. I believe in the past year about the Nation there were some 59 projects of a commercial type but these are to a much smaller extent than during the fifties when you held your previous hearings.

Senator ANDERSON. Isn't it a fact that most of the progress and most of the research work in weather modification during the past decade have been accomplished by universities and private organizations?

Dr. KAHAN. That is a fact.

Senator ANDERSON. How much of that is going on now? Is it substantially down from what it was? Are there some companies that are cloud seeding for their own use?

Dr. KAHAN. I believe there are some 15 private operators. There are some companies, power companies, that are doing work themselves. In general I think that there is a lesser application than in the old days but with, I think, considerably more understanding of what is being done in many cases.

Senator ANDERSON. Senator Jackson.

Senator JACKSON. I just wanted to follow up on what Dr. Kahan said. Has the state of the art of cloud seeding improved substantially since the early beginnings of this program?

Dr. KAHAN. There has not been anything which could be called a scientific breakthrough of great proportions. There has been an accumulation of understanding and observation of natural phenomena.

People who have been in the work for a long time are still having to operate based on assumptions about the atmosphere due to the lack of resources to do such things as measure the availability of nuclei on a wide scale.

Senator JACKSON. The effort has been undertaken not on a research basis but on the basis of somewhat hit or miss?

Dr. KAHAN. That has varied with various operators. Some have tried to build as much statistical design into their operation as circumstances would permit. Usually the support of these operations has been fairly limited and the cost of evaluation can exceed the cost of operation when thoroughly done.

But there have been some operators who have conducted statistical analyses of their work. It is largely on the basis of this information that the recent upsurge in acceptance has taken place.

There has been an examination of some of these results, which, while not the result of experimental design that would meet everyone's requirements, they still have been seen as offering valid evidence of the fact.

Senator JACKSON. We have obtained some useful data over the years from the various operations?

Dr. KAHAN. Yes, indeed.

Senator JACKSON. I suppose in the case of some of the operators where they have been more scientific the data has been more helpful than in other operations?

Dr. KAHAN. That is true.

Mr. BATES. If I may interject, I think it is important to recognize that you will have before you in the next 1 or 2 days some of the people from universities and commercial firms that Dr. Kahan has been talking about. Many of these, including those at universities, have considered the research aspect as one of the uppermost matters of concern. Although they have also been aiming at the possibility of inducing precipitation, the idea has been to research the problem.

Senator JACKSON. I can well understand that one operator merely wants to achieve a certain objective and that is what he is paid for. He may not or probably does not have the financial resources to make the necessary scientific effort concurrent with doing the applied job.

Senator ANDERSON. Senator Allott.

Senator ALLOTT. First, I want to tell you, Mr. Dominy, I thought your statement was excellent.

Mr. DOMINY. Thank you, sir.

Senator ALLOTT. I think one of the things we ought to recall is that we are not in an area where we know the answers yet. If we did there would be no need for the research that is going on, basic and applied.

I come back to the problem which I think I mentioned before, and that is the legal problem. In the early days, Doctor, when we were carrying on cloud seeding in Colorado I recall a situation involving a large farm operated by two brothers just north of Hartman. During

the course of these operations crops on this farm were hailed out 3 years in succession.

Nothing will ever convince these two brothers that the bailing out which they have not experienced before, or since, except just a small patch here or there, something like that, was not the direct result of cloud seeding.

Once we get into this area I think we are going to magnify this because I am sure that everyone who has been in an area where any of this has been carried on has received letters telling of the adverse effects also of cloud seeding.

So, I think the portion of your statement, Mr. Dominy, which points out very well that we are embarking on a relatively new area, although we have had experience now for 15 or 20 years, is a very wise one. I hope that we do not just go out willy-nilly and attempt to expend a lot of money.

I am very sincere in my feeling that in all of our areas this should be from a scientific standpoint a very hard program, proceeding as we can and, of course, part of it is going to be experimentation and some of those are going to be successful and some are not. I think now is the time to start.

Mr. DOMINY. In my earlier statements to this committee and members of the Appropriations Committee I emphasized that anything we undertook was going to be on the basis of a scientifically controlled research, the results of which would be acceptable to the scientific community as being validly arrived at.

This has been our objective. That is why some people think we are moving too slowly because in the early years we are concentrating on instrumentation and controls to know what we are accomplishing in the work we are undertaking.

Senator ANDERSON. I can confirm what Senator Allott said. In New York State a group of agriculturalists wanted some cloud seeding done. They had the unexpected result of raining out the county fair.

Senator JACKSON. I think we have left out something here though, trying to blame these experiments for one kind of weather problem or another. There is a wide feeling in the country that all of our nuclear tests have some effect on the weather. So, in order to give the lawyers a real task we let them try to find out what is the proximate cause of the trouble.

Senator ANDERSON. Senator Jordan.

Senator JORDAN. I have no questions.

Senator ANDERSON. Senator McGovern.

Senator MCGOVERN. You have mentioned your feeling that it would probably take one or two decades to complete the studies that are now underway. Would you anticipate that we would have to be prepared to wait that long for any useful application of cloud seeding?

Mr. DOMINY. No; I emphasized in my statement that I think we have to be prepared to learn by doing and in the process of learning by doing, to accept the risk of certain waste in efforts. On the other hand, as we gain knowledge around Elk Mountain, for instance, on the cap-cloud situation I would see no reason why we should not expand in that effort to actually try to induce additional moisture above the reservoirs in that area or to try to see by extrapolation whether the

results obtained at Elk Mountain are equally applicable to other areas of like terrain and cap-cloud conditions.

But we should not assume that because it works at Elk Mountain, it would work in New Hampshire or somewhere else.

We just don't know enough about the total atmospheric conditions to be certain that we can extrapolate with confidence.

Senator McGovern. Thank you.

Senator Anderson. Senator Moss?

Senator Moss. I have no questions, Mr. Chairman. I had to leave during part of the testimony. I was very much interested in it. I wish that I had not had to be absent during the latter part of the testimony. But the fact that the Bureau of Reclamation has been going ahead with this research thus far is heartening indeed. We need wider application and more of it.

Senator Anderson. Thank you very much for your presentation.

Mr. Dominy. Thank you, Mr. Chairman.

Senator Anderson. SecretaryHollomon of the Department of Commerce.

STATEMENT OF DR. J. HERBERT HOLLOMON, ASSISTANT SECRETARY FOR SCIENCE AND TECHNOLOGY, U.S. DEPARTMENT OF COMMERCE

Dr. Hollomon. Mr. Chairman, I have with me this morning Dr. Robert M. White, who is the Administrator of the Environmental Science Service Administration, who has the responsibility for the Weather Bureau and other agencies, and Mr. Gordon Christenson, who is Assistant General Counsel of the Department.

I have a statement, Mr. Chairman.

Mr. Chairman and members of the committee, I am pleased to be here today and to have the opportunity to present the views of the Department of Commerce on S. 2875.

I would like to say that it is my own personal opinion that the weather modifications activities of this country should be substantially increased and that they present for this committee of the Congress and the executive branch a number of very complicated problems that are technical and administrative.

It is our purpose in testifying this morning to present some of these problems as well as some of the opportunities.

This bill would authorize the Secretary of the Interior to conduct a comprehensive program of scientific and engineering research, experiments, tests, and operations for increasing the yield of water from atmospheric sources.

While we support the general proposition that the Department of the Interior should conduct a program for increasing the yield of water from atmospheric sources, the Department of Commerce is opposed to enactment of S. 2875.

We take this position because this bill goes far beyond simply authorizing a program to develop new techniques for augmenting precipitation. The program advanced by S. 2875, although mission oriented, is so broad that the Department of the Interior would—in practical effect—become the central focus within the executive branch for all weather modification efforts.

Thus S. 2875 would be incompatible with a Presidential reorganization plan now under consideration which would transfer to the Department of Commerce explicit weather modification authority now in the National Science Foundation. Further S. 2875, by its broad scope, would also seriously limit the general science and technology of weather modification which the Department of Commerce feels is vital to the national interest.

This program should be undertaken without delay, with major reliance upon the resources of the Environmental Science Services Administration in the Department of Commerce.

Let me say at this point I am speaking about all aspects of weather modification, not just those relating to increased water resources.

S. 2875, in effect, would authorize the Secretary of the Interior to formulate and carry out a comprehensive program of scientific and engineering research, experiments, tests, and operations directed at increasing the yield from atmospheric sources for beneficial use in all regions of the United States.

It would direct all appropriate Federal agencies to participate in the comprehensive program. It also would direct the Secretary of the Interior to establish or arrange to be established a central engineering and scientific center for the comprehensive program, as well as regional and local centers.

S. 2875 also proposes that activities, including those carried out by a Federal agency, intended to affect, or determined by the Secretary as likely to affect, the atmospheric water resources of the United States, may be carried on only pursuant to a license issued by the Secretary.

The bill recognizes that the foundation of weather modification research is atmospheric research and it would expressly authorize the Secretary of the Interior to engage in an extensive program of such research—to conduct "mathematical or other scientific analyses of clouds and cloud systems, and of the general continental or hemispheric circulation."

We estimate that in both the research and operational aspects of such problems ESSA is spending some $40 to $50 million for this purpose.

One difficulty is that this atmospheric research lies not only at the heart of precipitation control, but also at the heart of other types of weather modification, such a storm dissipation, hail suppression, lightning control, and fog dissipation, all of which would be included in a comprehensive national program.

Further, S. 2875 also fails to take into account the very close link that exists between weather modification research and weather prediction research. The work of creating mathematical models of the atmosphere and of simulating atmospheric phenomena on high-speed electronic computers—which, by the way, both you gentlemen spoke of, and for which Von Neumann was the instigator in this country—is fundamental to any systematic attack on the problem of weather modification.

This same work also lies at the heart of our efforts to improve our weather forecasting capability. Mathematical modeling of the atmosphere is the basis of all modern weather prediction. We use mathematical models in daily forecasting, and they are essential to

our search for new scientific knowledge of the dynamic processes of the atmosphere so that we may improve weather prediction. This dual function of mathematical modeling, its use for both modification and prediction, illustrates a crucial point—that it is virtually impossible to divorce weather modification research from weather prediction research, or from atmospheric science research generally.

Hence, the effect of S. 2875 would be to authorize the Secretary of the Interior to engage in a program of atmospheric research that is fundamental not only to weather modification but also to weather prediction.

The consequences could be serious. There could be costly duplication of effort. And there could be a new fragmentation of the atmospheric science programs of the Federal Government. This would reverse the recent trend. Over the past few years the executive branch has been seeking greater consolidation and coordination of its meteorological activities so that we may have a coherent, well planned, and well executed national program in meteorology that meets the needs of all the Federal departments and agencies. S. 2875 would seriously impair the ability of the executive branch to achieve this objective.

S. 2875 would also impair the ability of the Department of Commerce to conduct research to continue to improve weather service for the general public and to such vital segments of the Nation's economy as agriculture and transportation. And I include here the warnings we now provide of whether hazards and of hurricanes, tornadoes, and other servere storms.

It is section 202 of the bill that particularly gives me cause for concern. This section would require that all activities which are intended to affect, or which the Secretary of the Interior determines are likely to affect, the atmospheric water resources of the United States be licensed by the Secretary.

The scheme of licensing would be that now set forth in the Atomic Energy Act, which means that all Federal departments and agencies would be subject to this licensing requirement. My concern is prompted by the fact that all weather affects in one way or another the atmospheric water resources of the Nation. If section 202 were enacted into law, and taken literally, it could seriously hamper a project such as Project Stormfury, in which we are seeking to learn how eventually to modify hurricanes, which over the past 2 years have caused serious loss of life within the United States and damages totaling hundreds of millions of dollars.

And section 202 carries the broader implication that all atmospheric science activities which pertain to precipitation would have to have the prior approval of the Secretary of the Interior.

This committee is aware of the recent reports of the Panel on Weather Modification of the National Academy of Sciences and of the Special Commission on Weather Modification of the National Science Foundation—established after recommendation by the Interdepartmental Committee on Atmospheric Sciences, of which I am chairman.

These reports contain two salient points. The first is that we are on the threshold of achieving real progress in weather modification. The second is that the United States at present lacks a broad, systematic and comprehensive program to extend and exploit available scientific knowledge in the field of weather modification generally.

To date our efforts have been fragmentary and subcritical, far below the size and quality for effective work.

The Department of Commerce, as a result of its own studies and evaluations, similarly feels that the old order must change and that the United States must give vigorous new direction to its weather modification activities to extend and exploit our capabilities to make significant scientific and technical advances.

In our view, the most appropriate agency within the executive branch to provide leadership in a redirected Federal weather modification program is the Environmental Science Services Administration (ESSA) of the Department of Commerce. There are strong reasons. As you know ESSA was created by Reorganization Plan No. 2 of 1965, which consolidated the Weather Bureau and the Coast and Geodetic Survey. And by administrative order the Central Radio Propagation Laboratory of the National Bureau of Standards was added.

In transmitting the plan to the Congress, the President stated that ESSA "will then provide a single national focus for our efforts to describe, understand, and predict the state of the oceans, the state of the lower and upper atmosphere and the size and shape of the earth."

In this capacity ESSA is the central meteorological agency of the executive branch and is deeply and actively engaged in the atmospheric research that runs like a common thread through the various types of weather modification through storm dissipation, precipitation augmentation and redistribution, hail mitigation, lightning suppression, and fog dissipation.

An excellent example of this research is the work of creating mathematical models of the dynamic processes of the atmosphere on high speed electronic computers, of which I spoke a few minutes ago.

ESSA, through its Geophysical Fluid Dynamics Laboratory, has long been a leader in this area. The laboratory now utilizes one of the largest computers in the United States. The work of the laboratory has already generated much new scientific insight into the dynamics of the atmosphere and is establishing the scientific basis of determining the consequences of interfering in large scale atmospheric processes.

I spoke earlier of the close link between weather modification research and weather prediction research. In one sense, weather modification is simply an extension of weather prediction. Both are techniques for the protection of the public against weather hazards and for the furtherance of the national economy and the well-being of the American people through the science of meteorology.

There are also practical links between weather modification and daily weather forecasting. If we ultimately attempt to modify the weather on a large scale, we shall have to be able to predict beforehand what would have happened had we not made the attempt. In addition, many field experiments will require particular atmospheric conditions, and we must be able to predict when these conditions will exist. Finally, when any particular type of weather modification becomes fully operational, the decision as to whether to modify the weather in a given instance will depend in large measure on our prediction of what the weather will be.

Daily weather forecasting aside, it is important to bear in mind that weather modification research requires considerable background

information that only an organization steeped in the atmospheric sciences can provide. I am speaking now of such matters as the movement of water through the atmosphere, the interactions between the atmosphere and the underlying earth and oceans, the climatological history of any given area, and the nature of the processes for the exchange of energy in the atmosphere. I could easily prolong this list, but I think these examples make my point clear—that there is a wide range of atmospheric science activities that must be called upon in any meaningful program of weather modification research. This same point was made forcefully in the report of the Panel on Weather Modification of the National Academy of Sciences.

For all these reasons, ESSA is already deeply involved in weather modification research. One of ESSA's specific weather modification activities is the modification of severe storms. In conjunction with the Navy, it has been conducting Project Stormfury, to which I have already referred. At its National Severe Storms Laboratory in Norman, Okla., ESSA is conducting extensive research on tornadoes. The Norman Laboratory is also studying the origin and structure of hail so that we may learn more about hailstorms and how they may be modified. And ESSA is now designing a project for the Great Lakes area, which is a vast natural laboratory for the study of atmospheric processes and the structure of storms. We hope that this project will teach us more about the possibilities of modifying winter storm conditions. These projects require extensive facilities—network of observing stations, radar, and specially instrumented aircraft. ESSA already has much of them.

In the area of precipitation modification, ESSA already has carried out several major field experiments, as well as scientific evaluation studies of various cloud seeding activities, the most recent of which was at the request of the NAS Panel on Weather Modification. As precipitation modification is essential to all other research activities in weather modification and in order to provide the leadership contemplated by the proposed Presidential reorganization plan, ESSA has a continuing interest in precipitation modification. Further, ESSA would on request carry out precipitation projects for other agencies, as well as its own research on precipitation processes.

ESSA has also begun to study the interactions and the exchanges of energy between the atmosphere and the underlying earth and oceans. An understanding of these exchanges is fundamental to the development of a capability in large-scale weather and climate modification and the modification of local and regional climates. ESSA is also investigating the physics and chemistry of the atmosphere, particularly atmospheric electrical phenomena, the dynamics of tropical convective clouds, and variations in the chemical constituents of the atmosphere.

Finally, I should like to mention the inadvertent modification of weather and climate by man himself—by the burning of fossil fuels, by the expansion of cities, by the flight of aircraft, and by the launching of space vehicles. ESSA is very much concerned with the meteorolgy of inadvertent modification. It is continaully monitoring the levels of carbon diovide in the atmosphere and analyzing the effects of man's activities on weather and climate.

Let me be perfectly clear in pointing out that for an agency to carry out a specialized mission such as augmentation of precipitation

it must have a thorough knowledge of weather modification. Similarly, ESSA, in order to carry out its mission as to weather prediction, must also have this same thorough knowledge of weather modification. Both missions are deeply related to predicting and controlling the atmosphere. In other words, for two separate purposes two different agencies would have to be involved in some of the same fields.

Under the general scheme of things that I am proposing here, ESSA would have major responsibility for advancing the general field of weather modification—with developing the science and technology common to all types of weather modification. But I want to make it clear that other Federal departments and agencies would have important roles to play. They will need to develop special weather modification techniques or make special applications of existing techniques in order to perform their statutory missions. I have already mentioned the role of the Department of the Interior arising out of its concern with water resources. There are other departments and agencies as well. The Federal Aviation Agency is concerned with the safe and efficient operation of our airports, and it should be encouraged to develop special methods for the dissipation of airport fog. And the Department of Defense will be concerned with military applications.

This brings me to a final problem—that of interagency coordination. Whenever a number of Federal departments and agencies are engaged in a related activity, there must be a mechanism that permits them to consult, to eliminate duplication, to coordinate their activities, and to plan in concert. In the weather field, we now have two coordinating bodies. The first is concerned with broad questions of research policy. This is the Interdepartmental Committee for Atmospheric Sciences (ICAS), which was established by and reports to the Federal Council for Science and Technology. The Federal Council, as you know, is an advisory group composed of the science heads of the Federal departments and agencies and is chaired by the President's Special Assistant for Science and Technology.

The second coordinating body is the Office of the Federal Coordinator for Meteorological Services and Supporting Research, which was established by Bureau of the Budget Circular No. A–62 to coordinate meteorological activities of the Federal departments and agencies. This Office is directed by the Administrator of ESSA.

Similarly, the same scheme for coordination could apply to weather modification. ESSA could serve as a clearinghouse of information on what the departments and agencies are doing and plan to do in weather modification research and operations. It could seek to prevent duplication among their efforts and to iron out differences among them. It could seek to identify areas needing attention. It could provide a regular forum for the discussion of work and new ideas. It could also make studies of the national program to develop information for possible future regulatory control. Without this sort of coordination and study there would inevitably be unnecessary waste and confusion.

Mr. Chairman, this concludes my statement. Once again, I wish to thank the committee for the opportunity to appear here today.

Senator ANDERSON. Mr. Secretary, did you ever review what happened in 1951 when we introduced a weather modification bill?

Dr. HOLLOMON. I have not reviewed it in the last few months. I had some knowledge of it some time ago.

Senator ANDERSON. What was the attitude of the Weather Bureau?

Dr. HOLLOMON. My understanding is that the Weather Bureau was not very bullish with respect to weather modification.

Senator ANDERSON. Not very bullish?

Dr. HOLLOMON. That is right. Mr. Chairman, I also would like to point out that the Weather Bureau is not the same as it was in 1951.

Senator ANDERSON. They change like the weather

Dr. HOLLOMON. Sometimes change is desirable.

Senator ANDERSON. When did you reach this decision to change? When the two reports came out?

Dr. HOLLOMON. No, sir. I would like to make my own personal identification with the subject clear. Sitting on my left is a gentleman named Vince Schaefer. I worked with Dr. Schaefer and Dr. Vonnegut for 3 years on this problem and personally wrote a number of scientific papers about weather modification.

I think they will so assure you, if you ask them whether I personally have been bullish on the subject for 15 years.

Senator ANDERSON. You worked with Dr. Vonnegut and Dr. Schaefer in 1951?

Mr. HOLLOMON. Right. This was one of the most exciting experiments that I knew about. We worked with them on this subject.

Now to get to your question more explicitly. About 3 years ago I, with the assistance of Dr. White, initiated a study of all of the experiments that have been done to enhance orographic precipitation, that is, precipitation that occurs on the less side of mountains. This was done at my request.

This analysis was accomplished internally and indicated that there was very good likelihood that there could be substantial increase in precipitation in such cloud systems. As a result of that analysis and several other things the Interagency Committee on Atmospheric Science, of which I am chairman, asked for the formation of a Commission which the National Science Foundation put into effect in order to lay the groundwork for a new program.

This was at our request over 2 years ago.

Senator ANDERSON. I don't particularly mind what an agency does as long as we get it done but it does seem to be back where it stood 15 years ago.

Dr. HOLLOMON. I think one also has to take account of the past, Mr. Chairman. I think all of us learn by experience. I also feel it is perfectly clear now to those who were involved in the ESSA organization—Dr. White can speak for himself—that we believe that not only by increasing precipitation but in changing the energetics of large-scale storms that there is a good possibility with appropriate research we can make substantial modifications of the weather, both locally and, hopefully, on a large scale.

Senator ANDERSON. I think that is a very important aspect. In your testimony before the Senate Commerce Committee you said the ESSA has a large core of scientists and engineers numbering approximately 200 with special capabilities in the field of weather modification and related areas. Can you furnish the names of the 200 people?

Dr. HOLLOMON. We will be glad to furnish that for the record.

(The document referred to follows:)

ESSA SCIENTISTS AND ENGINEERS WITH SPECIAL CAPABILITIES IN WEATHER MODIFICATION AND RELATED AREAS

CLOUD PHYSICS, ATMOSPHERIC ELECTRICITY AND WEATHER MODIFICATIONS

Allee, Paul A.
Bradley, James T.
Ellis, Howard T.
Grote, Heinz H.
Hardy, William E.
Kasemir, Heinz W., Ph. D.
Komhyr, Walter D.
Kreig, John J., Jr.
Phillips, Byron B.
Simpson, Joanne, Ph. D.
Simpson, Robert H., Ph. D.
Weickmann, Helmut K., Ph. D.
Wiggert, Victor

STATISTICAL DESIGN AND EVALUATION OF EXPERIMENTS

Allen, Roger A.
Brier, Glenn W.
Carpenter, Thomas B.
Colson, DeVer
Glahn, Harry R., Ph. D.
Jorgensen, Donald
Kiser, William L.
Klein, William H., Ph. D.
Lewis, Frank
Roberts, Charles F.
Thom, H. C. S.

HURRICANE STRUCTURE AND MODIFICATION

Carlson, Toby, Ph. D.
Gentry, R. Cecil
Hawkins, Harry F.
Koss, Walter J.
Lateef, Mohammed, Ph. D.
Lewis, Billy M.
Miller, Banner I., Ph. D.
Rosenthal, Stanley L., Ph. D.

SEVERE LOCAL STORM STRUCTURE

Bigler, Stuart G.
Frankhauser, James C.
Kessler, Edwin, III., Ph. D.
Kinzer, Gilbert D., Ph. D.
Lhermitte, Roger, Ph. D.
Merritt, Lester P.
Sanders, Leslie D.
Ward, Neil B.
Wilk, Kenneth E.

ATMOSPHERIC CONTAMINATION AND INADVERTENT MODIFICATION

Allen, Phillip W.
Angell, James K., Ph. D.
Armstrong, Robert H.
Arnett, A. B.
Bernstein, Abram B.
Booth, Howard G.
Clark, John F.
Cleeves, George A.
Clupf, Frank D.
Cogdal, Ernest G.
Delver, Norbert F.
Demarrais, Gerard
Dickson, Charles R.
Ferber, Gilbert J.
Flowers, Edwin C.
Hosler, Charles R.
Hass, William A.
Heffter, Jerome L.
Herbert, Gary A.
Hoecker, Walter H., Jr.
Holzworth, George
Humphrey, Paul
Jessup, E. L.
Kennedy, Norman C.
Kussman, Abraham S.
List, Robert J.
Machta, Lester, Ph. D.
Martin, DeLance O.
McCormick, Robert
Miller, Marvin E.
Morell, Joseph R.
Mueller, Harold F.
Niemeyer, Lawrence E.
Pack, Donald H.
Pales, Jack C.
Palmer, Terrance R.
Peterson, Kendall R.
Pooler, Francis
Pribble, Lynn H.
Quering, Rolf F.
Richter, Alden P.
Slade, David H.
Slater, Herschel H.
Stoat, Albert H.
Telegadas, Kosta
Titus, Robert W.
Truppi, Lawrence A.
Turner, D. Bruce
Urban, Verdis D.
Van der Hoven, Isaac, Ph. D.

LARGE-SCALE ATMOSPHERIC MODELING

Adem, Julian, Ph. D.
Bedient, Harold A., Ph. D.
Bryan, Kirk
Carlton, Willette M.
Clarke, Reginald H.
Graham, Roderick D.
Hellerman, Solomon
Hembree, Daniel G.
Hiland, Catherine M.
Holloway, J. Leith, Jr.
Hovermale, John B., Ph. D.
Kennedy, Jerry M.
Kung, Ernest C., Ph. D.
Lipps, Frank B., Ph. D.
Manabe, Syrikuro, Ph. D.
Miyakoda, Kikuro, Ph. D.
Rasmusson, Eugene S.
Rintel, Lionel
Shulman, Irving I.
Shuman, Frederick G., Ph. D.
Smagorinsky, Joseph, Ph. D.
Stackpole, John D., Ph. D.
Strickler, Robert F.
Wetherald, Richard T.
Williams, Gereth P.

GLOBAL CLOUD ANALYSIS

Anderson, Ralph K.
Brodrick, Harold J.
Erickson, Carl O.
Ferguson, Edward W.
Gray, Thomas I.
Hubert, Lester F.
Johnson, Harry M., Ph. D.
Kuettner, Joachim P., Ph. D.
McClain, Paul E., Ph. D.
Nagler, Kenneth M.
Oliver, Vincent D.
Timchalk, Andrew
Whitney, Linwood F.

DROUGHT AND CLIMATIC VARIATION

Barger, Gerald L., Ph. D.
Blanc, Milton L.
Brown, Merle
Butson, Keith
Crutcher, Harold L., Ph. D.
Dale, Robert F., Ph. D.
Mitchell, J. Murray, Jr., Ph. D.
Pack, Boyd, Ph. D.
Palmer, Wayne C.

ATMOSPHERIC RADIATION, HEAT BALANCE AND CIRCULATION

Anderson, Calvin E.
Clapp, Philip F.
Finger, Frederick G.
Fritz, Sigmund, Ph. D.
Kochanski, Adam B., Ph. D.
Kuhn, Peter M., Ph. D.
MacDonald, Torrence H.
Namias, Jerome
Ruff, Erwin
Rubin, Morton J.
Teweles, Sidney, Ph. D.
Wark, David O., Ph. D.
Winston, Jay S., Ph. D.
Woolf, Harold M., Ph. D.
Wulf, Oliver R., Ph. D.

SEA AIR INTERACTION

Harris, D. Lee, Ph. D.
Holleyman, Jewell B.
Jelesnianski, Chester P.
McFadden, James D., Ph. D.
Ostapoff, Feodor
Shinners, Willard W.
Taylor, Albion D., Ph. D.
Williams, Anthony C.
Zetler, Bernald D.

TRANSPORT AND DIFFUSION IN THE ATMOSPHERE

Gifford, Frank A., Jr., Ph. D.
Johnson, Warren B., Jr., Ph. D.
Klug, Werner, Ph. D.

SPECIALIZED INSTRUMENT DEVELOPMENT

Acheson, Donald T.
Bell, Keith D.
Crouser, Herman H.
Harmantas, Christos
Hill, Augustus N.
Hodge, Mary W., Ph. D.
Kohl, Francis V.
Knibb, Robert R.
Munis, Richard H.
Reynolds, Richard R.
Seemuller, William W.
Shreve, Kenneth H.
Staats, Wayne F.
Waters, Richard H.
Zegel, Ferdinand H.

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HYDROMETEOROLOGY

Goodyear, Hugo
Lott, George A.
Miller, John F.
Myers, Vance A.
Paulhus, J. L. H.
Riedel, John T.
Schwarz, Francis K.
Weaver, Robert L.

RESEARCH FLIGHT SCIENTISTS

Ahrens, Merlin R.
Callahan, William S.
Conrad, Gerald, Ph. D.
Davis, Harlan W.
Decker, Richard D.
Friedman, Howard A.
Hatch, Marshall G.
Mason, Howard J., Jr.
Richardson, Isaac W.

MANAGEMENT AND PLANNING

Hall, W. Ferguson
Kline, Dwight B.
Landsberg, Helmut E., Ph. D.
Pocinki, Leon S., Ph. D.
Ringenbach, Maurice E.

SOCIOECONOMIC

Helbush, Robert E.
Hibbs, James R., Ph. D.
McQuigg, James D., Ph. D.
Russell, John C., Ph. D.

ECOLOGY

Jensen, R. E.
Newton, Oliver H.
Noffsinger, Terrell L., Ph. D.
Raniere, Lawrence C., Ph. D.
Sakamoto, C. M., Ph. D.
Stirm, Walter L.
Van Den Brink, C.

Senator ANDERSON. What do you mean by related areas? They are having a hearing in the Foreign Relations Committee on related areas.

Dr. WHITE. As indicated in Dr. Holloman's testimony, Mr. Chairman, those aspects of atmospheric science research which are very closely related to weather modification were included in those figures. We will be very pleased to supply the list of names to you.

Dr. HOLLOMAN. By related areas we mean things such as general dynamics of the atmosphere, and the physics and chemistry of what goes on in the atmosphere.

Senator ANDERSON. You mentioned hurricanes?

Dr. HOLLOMAN. Yes, sir.

Senator ANDERSON. I remember Dr. Shaefer, who rode a little airplane in a hurricane off the coast of Florida the other day and had a very interesting experience. Has anybody in ESSA done that?

Dr. HOLLOMAN. Yes, sir.

Senator ANDERSON. How did they come out?

Dr. HOLLOMAN. We have had interesting experiences. We have a regular program in cooperation with the Navy. We use research aircraft of our own and aircraft of the Navy and Air Force for flying through storms.

We have a procedure for hurricane seeding operations which specifies that seeding may take place only when the hurricanes are more than a certain distance away from the land since, we are not too knowledgeable about what goes on, we then proceed to seed the hurricanes.

In the last couple of years, we have not had hurricanes in the qualified seeding area. The last one, I think, was about 3 years ago. We have an area marked out which, essentially, says that if the hurricane

is less than 36 hours from the land we will not seed it. But there have been experiments in which the evidence as reported by the National Academy of Science as well as our own scientists is that significant changes in hurricane structure occurred simultaneously with the seeding.

Now the problem here, as in weather modification generally, is to be sure what you did would not have happened had you not done it. The evidence on that score is not clear.

Senator ANDERSON. Since 1957, the date of the issue of the President's Advisory Committee on Weather Control, what significant technical contributions has the Weather Bureau achieved in the field of weather modification applied to increasing the water supply?

Dr. HOLLOMON. I don't remember the figure exactly, but I think it is something like 35 or 40 percent of the water falling on the east coast of the United States, Atlantic region, South Atlantic region, originates from storms which are associated with large tropical disturbances such as hurricanes.

They are a major source of the water of the Eastern and Southeastern part of this country. This is one of the real problems. Hurricanes do affect in a very substantial way the water resources of this country. I don't remember the exact figure but, as I remember, it is something like 35 percent.

This raises the point that you cnanot separate the problem of interfering with severe storms wholly from the problem of enhancing the water supply. They are related.

Senator ANDERSON. There is a question of emphasis. I realize that the scientific work is to be done by the Weather Bureau. Among the people in Government should be someone interested in trying to increase the supply of water.

Dr. HOLLOMON. I agree with that.

Snator ANDERSON. If you do not increase the supply, several areas in the east will suffer.

Dr. HOLLOMON. I do not disagree with that statement at all.

Senator ANDERSON. At a time when Senator Case and I went up to New York City nobody worried about the water supply of New York City. Now you can say, without too much difficulty, that New York does not have a chance to get the water it needs.

There has been a change and there should be some recognition of that.

Dr. HOLLOMON. Mr. Chairman, you raised earlier the issue which I think is appropriate, the fact that the Weather Bureau was not enthusiastic about this problem several years ago. I also testified before. I think it is important now, that in a sense the assignment of the responsibility for applied research and development to the National Science Foundation did in fact discourage other agencies from pursuing this activity.

I really think that was the case. This is not to say that what NSF did do was not important because I think it was very important, but I think it did discourage some other agencies.

Senator ANDERSON. Did it discourage the Bureau of Reclamation?

Dr. HOLLOMON. No, sir.

Senator ANDERSON. Isn't it strange, they let the Bureau of Reclamation go ahead and not the other bureaus or did the Bureau of Reclamation want to increase the water supply?

Dr. HOLLOMON. I think that is the case. For a long period of time I think the general fact that it was operationally possible to lay out programs which would be engineering in character both for determining the effects on severe storms and on precipitation may have been delayed to some degree as a consequence of the reluctance of the Weather Bureau and the assignment of responsibility to NSF.

Senator ANDERSON. In the early days Senator Case and I were not primarily concerned about what department did the work. One of our participants was the Commerce Department, one of them was the Interior Department, one of them was Agriculture.

We were very anxious to get to work on it. It was very difficult to do. Why has the Weather Bureau not been more active in weather modification?

Dr. WHITE. Since the 1957 report, Mr. Chairman, the Weather Bureau resources in weather modification and closely related areas have been devoted to problems dealing largely with hurricanes, severe storms, and tropical cumulus. Of course, since 1961, the Weather Bureau has been extremely active in weather modification field experiments in connection with hurricanes and tropical cumulus systems.

Senator ANDERSON. I can understand your using hurricanes. I wish you would show why you are interested in adding to the water supply?

Dr. WHITE. Mr. Chairman, I think you will find that the Weather Bureau was active in preciptation modification in the early days.

It was active as far back as 1959 and 1950. In 1953 it mounted a very large program in the State of Washington in the Seattle area looking to the augmentation of precipitation. It has mounted field experiments in Ohio and over the years has been relatively active in this field.

In more recent years it has directed its resources toward the severe storm problem and towards the other fundamental problems of atmospheric dynamic and cloud systems.

Senator ANDERSON. I wish sometime you would take a look at the publication "Weather Control and Augmented Weather Supply," joint hearing by the subcommittees on Interior and Insular Affairs, Interstate and Foreign Commerce, Agriculture and Forestry, 82d Congress, 1st session, 1951, and I don't believe if you went through those hearings, as some of us did, you would gain the impression that the Weather Bureau was wildly enthusiastic about it.

Dr. HOLLOMON. Senator, in my opinion, over the past the Weather Bureau has not taken sufficient active interest in the whole field of weather modification both advertent and inadvertent. By "inadvertent," I mean the effect of all sorts of pollutants on the weather. I do not have any excuse for that. Neither Dr. White nor I were here at the time.

My own view has been since I personally first participated in such experiments with Langmuir and Schaefer now 20 years ago and my view since being in this office is that we are presented with an opportunity to possibly bring about very substantial changes in water resources as well as in severe storms and climate.

We now stand before you saying that we will do, within the limit of our resources, whatever we need to do in order to get that part that we think we ought to do, done.

That does not say that the Interior Department should not have a responsibility in the water resources area.

Senator ANDERSON. You recognize that the Department of Interior does have a program to try to augment our water supply?

Dr. HOLLOMAN. Yes, sir.

Senator ANDERSON. Do you have one?

Dr. HOLLOMAN. We do not have an active program at the moment other than the basic work on the physics and chemistry of clouds and on the simulation of the dynamics of the atmosphere. We do have a program planned for next year on the effect of seeding and related activities on the storm system in the lower Great Lakes area.

Senator ANDERSON. This program was started by the Interior Department 4 years ago. I thought you might have a plan in your Department. I am not trying to make this personal. I am sorry if it appears to be.

Dr. HOLLOMAN. That is perfectly all right.

Senator ANDERSON. The Weather Bureau might have a plan and the Department of Commerce might have a plan. You should have one now.

Dr. HOLLOMON. Mr. Chairman, we have been working on a plan for the last several months for the activities in ESSA in the broad field of weather modification. It is not completed yet. It is still in draft. But we will have one within the next several weeks.

Senator ANDERSON. ESSA has 200 scientists and engineers with special capabilities in weather modification and do you have a budget request in this field?

Dr. HOLLOMAN. Yes, sir.

Senator ANDERSON. For weather modification?

Dr. HOLLOMON. Yes, sir. The budget request on weather modification activity for ESSA is one and a half million dollars for fiscal 1967.

Senator ANDERSON. That is substantially less than the Department of Interior.

Dr. HOLLOMON. Yes, sir. This was an increase over last year of a million dollars which is about the same as the increase in the Department of Interior over its last year's program.

Senator ANDERSON. One million what?

Dr. HOLLOMON. $1,550,000.

Senator ANDERSON. That is an increase of a million dollars?

Dr. HOLLOMON. About a million dollars. This does not include the cost of operational aircraft with respect to exploring severe storms which, in addition, as I remember the figure, is about a half million to $600,000.

So the total related work, by this I mean directly related, we don't cost the aircraft that way, is about $2 million as a total program.

Senator ANDERSON. Can you give us an estimate of the figure directly related to the increase in precipitation?

Dr. HOLLOMON. I can't do it at the moment.

Senator ANDERSON. Senator McGovern.

Senator MCGOVERN. Mr. Secretary, recognizing the desirability of moving this program ahead as expeditiously as possible and considering the longtime interest that the Department of the Interior has had in water resources, would you not think it would give a new thrust to

the program or additional thrust to the program if that Department played an enhanced role in this weather modification field?

Dr. HOLLOMON. Senator McGovern, it is my view that the Department of the Interior and its program should be supported additionally. I have tried to make the point, however, that weather modification is deeply connected with weather predictions. It is deeply connected with all forms of weather modification, and I think it is necessary that both agencies have a serious role here. I also think it is also very important to point out that the regulatory and future legal problems are very serious here, not only with respect to whether or not seeding or other weather modification techniques affect precipitation but rather, in addition, whether they cause or ameliorate severe storms.

I think we have a very serious problem as to the roles of the States in licensing both for private and for public purposes. I think that we have problems in insisting that we have observational facilities around the country so as to know what did actually go on as a consequence of seeding, whether advertent or inadvertent, and this is deeply connected with the Weather Bureau prediction problem.

My own feeling is that both are necessary.

Senator MCGOVERN. Is your own specific objection to this bill that is now before us, section 202, the licensing requirement?

Dr. HOLLOMON. Well, that is certainly a very specific objection. I think that it is too early to have such licensing requirements at this moment. I would think, and I have so testified before the Commerce Committee, that it would be desirable at this stage to be able to have prior reporting of any experiments that are underway, whether for severe storms or for any other aspect of weather modification such as hail suppression or precipitation, and that the Federal Government should have the right to cause experiments, private experiments, to cease if they interfere with large scale experiments, whether carried out by Interior, Commerce, Agriculture, or anyone else.

I believe that authority is necessary at this time. But I do not think that it is desirable at this time to have a single agency licensing the other Federal agencies or in fact by implication——

Senator MCGOVERN. Is that in fact your major objection?

Dr. HOLLOMON. That is one objection. I have another objection where it tries to state the scope of the research involved, in section 100. To us this covers the same basic research that has to do with such problems as atmospheric circulation or the transfer of energy between the ocean and the atmosphere, which is central in the research activity of the Department. This research also involves our satellite activities. This can produce duplication and fragmentation of responsibility.

Senator MCGOVERN. Mr. Chairman, could I have a couple of minutes? I would like to ask a couple of questions about the concept and the mission of the environmental agency if we have the time?

Senator ANDERSON. Go ahead.

Senator MCGOVERN. I was wondering, Mr. Secretary, do you envision your responsibility in the Environmental Sciences Service Administration to embrace water all around the cycle and the atmosphere, the oceans, on and under the land? Where does your role begin and end?

Dr. HOLLOMON. There are two problems which we must be sure we take care of, and I hope this committee and the Congress does. I will try to describe these problems to you. It is perfectly clear to me that

the Secretary of the Interior, and appropriately with the leadership of this committee and by Executive order, has been granted responsibility for water resources.

This runs in my view to the question of the most economic ways to provide water by desalination and so forth. Now on the other hand it is also true that the environment is a whole. That is, the water is evaporated from the oceans by the sun, it is imparted to the atmosphere, which transports and condenses it to produce rainfall which flows back into the ocean. This is the hydrologic cycle.

The description of hydrologic cycle and its climatology has been over the years a function of ESSA. On the one hand you have water resources that need to have central focus which I believe this committee, as I say, has helped to give to the Department of the Interior. On the other hand the environment has to have a central focus because it is an interacting system. Now both of these things are true. It is my belief that the function of ESSA is to be in a position to describe, predict, and where appropriate, control the character of the physical environment.

Senator McGovern. I was told, for example, I don't know whether this is true or not, that you have plans to take over the work of the Geological Survey as far as the topographic mapping is concerned. Is that part of your mission?

Dr. Hollomon. I personnally have no such plans. This is a question that the President would have to decide.

Senator McGovern. There is no plan so far as the agency is concerned to take over that?

Dr. Hollomon. The question or reorganizaiton of that matter, which lies between two departments, is the responsibility and at the initiative of the President's office.

Senator McGovern. Thank you, Mr. Chairman.

Senator Anderson. Isn't it pending before the Bureau of the Budget right now?

Dr. Hollomon. This question is certainly being considered by the Bureau of the Budget at the present time.

Senator Anderson. I might discuss this licensing section just a minute. I don't say it is simple or easy but I have had the theory that you are going to have to have a controlled experiment to know what the effect will be of seeding iodide in the clouds. There was a time when Dr. Workman was working with Dr. Langmuir and his group and he would seed iodide in Albuquerque every 7 days, for example. Then every 7 days it would rain in Louisville. I know the Weather Bureau said the seeding did not have anything to do with the rain in Louisvile but some of us thought the coincidence was strange. We would have liked for him to so control the amount of seeding in the atmosphere to find out definitely whether that iodide he was putting in clouds in Albuquerque again was affecting the situation in Louisville but he could not do it.

I also saw some figures that were connected with Dr. Schaefer or Dr. Langmuir where the troposphere at Omaha would go up and down following the seeding. I thought there might be some influence on it by seeding.

I think there should be some sort of licensing procedure by which they could control what is done in that respect. I know the commercial operators at that time did not like the idea but I think it would

be beneficial even to them if they had some control over the experiments.

Dr. HOLLOMON. Senator, the problem you raise is a real problem. I would not like to indicate that it is not. Our suggestion has been that for all major Federal programs, whether having to do with increased precipitation or any other kind of weather modification activity, that the Federal Government have authority to prevent seeding activities when they are judged to interfere with major commitments of the Federal Government with respect to such programs.

Senator ANDERSON. How does that differ from licensing?

Dr. HOLLOMON. You don't license them if there is no indication at all that the activity being carried out in an area is likely to have an effect.

Senator ANDERSON. Then the program should be national in scope?

Dr. HOLLOMON. Yes. What you would do, you are not going to experiment everywhere simultaneously. It is our proposal that you look at the particular programs to see whether or not private activity would in fact interfere and make a judgment after hearings on that basis but you would not license in advance.

Senator ANDERSON. If you don't know how to run a silver iodide machine how do you know what is going on?

Dr. HOLLOMON. We also would suggest it be required that anyone engaging in weather modification activity give prior notice to the Federal Government.

Senator ANDERSON. Isn't that a little like licensing?

Dr. HOLLOMON. Yes, sir.

Senator ANDERSON. Are you opposed to licensing?

Dr. HOLLOMON. At this time; yes, sir. I don't think we know enough at this time.

Senator ANDERSON. If the program is going to succeed by use of experiment and you are opposed to licensing, then you are opposed to the program, aren't you?

Dr. HOLLOMON. I don't think so.

Senator ANDERSON. I would not say so either, but it seems to me you have to be able to control experiments in order to find out what actually happened.

Dr. HOLLOMON. Yes, sir.

Senator ANDERSON. You have to be able to control them completely.

Dr. HOLLOMON. So far, I agree with you.

Senator ANDERSON. If we leave it that way, we will be all right.

Dr. HOLLOMON. That was my suggestion that two things be done. One is that the authority which is now vested in the National Science Foundation, having to do with reporting, be clarified to insure that the reporting would have to be done prior to the seeding operation or any other kind of operation and, second, where such reported activities would interfere with a major activity on the part of the Federal Government, that the Federal Government would have the right to cause those activities to temporarily cease.

Senator MCGOVERN. Mr. Chairman, one of the reasons I raised this question about the recommendation relating to the Geological Survey, we have authority under our State law to enter into contracts, that is, the South Dakota State Geological Survey, with the U.S. Geological Survey. We would not have that authority with ESSA or with other Government agencies.

I am wondering if either you and/or Dr. White can shed any light on what the rationalization is for this proposal that you say is pending before the Budget Bureau to transfer that topographic mapping function into ESSA. What is the purpose of it? Is it felt that you can do a better job than the Geological Survey or what is behind it?

Dr. HOLLOMON. This proposal is being considered by the President's Office. The rationalization for it, if the President decides to send it to the Congress, hopefully will come forward. I can report from my own knowledge of some of the factors that are involved that it is believed that the geodetic work of the Coast and Geodetic Survey and the topographic work of the Geological Survey could best be carried on if they were integrated in a single whole.

Senator MCGOVERN. There are a lot of uses for those maps. Land use planning and reservoirs require mapping work. To me, this would be moving away from a concept of a general centralized and coordinated function of the kind you describe as desirable.

Dr. HOLLOMON. Senator, as I say, I am in a difficult position. This is not something I have proposed. I believe there are very real economies and efficiencies if we had a central mapping service. If the President proposed it, I think it is on that basis he would propose it.

Senator MCGOVERN. Thank you, Mr. Chairman.

Dr. HOLLOMON. Thank you very much, Mr. Chairman.

Senator ANDERSON. I think we are going to have to adjourn until 2 o'clock. We have two witnesses for the afternoon. We had better not try to hear them this morning. Mr. Chamberlain, do you want to go ahead now?

Mr. CHAMBERLAIN. At your discretion.

Senator ANDERSON. Let us adjourn until 2:30 then.

(Whereupon, at 12:30 p.m., the subcommittee recessed, to reconvene at 2:30 p.m., the same day.)

AFTER RECESS

(The subcommittee reconvened at 2:30 p.m., Senator Clinton P. Anderson, chairman of the subcommittee, presiding).

Senator ANDERSON. The first witness this afternoon is Mr. Gordon J. F. MacDonald, director, and chairman, Department of Planetary and Space Science, University of California, and Dr. Thomas Malone. We appreciate your coming, gentlemen.

STATEMENT OF DR. GORDON J. F. MacDONALD, CHAIRMAN, DEPARTMENT OF PLANETARY AND SPACE SCIENCE, UNIVERSITY OF CALIFORNIA

Dr. MACDONALD. The chairman's longstanding and deep interest in this subject is providing continuing encouragement to workers in the field of weather and climate modifications. It is therefore with special pleasure and appreciation that I take this opportunity to discuss with you certain problems of weather and climate modifications, with special emphasis on how these relate to the proposed legislation, S. 2875.

I appear before you as Chairman of the National Academy of Science Panel on Weather and Climate Modifications. Since you will be hearing from several other members of the Panel, I will not attempt to summarize the Panel's report.

Rather, I wish to indicate how I view the proposed legislation in the light of the Panel's major recommendations.

The complexion of weather and climate modification has changed subtly since 1957 when an advisory committee on weather control reported to President Eisenhower. In many fundamental areas and respects, the earlier era of speculation has been gradually superseded by the present period, in which systematic exploration of modification possibilities has become possible. Three factors are responsible for this shift in emphasis. First, there are encouraging advances in the development of moderately realistic mathematical models for atmospheric systems, ranging in scale from a cloud to planetary scale phenomena.

Secondly, the high-speed electronic computers make possible numerical simulations of the atmosphere, that can significantly contribute to an understanding of the interdependent workings of this complex system.

Thirdly, the availability of new platforms including meteorologic satellites, together with advanced observation techniques, can provide abundant new data required for monitoring the atmospheric systems one seeks to modify.

These broad advances have been accompanied by an increasing number of studies of the modification of clouds and cloud systems.

In its studies, the National Academy Panel emphasized those aspects of weather modification that dealt with the enhancement of precipitation. This emphasis reflects the concern of the Panel with problems of water resources.

At present, the success of precipitation enhancement experiments can be judged only on statistical grounds.

The target area, one in which clouds are seeded, is compared with adjoining and similar control areas where the clouds are not seeded. In properly designated experiments, the target and control areas are selected on a statistical basis.

Such statistical evaluations can lead to statements regarding the probability that precipitation has, indeed, been increased or decreased. On the basis of the analysis of a large number of such statistical experiments, the Panel concluded that there was increasing evidence that precipitation could be increased or redistributed by seeding, using silver iodide.

Experiments or operations in which only data regarding precipitation is obtained cannot provide information regarding the mechanisms by which the precipitation is increased or redistributed. Such information can be gained only by a comprehensive program of observation and experimentation on clouds and cloud systems.

Two recent studies quite clearly indicate the complexity of the physical processes that enter into determining whether or not precipitation can be increased by seeding. Recent investigations carried out by the Pacific Gas & Electric Co., in northern California and by Australian workers indicate that seeding of cloud systems in which the cloud tops are cold—temperature of 14° F. or lower—led to an increased rainfall. However, the seeding of clouds in which the cloud top temperature was higher that 14° F. led to decreased precipitation. The cause of the difference is unknown.

At present, the efficacy can only be tested on statistical ground. The goal for the future is to understand the physical processes leading

the precipitation in sufficient detail, so that given a developing meteorological situation, predictions can be carried out.

Numerical methods and electronic computers might be used to determine whether or not seeding will increase or decrease the precipitation from a particular storm system. We are a long way from having the kind of physical understanding that would allow such meaningful prediction.

This is one example of a number of strange and puzzling phenomena on which we can obtain an understanding through detailed studies, studies that undertake to measure properties of clouds other than just the amount of precipitation that falls from the clouds.

As we consider weather modification on scales larger than that of a cloud, the importance of prediction increases.

Thus, if at some time modification of the weather over large areas or of the climate of continental dimensions is envisaged, then it is absolutely essential that a means be developed to allow the prediction of the results of such experiments.

The Panel concludes that an essential element of weather modification, and particularly of precipitation enhancement operations, is the prediction of the consequences of the modification operations.

Because of this, the Panel suggests that weather modification cannot sensibly be separated from other aspects of the atmospheric sciences. Weather modification is a very important element in a group of scientific and technological endeavors dealing with the whole of our physical environment.

Isolation of this effort may very well hamper the long-term development of the subject. For example, those problems that relate to water resources cut across all aspects of the environment. The large-scale water budget of the atmosphere is influenced to a very large extent by the interaction of the atmosphere with the oceans.

An understanding of the hemispheric water budget will require comprehensive studies of the oceans as well as the atmosphere.

The proposed legislation deals primarily with water resources and not with problems related to modification, where attempts would be made to decrease the effect of severe storms.

In the view of the Panel, this separation of water resources activities and those dealing with modification of violent storms is an unnatural one. The two are closely linked, since in increasing precipitation one can also affect the dynamics of clouds and cloud systems. It is through the dynamics of cloud systems that one hopes to modify violent storms.

In summary it would appear that in the field of weather modification, the Federal Government should perform the following functions:

(1) Recommend national policies concerning atmospheric interest for the United States.

(2) Foster the exploration of the atmospheric environment, in order to provide capability for using water resources of the atmosphere, and for the prevention of amelioration of natuarl disasters.

(3) Provide predictions of the atmospheric environment as an essential service to those involved in the use of atmospheric water resources and to those concerned with ameliorating the effects of natural disasters.

(4) Initiate, support, and encourage programs of education, training and research, and a program of services relating to relevant science and technology.

Because of the complex interdependency of the various aspects of weather modification on other environmental sciences, it is the view of the Panel that major responsibility for weather modification should be centered in a single agency. This agency should have broad responsibility in the environmental sciences and related activities.

It is my view, and I believe it is the view of the Panel, that the proposed legislation, in which efforts will be diffused among several agencies, runs counter to the major recommendation of the Panel.

I believe, the legislation does not adequately recognize then that weather modification is an important part, but only a part, of questions dealing with our physical environment. These questions present some of the most pressing problems of our society.

It is my belief that a far more comprehensive view will be required if we as a nation are to satisfactorily meet the demands of society.

Senator ANDERSON. Thank you, Dr. MacDonald.

Dr. MacDonald, I am pleased to see that the National Academy has finally concluded that the Senate Interior Committee has been on the right track for more than 15 years in stimulating scientific and engineering research in weather modification. It is good to have you folks on the team, too.

The findings of the Panel deserve careful and thoughtful consideration by your Government and the Nation at large. These hearings are planned to serve this purpose.

Your report says, "To be successful, the national program recommended by the Panel must represent a fine balance between unwarranted optimism and undue skepticism. There is an unparalleled opportunity for our scientific community and our Federal Government to demonstrate imagination, perception, and wisdom in the management of a program having both intrinsic scientific interest and potentially for ranging socioeconomic and political consequences."

Would you amplify that a bit?

Dr. MACDONALD. Yes, we feel that the weather modification is a problem of enormous complexity. It is complex in its scientific and technological aspects since you are dealing with an atmopshere, an atmosphere whose basic properties are only poorly understood, an atmosphere which interacts with other portions of the environment.

Much of what again happens in the atmosphere depends on what happens when the air comes into contact with the ocean. Much of what goes on in the atmosphere depends on the interaction of the atmosphere with the solid earth. It is this enormous complexity which poses these very challenging and interesting problems.

It is because of this that we feel that really a whole new look should be taken at the question of how Government fosters activities in this field.

It is complex. It deals with complex sicentific problems and at the same time impinges on all areas of society. I think in weather modification we see illustrated really the main characteristic of modern science. It is not so much the expanded scale of discovery or application but it is rather than that the interpenetration of science into all aspects of human endeavor and in weather modification these are, of course, greatly amplified.

Now what the Panel had in mind, or the main thrust of the Panel's recommendation with regard to the governmental action, was that weather modification forms part of what we would call the sciences and technology of the atmosphere.

In turn this forms part of the science and technology of the environment as a whole—ocean, solid earth.

I think it is time to take a rather bold and courageous look at what can be done to bring these various sciences and technologies together, since they have so much in common, and deal with very much the same kind of phenomena, only in slightly different forms.

Senator ANDERSON. Did your panel make an evaluation of actual weather modification experiments?

Dr. MACDONALD. Yes. We carried out a statistical study of 14 operations in the Western Middle Atlantic States and 4 operations in the Western States.

Senator ANDERSON. Dr. Malone, do you have some comments to make at this time?

STATEMENT OF THOMAS F. MALONE, SECOND VICE PRESIDENT AND HEAD OF RESEARCH DEPARTMENT, THE TRAVELERS INSURANCE CO.

Mr. MALONE. Thank you, Mr. Chairman. I would like to make a few comments. With your consideration I propose to summarize my testimony.

First let me say as a meteorologist and as a former South Dakota farmboy who was motivated to go into meteorology by massive, crushing disappointment and frustration because of the vagaries of the weather, I am delighted at the deep and perceptive interest shown by you and your colleagues here.

From my prepared testimony I would pick out three issues that seem to be of special importance. One is the management problem. Second is the international problem, and the third I think is a minor one but an important one and that is the regulation question.

In my opinion the most crucial issue before Congress is the issue of agency responsibility, or viewed more broadly, the management of a national scientific program with potentially far ranging social, economic, and political consequences and really transforming into a coherent national program something which is now a somewhat fragmented national effort.

Frankly, Mr. Chairman, I am distressed, deeply distressed, to observe what I detect as a general agency jurisdictional problem.

I am hopeful on the other hand that the point of view that you expressed this morning, that it is important to get on with the job, and that is more important than who does it, will prevail.

I do believe that there is the opportunity for Congress to exercise great wisdom here. I am not sure that I can help, but in observing the work of Professor MacDonald's panel in participating in the activities of the National Science Foundation Commission, in participating in this and other testimony, I have some thought on this problem that I would tender with some trepidation.

It seems to me that fundamental is the analysis of the job that has to be done. Then perhaps agency responsibility can be matched up to that.

There are, it seems to me, four basic elements of this program. The first is the underlying basic research, the understanding of the atmosphere, extension and strengthening of that which has been going on. And this is the responsibility of all agencies, the National Science Foundation and, under Executive Order 10521, every agency has a responsibility here, a share.

Then the second element of the program is the bringing into being of the technology of weather modification: how to do it, the techniques, the instrumentation, the whole apparatus which actually makes it possible to modify the weather.

Here, it seems to me, is where the push needs to be. Here is where I think the wisdom of the Panel in recommending a strong centralized well-coordinated push to bring into being this technology is manifest.

With respect to that particular task I would emphasize the inextricable link, to my mind, between predictions and control, in two senses. The first is that one of the most promising of the tools that have come on the horizon in the last 15 years is the technique of the mathematical modeling, which is a variation of prediction, putting into mathematical form the processes that determine what the weather is going to be and then running them off on a computer.

This is useful in predictions and is useful in determining what the consequences of an intervention would be on a computer. So in that sense these two things are interwoven. In the second sense, until you can predict what the atmosphere would have done if left to its own devices, you are hard put to determine what your invention caused.

Now passing on them from the basic research to the development of the know-how, the techniques, what I call the technology, the third task is in the application. That is building the dams, suppressing the hail, stopping the lightning, exploring the consequences of increasing the CO_2 in the atmosphere, tinkering with the hurricane or the tornado.

These are operational jobs. And in contrast to the desirability of concentrating the development effort into a single agency here is where the other agencies have, I think, a major responsibility and it belongs to the framework of their larger responsibilities, their larger missions.

Finally, there is the task of regulation, which seems to me to be imperative if we are to preserve the integrity of the experimental work which still must be done to bring into being this technology. My comment there is that regulation should be separated from both the operations and the research which involves operations.

Now if those tasks which have to be done cannot be patched up with the agencies, if that produces problems because we live in an imperfect world, then there is an alternative, Mr. Chairman, that would be quite responsive to the report of the Academy's Panel and yet not be inconsistent with the alternatives set forth by the National Science Foundation Commission, and that would be to recognize forthrightly the obsolescence of the present administration and administrative division of the environmental science in the Government and provide perhaps a new and more appropriate home for weather and climate modification within a new structure that would take proper cognizance of what Professor MacDonald and his colleagues pointed out as the increased interdependency among the areas of environmental research and engineering.

I would call your attention, Mr. Chairman, particularly to pages 20 and 21 of the report for amplification and elucidation of what they were getting at there.

Now, I am not blind to the difficulties if this broad approach should be attempted, but the benefits that might flow from it, and the appropriateness of Congress, whatever is the proper cognizant committee, I have no knowledge of this, prompts me to suggest it as something which you might wish to consider.

The second issue, and here I can express delight, Mr. Chairman, at the remarks around your committee relative to the importance of the international aspects, is a point on which I feel very strongly. Neither we in this country nor our counterparts in other countries as yet know how to manipulate large-scale weather processing.

A formidable scientific problem must first be solved. But fortunately today it is only a scientific problem and if it is solved it becomes a political problem incredibly more difficult even than the scientific problem.

Mr. Chairman, it seems to me that we have the rare opportunity of being able to plan a deliberate course of action rather than reacting to crises that may develop.

A byproduct that may be more than a byproduct is this: That by doing on an international cooperative basis that thing which can only be done really in a cooperative sense we may incidentally be laying the groundwork for cooperation in other areas which would help alleviate some of the great, really great, problems confronting mankind today.

So, I applaud the interest of your committee in this aspect of it. I applaud your reference this morning to John Von Neumann. In my prepared text I had quoted his expression of the need for suitable new political forms and procedures if this comes into being.

We are proceeding with this in the scientific community, in the international council of scientific unions. We have a committee which is very much interested in the international cooperative aspects of studying the global weather systems and the problems that arise because of weather modification. I have discussed this in Geneva with scientists from Australia, South America, and India, and even with scientists in the Soviet Union.

I can report to you a receptivity to international cooperation among the scientists. They think this is as it should be. I think without being again naive we should try to cultivate that. This certainly has some bearing on the management problem.

Finally, and very quickly, Mr. Chairman, I have expressed myself on the matter of regulations. I would urge you to look again at section 202, which puts the responsibility for regulations in the hands of the same officers of the Government who have responsibility for the programs and you might wish to consider the wisdom of separating that if your bill is the one that eventually becomes the legislation.

Thank you very much.

(The document referred to follows:)

STATEMENT OF THOMAS F. MALONE

Mr. Chairman, it is a great pleasure to appear before this committee of Congress (1) to discuss with you the issues raised by the findings of the Panel on Weather and Climate Modification of the National Academy's Committee on

Atmospheric Sciences; and (2) to share with you both a vision and a nightmare of the future that, by turn, inspire and trouble the scientific community.

I am also Chairman of the Committee on Atmospheric Sciences of the National Academy of Sciences and past president of the American Meteorological Society and of the American Geophysical Union.

My particular delight in being with you this morning has its roots deep in the hope that the wisdom of Congress will be exercised with the right mixture of prudence and imagination so that our nightmare may be banished forever and the vision remain as a national goal worthy of our mightiest efforts.

The importance of the decisions now before Congress can be summed up succinctly in some thoughtful words set forth a few years ago by the Committee on Science in the Promotion of Human Welfare established by the American Association for the Advancement of Science:

"For nearly two decades, scientists have viewed with growing concern the troublesome events that have been evoked by the interaction between scientific progress and public affairs. With each increment of power, the problem of directing its use toward beneficial ends becomes more complex, the consequences of failure more disastrous and the time for decisions more brief.

"The problem is not new, either in the history of human affairs or of science. What is without past parallel is its urgency."

We in the atmospheric sciences have rather special responsibilities in this regard for three reasons:

(1) The first is the immediate, vital, and profound part played by weather and climate in the lives and affairs of all men.

(2) The second is the special international character of an atmosphere that is constantly in restless motion, crossing and recrossing national boundaries—an international resource, if you will, shared by all men.

(3) The third is the obvious choice that lies before us to use mastery over this international resource to aggravate or to ameliorate conflict among nations.

The particular strength of our position in these early months of 1966—and if I may say so, Mr. Chairman, the challenge and the opportunity before Congress—rests in the fact that there is still time for deliberate thought and decision on the issues raised by the reports of the Academy Panel and the National Science Foundation Commission.

The Academy report itself has been summarized by Professor MacDonald. I would propose to comment briefly on what I believe to be the principal issues of public policy raised by this report.

These issues include—

(1) The need to transform our somewhat fragmented national effort in this field into a coherent national program.

(2) The character of that program.

(3) The size of that program.

(4) The rate of growth at which the national program is developed.

(5) The manner in which it is organized and managed.

(6) The international implications.

In support of an affirmative conclusion on the first issue are these four points:

(1) Development of mathematical modeling of physical processes in the atmosphere, the availability of electronic computers, and prospects for more precise measurements—all of which have combined to thrust the problem of conscious and meaningful tinkering with the atmosphere across the theshold that separates speculation from rational and systematic exploration of possibilities and limitations.

(2) Demonstration of operational capability in dissipating supercooled fog and the still incomplete, but very persuasive, evidence that rainfall can be influenced by seeding techniques.

(3) The prospects for significant economic benefits in land utilization and water management in a world which is confronted with growing problems of agricultural productivity.

(4) The compelling necessity of understanding and being able to anticipate the kinds of inadvertent modification of climate that may be set in motion within the next generation or so as the population expands into an environment with fixed limits.

With respect to the second issue—the character of the national program—quite apart from that portion of the effort which is concerned with national defense, it should possess the attributes of—

(1) Diversity in that big science should be balanced with little science, research in the physical sciences accompanied by research in engineering

and the social and life sciences, and activity in the public sector complemented by activity in the private sector.

(2) Balance—by that I mean a balanced program which addresses itself to the problems of cloud physics, hurricanes, tropical convection, hail, lightning, water budget—all conscious attempts at intervention, as well as the inadvertent modification caused by increases of carbon dioxide, air pollution, and rocket exhaust at high levels.

(3) Integrity—in that the unity of the four principal tasks of the meteorologist be preserved, that is the observation, understanding, prediction, and control of atmosphere phenomena.

(4) Stability—in that budgetary support should be consistent with the long-range nature of the program and should avoid violent fluctuations.

(5) Adequacy—in that the level of the effort should be commensurate with the difficulty and complexity of the problem.

The character of the program will, to a large extent, be determined by the kinds of things that need doing; that is, the elements of the program. They would appear to be these four:

(1) Basic research directed at a fundamental understanding of the principal aspects of the problem.

(2) Applied research directed at the development of techniques for successfully intervening in normal atmospheric processes as well as for assessing the consequences of inadvertent modification.

(3) Operational application of proven techniques as soon as their efficacy is established.

(4) Regulation as may be needed to protect the interests of the public and to prevent the contamination of field research projects.

It seems clear that the most conspicuous gap in the present national effort is in the applied research activity directed at the development and evaluation of techniques for weather modification.

Important considerations in the third issue—size of the program—are—

(1) The need to conduct large field studies which require substantial logistical support.

(2) The need to assemble groups that are sufficiently large and diverse in their disciplinary interests to make an impact on a very difficult and complex problem.

The level of $30 million by 1970 as proposed by the Academy Panel is, in my opinion, an austere estimate which takes into account these two factors.

An important consideration in the rate of growth of the program—the fourth issue—is the availability of competent manpower. I endorse and call to your attention the comments of the panel that the intrinsic scientific interest and the national importance of this problem are likely to attract to it both the quality and the quantity required to expand the program from a $5 million level in 1965 to the $30 million level by 1970.

Perhaps the most crucial issue before Congress is the fifth issue—the question of agency responsibility or—viewed more broadly—the management of a national scientific program with potentially far-ranging socioeconomic and political consequences.

Several options would appear to be open. One would be to allocate among existing agencies the four program elements mentioned earlier. Generalized guidelines are provided for this course of action in the report of the NSF Commission. Another, and one that would be quite responsive to the report of the Academy Panel and yet not be inconsistent with the alternatives set forth by the NSF Commission, would be to recognize the obsolescence of the administrative division of the environmental sciences in the Government and provide a more appropriate home for weather and climate modification within a new structure that would take proper cognizance of the "increased interdependence among the areas of environmental research and engineering" noted by the Academy Panel. I am sure that it is not necessary to point out the difficulties were this second option to be exercised, but the benefits that might flow from it and the appropriateness of Congress undertaking this task prompt me to suggest it as an opportunity to exercise statesmanship of the highest kind.

The final issue—and one that I would personally rank first in importance—is concerned with the international implications. Neither we in this country nor our counterparts in other countries as yet know how to manipulate large-scale weather processes. A formidable scientific problem must first be solved.

But today, it is only a scientific problem. If it is solved, it becomes a political problem incredibly more difficult even than the scientific problem. We see about us the vexations in containing this kind of problem. Question: Would it be pos-

sible to ameliorate potential difficulty in things scientific and political by a cooperative effort among nations while problems are only scientific? I think so—for four reasons:

(1) The atmosphere itself is international.

(2) There is a fine tradition of international cooperation in meteorology.

(3) With only 6 percent of the world's population, 20 percent of the world's scientists and 40 percent of the aggregate gross national products, we can multiply our own efforts through cooperation guided by the mind as well as the heart.

(4) Dedication of this effort to peaceful purposes might in some small way contribute to the unity of a world increasingly troubled and tormented by conflict.

In conclusion, a word about our vision—and our nightmare.

The vision:

A world in which one finds in place "the suitable new political forms and procedures" that the great mathematician, John von Neumann, pointed out a decade ago will be required after global climate control becomes possible.

A world in which the benefits of weather and climate control are allocated equitably among nations by methods that will have been developed—not by some novel cure-all but, as von Neumann phrased it, by "a long sequence of small, correct decisions"—precisely the kinds of decisions before Congress during this session.

The nightmare:

A world in which the conflict—that will probably always, to a greater or lesser degree, be the lot of imperfect man—has been aggravated by dispute over the rights to one of the most international of our natural resources—the atmosphere.

A world in which the "race to the moon" is replaced by a race to extend mastery over the atmosphere; the problem of nuclear proliferation replaced by the proliferation of environmental modification capability.

A world in which scientists meet interminably in Geneva to put the genie back in the bottle.

A world we do not want to see.

A world that need not be.

Senator ANDERSON. Thank you very much. What about the Russians?

Do you think they are experimenting with control modifications?

Mr. MACDONALD. Yes, Mr. Chairman. We made an effort to estimate the scale of activities in the Soviet Union in weather modification. This estimate was based in part on literature and in part on visits to the Soviet Union by members of the Panel and also by other meteorologists.

We would guess that there their total effort in weather modification is probably two or three times that in this country at present. They have specialized in certain particular kinds of weather modification. One that comes to mind, which is a startling example, is a rather large attempt at decreasing hail in the Caucasus, which is a really large operation involving many radar sets and involving artillery units that will place the iodide crystals into the clouds.

It is an integrated operation. The only difficulty that we have is really finding out how successful they are. All the verbal communications say they have been very successful. We have not been able to get the hard data on that particular operation.

Senator ANDERSON. Senator Jordan.

Senator JORDAN. Thank you, Mr. Chairman.

Mr. Malone, you referred to the political problems, and political problems are likely to be of greater magnitude than the scientific problems. Secretary Hollomon this morning touched on the same subject when he said:

> If we ultimately attempt to modify the weather on a large scale, we will have to be able to predict beforehand what would have happened had we not made the attempt.

This is of great significance to me as we approach this problem because it seems to me when man undertakes to regulate the weather or to take upon himself the responsibility of doing something about weather, weather modification, then he makes himself liable for any bad effects that might happen to anyone weatherwise, whether they are directly traceable to what he is doing in his weather modification efforts or not.

I had a little experience with this.

It fell to my lot to do some of the details working out the St. Lawrence Seaway on the power project with Canada. When we took Lake Ontario and changed the levels at Lake Ontario from the state of nature to manmade regulations we had a lineup of people who said, "Whom do we sue when we are damaged by wave action at our summer homes on Lake Ontario?"

Even though we sought to make an improvement for all concerned by increasing the minimum level for navigation purposes, by taking the crest off the top to help the people who had summer homes on the lake or year-round homes on the lake, we found ourselves faced with the responsibility of being accountable to anyone who alleged that he was damaged by weather in that whole vicinity.

Now how do we address ourselves to such a far-reaching problem as this?

Mr. MALONE. I believe, sir, if I may revert to John Von Neumann again, that he pointed the way in his famous article in Fortune magazine. He said there would be no novel cure-all but "a long sequence of small correct decisions."

I believe we are going to have to approach this problem with the enormity you have sketched out by a series of small steps. I don't believe it is possible or intellectually honest to sit here and tell you that I or anyone else knows the answer to issues that we are posing.

Senator JORDAN. Dr. MacDonald?

Dr. MACDONALD. Yes. I think the problems you raise are crucial to the whole question of how we evolve a weather modification program. I think your comments also point out the necessity of coupling predictions with modifications.

In my prepared statement I said one of the goals for the future is to be able to take a given meteorological situation, a decision is made to perturb it or not, perhaps let us say we cloud seed it, and be able to predict what the results of that experiment will be.

It is only when we develop that predictive capability to a sufficient extent that we have the same kind of reliance on it as we do on present forecasts, and it will be imperfect at best, but none the less we will then be able to make decisions in such a way that we can reduce the damage or the ill effects and maximize the return.

But it is necessary—I wish to underline this in a very important way—that the needed research to develop that capability be pushed very hard. We must have that before we can really go into massive weather modification systems.

I cannot see us attempting to carry out even very large scale precipitation and enhancement operations without the ability, at least, to predict some of the consequences of such actions.

Senator JORDAN. We always have the problem of trying to convince this claimant, who alleged he was damaged, and his attorney that he might have been damaged worse in a state of nature.

Dr. MACDONALD. Yes. I think, if we did have this predicted capability, taking one of these small steps that Dr. Malone speaks of, that at least one can compare and say, "Well, if we had done this this would have happened, if we had not seeded this would have happened."

Whether this would ever stand up in a court of law, of course, is something else.

Senator JORDAN. Thank you.

Senator ANDERSON. Thank you very much. You have been very interesting.

Dr. MACDONALD. Thank you, Mr. Chairman.

Senator ANDERSON. Now we will hear from Dr. Chamberlain.

STATEMENT OF A. B. CHAMBERLAIN, VICE PRESIDENT OF COLORADO STATE UNIVERSITY; ACCOMPANIED BY TOM JONES, DIVISION DIRECTOR, ENVIRONMENTAL SCIENCES, NATIONAL SCIENCE FOUNDATION; AND DR. EARL DRESSLER, ATMOSPHERIC PROGRAM, NATIONAL SCIENCE FOUNDATION

Mr. CHAMBERLAIN. Mr. Chairman:

My name is A. B. Chamberlain. I am vice president of Colorado State University. I am accompanied this afternoon by Tom Jones, Division Director of Environmental Sciences of the National Science Foundation, who will speak on behalf of the National Science Foundation; and Dr. Earl Dressler, of the Atmospheric Program of the National Science Foundation.

I would like to present to you a statement in my capacity as draft Chairman of the Special Commission on Weather Modification. This statement reads as follows:

The results of the work of National Science Foundation Special Commission on Weather Modification are very pertinent as you consider S. 2875. The Commission was charted to make recommendations to the National Science Foundation and to provide information requested by a committee of the Federal Council on Science and Technology. The assignment included consideration of the physical, legal, social, biological, and political aspects of weather and climate modification.

INTRODUCTION

Man's growing knowledge of the natural environment has given him an increasing awareness of the changes taking place in his earthly habitat. Fortunately his increasing knowledge has also indicated some possible means of deliberate modification of the environment. This knowledge may make it possible for him to plan effectively for conservation and development of the total global environment for the benefit of man. Man is rapidly learning he cannot consider himself free to exploit the air, water, land, and growing things of the earth without degradation of the quality of his environment.

The major issue of public policy considered by the Commission is simply stated in the form of the following question. Are the scientific and engineering possibilities of deliberate weather and climate modifications sufficiently promising of significant social benefit to indicate the time has arrived for the Nation to direct substantially larger resources of money and manpower to the many facets of the field? The

Commission concluded the question should be answered in the affirmative. For reasons of scientific, human, biological, legal and international need the time has arrived to greatly expand the Nation's activities in weather and climate modification. Such a program must consider modification of both natural systems and the adverse changes induced over cities by air pollution. Such a national program will require a budget increase of at least $40 to $50 million per year by 1970 over the fiscal year 1966 level for weather and climate modification research and development activities.

SCIENTIFIC PROSPECTS

The Commission feels the study of weather and climate modification is ready to pass from being considered a speculative field to one ready for a rapid expansion of carefully planned research and development. Many interesting and potentially valuable scientific and engineering opportunities are becomng evident that will attract some of the Nation's best minds to the field if fiscal resources are made available to support the intellectual talent of industry, academic institutions and government agencies.

The atmosphere can be viewed as a complex physical system in which changes in air motion will take place in response to identifiable forces. If the forces are altered, in principle the motion of the air can be influenced. Therefore, in principle, meaningful modification of the weather and climate should be feasible if one can demonstrate the capability to alter these natural forces so as to produce predictable consequences. In a practical sense, it is necessary to establish only beyond reasonable doubt that the cause and effect are related; and that the effect will lead to socially desirable results. Aside from intellectual curiosity, which admittedly has great value in itself, this has been the central problem of weather modification research.

Progress has been made. That seeding (the cause) can dissipate supercooled fog (the effect) has been so clearly demonstrated it is moving to the operational phase for some airports.

On a larger scale, there is evidence (though somewhat ambiguous) to support the view that precipitation from some types of clouds can be increased by the order of 10 percent by seeding. The question of corresponding decreases outside the target area is unresolved. Hail and lightning research is beginning to show some promise. A program of large, carefully instrumented and statistically designed field experiment is needed. These will take a great deal of money.

The study of the energy levels of atmospheric subsystems such as tornadoes, hurricanes, and extratropical cyclones leads to the conclusion that it is not practical to think of altering these subsystems by direct application of energy. Yet the study of instabilities in the atmosphere indicates at least four kinds of instabilities may be susceptible to man's efforts to "trigger" natural reactions, thereby potentially obtaining a large result for a relatively small input of energy. To affectively utilize these "triggers" in a way which will not result in undesirable consequences will require a great deal of thoretical, laboratory and field research.

Improved prediction of weather phenomena may be as important in many cases as modification, in terms of social and economic benefits.

For this and others a global observation network will be necessary. Numerical simulation studies on large computers need to be expanded.

The Commission was greatly concerned about the inadvertent modification of weather and climate due to the activities of man. Air pollution from our cities is an example. This is a problem of grave importance. Little is understood of the weather and climate modification being induced by this means, or of ways to modify the weather so as to dissipate or alleviate smog and ventilation problems of urban environments.

Weather modification is usually assumed to mean cloud seeding. Yet this is certainly not the only means of weather and climate modification. Other means exist. Since the atmosphere interacts with the expanses of earth and sea it may be possible to modify the characteristics of the land or the sea and thereby modify the weather and climate. Man's ability to induce large-scale alterations of the land and sea continues to increase. Such nonatmospheric means of modifying weather and climate also need to receive increased attention. The possible consequences of such alteration of weather and climate need a great deal of study since it appears some of the technical possibilities, though now largely speculative, could be irreversible.

The Commission concludes the scientific and engineering prospects of meaningful progress in weather modification are sufficiently attractive that a great deal more manpower should be drawn into the field. This expansion of activity will require talent from several intellectual disciplines. Also required will be a great increase in the logistics support for field and laboratory research and operation. The results of increased concentration on the field would be important not only to those interested in precipitation augmentation but also the entire field of atmospheric resources.

BIOLOGICAL RELATIONSHIPS

Anything that has a significant effect upon plants and animals is of primary concern to man. Plants and animals are the foundation of his existence. Modifying weather and climate may intitiate changes in the abundance of certain plants and animals. It may also induce instabilities in numerous biologic populations—including those that prey on man and challenge his existence. Thus, a national program of weather and climate modification must include support for a substantial research program in ecology and related biological sciences.

The field of ecology has developed to a considerable level of sophistication in recent years. Yet, to date, no real opportunities have been available for this knowledge to be applied to a long-range large scale field experiment in weather modification. Thus it is not known how adequate the present state of knowledge is for making good predictions of the biological consequence of specific weather modification projects, except under limited conditions. For example, the ecological system associated with agricultural fields is well enough understood that good predictions can be made. But in a more complex system such as that of large uncultivated watersheds containing many species of interacting plants and animals it is not now possible to make quantitative predictions. One should add, however, that for many social purposes of weather modification a qualitative description of anticipated effects on the biological system may be adequate for public

policy decisionmaking. Atmospheric water resources may be such an area.

Living things are adapted to the weather that prevails. Any change in the weather will be generally deleterious to them. Weather and climate modification over large areas of a few hundred square miles or larger for long periods of time is likely to induce a decreased stability of biologic communities. This instability would manifest itself at least as an initial increase in pests, weeds, and pathogens.

It is extremely important that a national weather modification program involving large areas for field experiments have fiscal support for ecological studies by numerical simulation and both quantitative and qualitative field studies. Much better knowledge is needed than now available regarding the interactions of weather and organisms. Such research is expensive. The research studies may span several years in order to obtain meaningful conclusions.

The largest social credit item for weather modification is likely to be an increase in the production of food and forage plants on the drier parts of the earth's surface.

STATISTICS

As is well known, a controversy among statisticians over the validity of the conclusions of early research did not encourage weather modification research during the late 1950's. The situation is better now. The current central question on the role of statistics in weather and climate modification research is not whether to use statistics but how to use it in the early design through to the analysis of the research data.

The national program in weather and climate modification needs to provide for support of statisticians to work on all facets of physical, engineering, and biological studies in the field. Furthermore, support is needed for basic statistical methodology research. Arrangements are needed which will encourage a continuous dialog between statisticians and those scientists and engineers conducting studies in weather modification.

HUMAN EFFECTS

Sound public policy in the face of uncertainty about the techniques of weather modification requires that research also be initiated on the social and economic effects. Such research is needed to fully exploit what may be an historic opportunity to improve the environment for humanity and, at the same time, avoid activities which might be detrimental to man. So intricate are the interlocking motivations in human behavior that subtle changes may be initiated by weather modification and not even be detected. Some beneficial changes, such as bountiful crops and their impact on the economy, can be readily followed. But because the organization of society is so complex it is not evident whether the quality of life may be enhanced or degraded by every possibility of weather and climate modification. It seems clear, for example, that the power and motion of severe storms provides some of the most exhilerating experiences that the human mind assimilates. Would it be of social benefit to completely control weather and remove these phenomena from the realm of human experience? How

could one put a dollar value on such a possible degradation of the quality of the life experience?

From an economic point of view many effects of precipitation augmentation for crops, hydroelectric power, et cetera can be fairly readily measured. But other effects might not be so simple to evaluate. As an example, what would be the economic, social, and political problems of shifting the path of a hurricane so it hit North Carolina rather than Florida or some other State? To learn how to deal with such problems in advance of the technological capability, in the face of large uncertainty about the ability to modify weather, will require a great deal of effort.

Several areas of potential conflict of interest are already recognizable. Public policy should seek to provide a means to reconcile conflicts equitably. It should seek to prevent victimization, either by people who mistakenly think they are gaining benefits or of individuals who are unaware of damages being inflicted on them. Conflicts may arise between those trying to conduct experiments and those wishing to carry out operational projects for utility or agricultural clients.

A national program on weather and climate modification should include support for research on the social and economic consequences of alternatives to weather modification. For example, it might be more profitable to pursue research in crop genetics to improve drought resistant crops than to augment precipitation. Further, if weather modification induced serious pest and weed problems the costs of these might overshadow the benefits of increased crop production. Because the answers to such questions are not known, research is needed.

Research is needed on the basic relationships between weather characteristics and human behavior. The decisionmaking process of man in the face of uncertainty needs further study in this field as it does in numerous other fields of human endeavor. The social effects of inadvertent weather and climate modification such as induced by smog need further investigation. The social consequences of commercial operations and field experimentation need to be studied in their manifold impacts from recreation to agriculture.

The providing of indemnification against damages for federally supported work would encourage more academic, industrial, and private scientists and engineers to seek support for research and development work.

LAW

A demonstrated capability to modify weather and climate over areas of substantial size presents legal problems of great difficulty. Yet even before such an ability is assured the law is involved on at least two counts: (1) The rules over responsibilities and liabilities of weather and climate modification to other members of the public, and (2) regulation by Government.

It does not seem possible to recommend, without a great deal of further study, appropriate rules of law to govern "property rights in weather." Easy analogies to the law regarding water, land, airspace, et cetera, do not seem adequate for the problems of weather modification. The liability of weather modifiers with respect to those claiming injury to their person or property, for example, need to be decided

on their own merit, not on a few analogies. The few court cases to date do not give much basis for predicting how the law will develop.

Some 23 States have enacted laws regulating weather modification. Most of these States require licenses. Effective January 1, 1966, the National Science Foundation increased its recordkeeping requirement and imposed on all operators a requirement of advance notice to it of any activity. This information is an aid to the Federal research and development effort.

The Commission concluded that Federal legislation should be enacted adequate to—

(1) Delay or halve all activities—public or private—in actual or potential conflict with weather and climate modification programs of the Federal Government, whether these programs are conducted for the Federal Government by its own agencies, or by its public or private grantees or contractors.

(2) Immunize Federal agents, grantees, and contractors engaged in weather and climate modification activities from State and local government interference.

(3) Provide to Federal grantees and contractors indemnification or other protection against liability to the public for damage caused by Federal programs of weather and climate modification.

These recommendations are restricted in scope because it is felt that regulation should be only the minimum necessary for permitting accomplishment of immediate goals As knowledge develops more comprehensive regulation will be required. And since weather transverses national boundaries, study needs to be made of international legal problems.

INTERNATIONAL

As weather and climate modification research and development continue to expand, some form of international collaboration will be essential in the planning and carrying out of operations which may affect localities of other countries and continents far distant from the scene of the weather modification operation. Such events have an obvious bearing on the political relationships among nations.

With weather modification still in its infancy, it provides an inviting opportunity to encourage multinational interest in mutual cooperation among the people of rival nations. Weather and climate modification could serve as an avenue to widening the areas of common interest among nations, thereby helping in accomplishment of the objective of easing international tensions. At the same time the field of weather modification may be able to contribute significantly in the growing international food crisis.

The international aspects of weather modification require careful study of the biological, social, economic and political factors. The results of study of these fields in the United States may not be directly applicable to many of the developing countries where the social institutions, biological environment and political systems are different.

Now is the time to start the steps, in concert with other nations, to explore the international institutional mechanisms that may be appropriate to foster international cooperation.

To provide an appropriate public policy setting for weather and climate modification, the Commission feels the Nation should enunciate policy containing these two points:

(1) It is the purpose of the United States, with normal and due regard to its own basic interest, to pursue its efforts in weather and climate modification for peaceful ends and for the constructive improvement of human life throughout the world.

(2) The United States, recognizing the interests and concerns of other countries, welcomes and solicits their cooperation, directly and through international arrangements, for the mutual achievement of human well-being.

FISCAL NEEDS

The Commission concluded that weather and climate modification research and development activities of the Federal Government should be increased by $40 to $50 million per year by 1970, excluding any national laboratory type capability which might be initiated.

These figures were derived by estimating the program needs which should be increased from the fiscal year 1966 level of $7.2 million of agency budgets, excluding logistical support provided by the Department of Defense. About half of the increase will be needed for basic research, including such things as much larger computer capability. Much increased support is necessary for conducting carefully designed and adequately instrumented field experiments.

The budget increases should definitely include funds for the physical sciences, statistics, engineering, the social and biological sciences, and the law.

No estimate beyond 1970 was made by the Commission. It was felt the level of funding for the 1970–80 period could be much better estimated after a couple more years of experience. The field is capable of going ahead so rapidly that long-range cost estimates would probably have little validity.

ORGANIZATION OF GOVERNMENT

The field of weather and climate modification needs to have the services of Government, private industry, and academic institutions. It must be able to accommodate participation by the individual scientist who only needs pencil and paper to the large complex organization necessary for a massive field experiment. The following factors enter into analysis of the organizational needs:

(1) There is need to bridge the organization gap between laboratory research and large-scale field experiments; this gap can exist even in the basic research aspects. There is need for organizational arrangements for enough applied research to develop the field, while preserving scientific objectivity in the basic research effort. The economic, political, and spectacular aspects of weather and climate modification operations must not be permitted to crowd out the basic research.

(2) There is need for biological and social science research to go hand in hand with the physical science and engineering research in support of the missions of all agencies, contractors or grantees concerned with weather modification. There is need to preserve diversity in the research effort, but there is the need also to establish a Federal

organizational mechanism for accomplishing what cannot be done through diverse research activities.

(3) Responsibility should be clearly assigned for the formulation of arrangements for appropriate scientific cooperation with the governments of other nations.

(4) Adequate enforcement power needs to be provided an administering agency so as to insure the filing of information relative to all weather modification field experiments and all commercial operations. The agency assigned regulatory functions should have a regional or field office establishment.

(5) The conduct of research and development in this field should be kept insulated from activities involving the regulation of weather modification operations, but at the same time the two types of activity should be sufficiently proximate organizationally to assure immediate access to data derived from the operations being regulated.

Based on these considerations, plus the fact several Federal agencies have missions (such as Defense) that require weather modification knowledge, the Commission concluded a pluralistic organization for assignment of responsibility would best insure progress of an expanded national program. The suggested assignment of responsibilities can be summarized as follows:

(1) The mission of developing and testing techniques for modifying weather and climate should be assigned to an existing or new agency in the executive branch of the Federal Government. The mission should include support and conduct of research and development and such operational activities as are needed for the furtherance of the technology of weather and climate modification. Substantial authority to contract for services with industry, universities, and other Federal agencies should be provided. This agency should have major but not exclusive responsibility, in collaboration with the State Department, for formulating and implementing programs of weather and climate modification involving international cooperation.

(2) The National Science Foundation should continue and expand its support of research in the atmospheric sciences, including its program directed at providing a satisfactory scientific basis for weather and climate modification. This should be carried on primarily at universities and colleges. The National Science Foundation program has been the major source of funding for development of manpower for weather modification activities. NSF should be given increases in funds for expanding this support since the manpower needs will continue to grow. NSF should continue maintenance of the National Center for Atmospheric Research as a facility for the conduct of basic research on a scale beyond that feasible for individual university investigators. Of particular importance, continuing and special attention should be given by the Foundation to the support of engineering, the biological sciences, and the social sciences aspects of weather and climate modification, as well as the physical sciences. The levels of support should be reviewed from time to time in the light of the progress of the overall national program.

(3) Federal agencies should undertake such operational activities as may be required for the effective discharge of their missions. Also, pursuant to Executive Order 10521, Federal agencies should be free to conduct and support such research and development as may be required in the discharge of their missions.

The Commission felt that a national laboratory-type of capability is needed for an expanded interdisciplinary program encompassing all the relevant disciplines. Yet it is not clear that creation of a national laboratory per se is the answer. The President's Special Assistant for Science and Technology could perhaps be called on to initiate appropriate feasibility studies.

Insofar as the nature of the regulatory agency is concerned, care must be taken to insure access of all agencies to the information generated, while at the same time keeping regulation organizationally separated from research and development. Whether the regulatory function needs to be divorced completely from the operating agencies, or can be assigned to a separate branch or subagency of an existing agency, will depend largely on the extent of activity and the degree of regulation required.

As to the jurisdiction of a regulatory agency over other Federal agencies, to the extent regulation involves requirements of notice, reports, licensing of activities, and so forth, there seem to be good reasons why all agencies should be subject thereto. In addition, the regulatory agency should be given power to resolve minor conflicts between agencies, such as the timing of particular experiments.

The Commission recommends that the Office of Science and Technology be requested to consider establishment of a special mechanism for the coordination of weather and climate modification policies and programs. Such an entity could not only serve to resolve major difficulties but could serve to promote unity in policy and deployment of funds and manpower with optimum effectiveness.

Both the executive branch and the Congress may wish to have available scientific and public policy advice from a group of knowledgeable people from outside the Federal Government. This need might well be met by the appointment of a standing committee in the National Academy of Sciences, in cooperation with the National Academy of Engineering. The group should include persons with experience in the physical sciences, the biological sciences, and social sciences and engineering. In this context, law is considered to be one of the social sciences.

CLOSING REMARKS

The NSF Special Commission on Weather Modification was made up of 11 men from several professional disciplines. None of the Commission members was an employee of the National Science Foundation. They were provided background data from sources as—

(1) The Panel on Weather and Climate Modification of the National Academy of Sciences, the chairman of which spoke to you earlier this afternoon.

(2) The study committee of the Ecological Society of America.

(3) The reports of the University of Minnesota conferences on statistics and weather modification.

(4) Participants in the University of Chicago Symposium on Economics and Social Aspects of Weather Modification, and the

(5) Report of the Southern Methodist University study of certain legal aspects of weather modification.

In summary, the Commission feels the time has arrived for the United States to initiate a much expanded interdisciplinary research

and development program in weather and climate modification. This program should be adequately organized and funded. Provisions should be made for participation by individuals, educational institutions, private firms, the several levels of government, and foreign countries. Regulation should be kept to a minimum consistent with available knowledge.

To be able to deliberately modify our environment in a predictable manner favorable to the welfare of mankind may be our only avenue to fulfilling the desire of all humans to have a good life.

Thank you, Mr. Chairman.

Senator ANDERSON. Thank you, Mr. Chamberlain. Reference was made this morning to a proposal to transfer the National Sciences Foundation weather functions to ESSA. Do you have a position on this proposal?

Mr. CHAMBERLAIN. The discussion of the Commission indicated that the objective of the National Science Foundation could well be accomplished if the regulatory function was not within NSF. Aside from that, the Commission strongly supports the idea that the National Science Foundation should have a strong research program, including support for the social sciences, biological sciences, engineering, and physical sciences, to undergird the overall program.

Senator ANDERSON. You indicated the National Science Foundation should support the research program.

Mr. CHAMBERLAIN. It is the position of the Commission that the NSF should continue to support research in weather modification.

Senator ANDERSON. Do you have a recommendation on what single agency or multiple agency should handle this?

Mr. CHAMBERLAIN. The Commission felt very strongly that the purposes of the national program did require that an agency either new or existing should be designated to carry a major responsibility for the development of the technology of weather and climate modification The Commission did not, however, take a position as to which agency should have this responsibility.

Senator ANDERSON. Senator Jordan.

Senator JORDAN. That is a very fine statement, Dr. Chamberlain. You say:

> The mission of developing and testing techniques for modifying weather and climate should be assigned to an existing or new agency in the executive branch of the Federal Government.

Do I understand you to say that you do not propose to say whether it should be a new agency or one that is presently in existence?

Mr. CHAMBERLAIN. That is our position. Our position is that either the executive branch or the Congress should decide to which existing or potentially new agency the responsibility should be allocated.

Senator JORDAN. But that it should not be superimposed upon some present agency of the Government? I don't get your distinction here.

Mr. CHAMBERLAIN. The Commission took the position that it would be feasible to assign this lead agency responsibility to an existing agency, but it also might well justify establishing a separate new agency. The alternative was that it was available so far as the Commission is concerned.

Senator JORDAN. The present bill authorizes the Secretary of Interior to carry out the responsibilities under the act. Would you go along with that?

Mr. CHAMBERLAIN. The Commission took the position that the designation of the specific department was within the prerogative of the Congress or the executive branch of Government and as a Commission we did not take the position on a given department.

Senator JORDAN. Thank you.

Senator ANDERSON. We have Dr. Tom Jones, the Division Director of the Division of Environmental Sciences, National Science Foundation.

Go ahead, Dr. Jones.

STATEMENT OF DR. THOMAS O. JONES, DIVISION DIRECTOR, ENVIRONMENTAL SCIENCES, NATIONAL SCIENCE FOUNDATION

Dr. JONES. Mr. Chairman and members of the subcommittee as Division Director of the Foundation's Division of Environmental Sciences, I am pleased to appear here this morning with Dr. Chamberlain to discuss certain aspects of S. 2875 and some of the implications of weather and climate modification.

Inasmuch as Dr. Chamberlain has reviewed the work of the Special Commission on Weather Modification and its recommendations, I will not dwell on these subjects at length. I feel sure, too, that it is not necessary for men to do more than mention the report of the National Academy of Sciences Panel on Weather and Climate Modification, since this report is well known to your committee and you have heard testimony from its chairman. These and other recent publications have set forth in some detail the historical development of weather modification over the past two decades.

The bill which you are considering has as its objective the creation of a comprehensive program of scientific and engineering research, experiments, tests, and operations for increasing the yield of water from atmospheric sources. This is indeed a truly critical requirement for the Nation's welfare, and one for the Nation's welfare, and one for which there may, happily, be a solution if we attack the problem using all needed scientific research capabilities and engineering skills. Statistical evidence from recent cloud seeding research and operations seems to indicate that, under certain conditions of atmosphere and terrain, precipitation may be increased. The interpretation of data from operational and experimental sources is still subject to question, and the theory underlying seeding techniques is weak owing to the lack of a firm understanding of the details of cloud processes. Yet there seems no doubt that further study and research will point up the critical features of the problem and permit the development of improved techniques.

I am reminded here of the situation we were in when radio-activity was discovered. In a sense this discovery was a first step toward the realization of nuclear power. However, it was obviously premature to assume that we were fully prepared to build devices to produce atomic power. As we all know, there remained many problems to be solved and much basic and applied research was required.

Stimulation of precipitation is a limited aspect of the whole field of weather and climate modification, which I would like to discuss for a moment. We are at a point now where hope of further progress is luring us on to increased efforts to manipulate our environment. At

the same time, as the reports you are familiar with have made clear, we are not sufficiently aware of the basic mechanics of environment—in this instance, of cloud physics and the processes by which precipitation forms—to devise an immediate plan for the most efficient exploitation of this resource.

Herein lies our dilemma and a potential danger to our civilization. The sum is the sole supplier of energy to the earth, its oceans, and atmosphere. Outer space is the energy sink in which energy is lost by thermal radiation. Between these is a delicately balanced environment whose preservation is essential to man's survival. This system is not uniformly in balance but contains many instabilities. The Academy's Panel on Weather and Climate Modification has pointed out how triggering a reaction in one unstable situation might escalate a transfer of energy from one instability to another, resulting in a major effect on climate.

That man can inadvertently modify his climate looms as a possibility to be considered with all its hazards and implications. You have read last week in The Washington Post for March 15 of an interview with Dr. Reid Bryson of the University of Wisconsin where he told of the effects of dust in the atmosphere above the Great Indian Desert preventing precipitation over the desert.

Bryson and his collaborators have found that the dust affects the flow of radiation—heat and light—through the atmosphere. One of the consequences of the change is that the direct infrared cooling rate of the atmosphere at altitudes near the middle of the troposphere is increased abnormally, thereby increasing the subsidence, or descent, of cool middle tropospheric air. An Indian scientist has shown that the descent of such air in this manner has a tendency to suppress precipitation. There is some archeological evidence showing that the Indian Desert, from which a large fraction of the dust comes, was at one time covered by vegetation and that the removal of the vegetation cover and the introduction of desert conditions resulted at least in part from farming practices introduced by early man. Thus, there is reasonable evidence that the desert, once established with man's inadvertent help, is at least partly self-sustaining. Bryson conjectures that by proper efforts some of the desert could be converted into new, productive farmlands and at the same time by covering the areas with vegetation reduce the release of dust. However, he warns that further research is necessary in order to determine the effect upon the vital monsoon rains in the rest of India of manipulation of local weather over the desert.

I may suggest that today climatic changes are underway perhaps so subtly that they have not yet been detected. Certainly the magnitude and character of our disruption of the ecology of the great western plains of the United States and the African veldts are conducive to a modified climate, as are the enormous population belts of our two coasts with their uncalculated transformations of fuels into heat, carbon dioxide, and water vapor. And I have recently seen the commencement of yet another possible triggering of climatic change in Patagonia, where the virgin timber is being burned over on an awesome scale to provide sheep pasturage.

Just as Bryson has examined the characteristic feature of the climate of the great Indian desert by uniting meteorologists, paleogeographers,

physicists, archeologists, and historians into a team of research workers, so must we combine a broad range of scientific and technical forces in the physical sciences, biological sciences, social sciences, and engineering in order to cope with what appear to be emerging as the central scientific problems of the immediate future. To the increasing alarm of scientists, among others, the magniture of environmental problems is becoming more apparent with each day.

How do we go about developing an understanding of our environment adequate to insure detection of changes resulting from cultural influences before they become significant to the future of our culture? How do we predict man's influence on the environment well enough to provide a basis for decisions on resources utilization? In the immediate future, a continuation of research and experimentation in the laboratory and field is needed. If our understanding of the atmosphere continues to develop and if some of the currently exciting speculations prove to have merit, the tremendous economic potental of even rather modest increases in percipitation in some areas of the country may be realized.

More importantly, we should develop our basic understanding rapidly enough to insure that our projects are not rash and ultimately harmful because their long-range effects were not adequately appreciated. For, in the words of Sir Francis Bacon, "We cannot command nature except by obeying her." There are many scientists including members of the Foundation staff of the National Science Board who have become increasingly convinced that the changing character of man's interaction with his environment will constitute the central scientific problem for the next generation or two.

The Foundation is vitally concerned with developing and shaping the role it must have in this general problem area in order properly to serve the coming needs of society. The study of the problems of human interaction with the environment requires a broad range of scientific skill, physical sciences, oceanography, meteorology, geophysics, geology, chemistry, social sciences including anthropology, sociology, engineering including transportation, sanitary engineering, systems engineering, biological science including ecology, and so on. The magnitude of environmental problems is growing at an amazing rate as is the number of thoughtful citizens, both scientists and others, who are becoming alarmed at the prospects before us.

We in the Foundation intend to utilize our background and assocation with the scientific world, our experience in science education and information to hone the cutting edge of the Nation's attack on these crucial problems. It is our opinion that the Foundation must increase its support of research to undergird activities in the field of weather and climate modification. In addition, other Federal agencies should undertake applied research and development in weather modification related to their approved missions. The Foundation has been pleased to witness the development of the Department of the Interior's program in atmospheric water resources and believes that the continued development of that program in consonance with the spirit of S. 2875 should continue. The Foundation does not feel it appropriate to express an opinion as to whether or not the passage of S. 2875 is necessary to assure adequate development of the Department of Interior's atmospheric water resources program.

Thank you for allowing me to appear before you today. I shall be pleased to try to answer your questions.

Senator ANDERSON. Will the National Science Foundation welcome the opportunity to obtain this responsibility for weather modification?

Dr. JONES. You mean the entire responsibility, Mr. Chairman?

Senator ANDERSON. Its present responsibility.

Dr. JONES. Well, the Director of the National Science Foundation has indicated that he was not opposed to transferring responsibilities for central coordination of weather modification and such responsibilities related to control.

Senator ANDERSON. Senator Jordan.

Senator JORDAN. I have no questions.

Senator ANDERSON. Thank you very much. Thank you for your patience.

The committee will recess until tomorrow morning at 10 o'clock.

Mr. CHAMBERLAIN. Thank you for the opportunity of appearing before you.

(Whereupon, at 3:50 p.m., the committee recessed to reconvene Tuesday, March 22, 1966, at 10 a.m.)

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WEATHER MODIFICATION

TUESDAY, MARCH 22, 1966

U.S. SENATE,
SUBCOMMITTEE ON WATER AND POWER RESOURCES OF THE
COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D.C.

The subcommittee met, pursuant to recess, at 10 a.m., in room 3110, New Senate Office Building, Senator Clinton P. Anderson (chairman of the subcommittee) presiding.

Present: Senators Clinton P. Anderson, of New Mexico; Frank Church, of Idaho; Frank E. Moss, of Utah; Gordon Allott, of Colorado; Len B. Jordan, of Idaho; and Paul J. Fannin, of Arizona.

Also present: Senator George McGovern, of South Dakota.

Professional staff present: Jerry T. Verkler, staff director; Stewart French, chief counsel; Roy M. Whitacre, professional staff member; Frederick O. Frederickson, special counsel, and E. Lewis Reid, minority counsel.

Senator ANDERSON. Our first witness this morning is Mr. Vincent J. Schaefer, director, Atmospheric Sciences Research Center. Dr. Schaefer, I am glad to welcome you back to the fold after all these years.

Dr. SCHAEFER. Thank you very much, Senator. It is a great delight to be here.

Senator ANDERSON. I will never forget the trips we had under the administration of Dr. Von Neumann. I very much appreciated them then and I very much appreciate it now.

STATEMENT OF DR. VINCENT J. SCHAEFER, DIRECTOR, ATMOSPHERIC SCIENCES RESEARCH CENTER, STATE UNIVERSITY OF NEW YORK, ALBANY, N.Y.

Dr. SCHAEFER. Mr. Chairman and members of the committee, I wish to thank you for the opportunity of appearing before you.

In the nearly 20 years that have elapsed since November 13, 1946, when I seeded a supercooled cloud in the sky near Greylock Mountain in western Massachusetts, I have witnessed many fascinating developments in the field of experimental meteorology.

The tremendous flare of publicity which followed this activity led some to believe that man had finally achieved a major control over atmospheric processes. Some entrepreneurs took advantage of this opportunity and played on the naivete and gulliability of the uninformed public. Others started the long and often frustrating path of research in a sincere attempt to establish the scientific facts about experimental meteorology.

For many years, many long years the more conservative individuals and groups among the scientific community were totally unimpressed with the findings and claims of the enthusiastic persons conducting commercial and experimental operations in the field of cloud modification. Such conservative individuals are necessary and important in science as well as other fields of endeavor, since they force their more enthusiastic and daring colleagues to a fuller exertion toward establishing the validity of their observations.

Unfortunately there are also those who become biased and antagonistic toward new ideas, often refusing to look at the evidence. This field of experimental meteorology, I fear, has had more than its share of such persons.

Fortunately for science, it is not the prerogative of any nation or individual to long control an idea or a natural phenomenon. As a result, we are now in serious danger of losing our original initiative in the important area of weather modification and control.

Fifteen years ago in mid-March and early April 1951, Dr. Suits of the G. E. Research Laboratory in testifying at a hearing before this same committee, which then was considering S. 5, S. 222, and S. 798, all concerned in some manner with cloud modification, pointed out the possible high potential importance of this subject.

Part of his testimony reads:

> It is my considered opinion, however, that the results of most recent work are of the very greatest importance to the Nation. We have at hand a means of exerting a very considerable degree of control of weather phenomena. Precisely how much control can be accomplished will come from further study. Much work remains to be done and it would be a national tragedy if legislation did not provide a proper framework for developing the full potentialities of weather modification and control. It cannot be said that this result is assured by any means but the results to date give great promise in this direction.

Dr. Vonnegut and I also testified at length and were subsequently questioned by Senators Anderson, Cordon, Hunt, Case, and Smathers.

A portion of my testimony:

> On the basis of the results of the flight operations and the laboratory and field studies, it is obvious to me that further activities in this field justify an increased activity on the part of the Federal Government, both in exploratory basic research, as well as a well formulated program designed to apply and evaluate the discoveries in this field which are the basis of our present knowledge.
>
> Despite our difficulty in defining the very complex interrelationships which exist in the atmosphere between air, pressure, radiation, moisture, and suspended particles, the reactions which occur are, in general, physical and chemical in nature and therefore should be susceptible to an eventual understanding. As in any of the experimental sciences, unstable conditions occur which, if properly recognized and exploited, may be forced to yield results of a very specific nature. It is of the utmost importance that a broad study be made to establish the nature and degree of these instabilities and of the possible reaction which may be initiated by trigger actions and other mechanisms which may be quite minor in their magnitude but lead to major reactions as they run their course.
>
> Since the movement of storms and other weather phenomena show no respect for State or even national boundaries, it seems reasonable to anticipate that the Federal Government should concern itself through Congress with the establishment of a commission to institute a broad program of basic and applied research toward reaching a better understanding and utilization of weather processes. Such activities may lead to results conducive to the advancement of the economic welfare of our Nation through the better utilization and conservation of atmospheric moisture, as well as the prevention or moderation of the intense storms such as produce torrential rain, lightning, hail, and high winds.

Our studies show that great variabilities occur in the concentration of ice crystal nuclei in the atmosphere. These variations cover a range of at least a millionfold and are probably directly related to the great difficulties which weather forecasters encounter when they attempt to predict icing hazards for aircraft due to supercooled clouds. This variation in ice nuclei is probably intimately related to the sudden development of intense storms, including thunderstorms, hail, and tornadoes, since such types of storms develop in areas which favor the development of large vertical thicknesses of supercooled clouds. As is well known, such storms are also difficult to forecast except in general terms.

If such factors were not of common experience, it would be foolish, indeed, to urge that an intensified research and development program be sponsored by the Federal Government. Since it is possible to modify supercooled clouds on an extensive scale and to equal or even exceed the natural supply of ice crystal nuclei in the atmosphere, it seems reasonable to expect that a Federal program of research and application is justified at this time.

It is very important, in my opinion, that weather studies involving experimental meteorology be conducted in such a manner that all of the modifications attempted by man-conducted seeding operations be known and controlled. If this is not done, the effort of attempting to understand the reactions which occur is a hopeless one. Whether such operations can be conducted by licensing the private groups now in this field and soliciting their active cooperation or whether it will be necessary to attempt the exercise of complete control over such seeding activities is a problem which must be solved in the near future. I believe that the former procedure—licensing of private groups—is to be preferred if at all possible.

It is obvious that some type of national legislation is of the utmost importance at this time to protect the public in the future from unscrupulous individuals who would play on the gullibility, hope, or desperation of individuals or groups in need of water or other relief from an undesirable climatic situation. It is important that the efforts of some of our best scientists interested in the many complex relationships existing in weather phenomena be directed toward determining the facts and properly informing the general public of their findings.

I believe that an intelligent, scientific, and well-planned program of research and application approached with enthusiasm and using presently known techniques, but geared to exploit new ones that would flow from the proper kind of basic studies would certainly be worth the effort which will be required to initiate and establish such an activity for the national defense and eventual welfare of ourselves, as well as the other peoples of the world.

I somewhat apologize for reading ancient history. This was said 15 years ago, Senator, but it still applies in every aspect.

Our most serious problem at the present time is whether we have enough of the right type of people to carry out the big job ahead of us. It will be necessary to seek the assistance of public and private groups and individuals to mount the effort that is now required. In 1961 I again pointed to the need for concerted action on the part of everyone interested when I wrote:

The logical partners in such activity are the National Science Foundation (to provide support for basic studies), the Bureau of Reclamation (to provide the engineering design and supervision), and the Weather Bureau (to provide the weather forecasts and observations). Cooperation from the scientific and engineering community will support a comprehensive plan if it is carefully developed and conducted with enthusiasm and imagination. The best individuals in each area of activity must be utilized in making the plans. We should continually search for high ability young people to become actively involved in these activities if we are to achieve the long-range potential of such efforts.

I sincerely hope the time has come when we can go forward without further delay with a comprehensive plan for the development of our water resources in the sky, on and under the ground, enjoying the fullest cooperation of public and private organizations, and scientists, engineers, technicians, and our representatives at the State and Federal level. All are essential since we deal with one of the most complex and challenging problems in science.

Water and air are among our most valuable natural resources. Until we adequately understand them and their interrelationship we will not be able to properly develop, conserve, and utilize them to the betterment of mankind.

This is still very much in order in my opinion.

In view of the recent rather optimistic reports on this subject issued by the National Academy of Sciences and the National Science Foundation, it may be well to question whether there were valid reasons for the slow pace that marked our progress in this field. With respect to S. 2875 I strongly endorse the action it proposes.

In order to make up for the time lost in the past decade I suggest the following procedure:

1. The reestablishment of the President's Advisory Committee on Weather Control, or some similar type of high level commission. This should be a group rather similar in membership to that appointed some years ago by President Eisenhower. The Committee would assume primary responsibility for laying out and monitoring long-range goals, the establishment of basic policy, and the designation of cooperative programs which would involve private as well as Government organizations. It should be in a position to request cooperation from groups having facilities or to take measures to implement programs which would involve the best talents available in the United States.

It should also, of course, establish proper legal and liability safeguards.

2. The vast array of industrial talent in America and its capabilities should become actively involved in our activities. This group is virtually unaware of problems in the field of weather control in which they could play an important role. This is due, in large part, to the completely unrealistic attitude on the part of Government agencies concerned with the atmospheric sciences which disburse grant and contract moneys toward the amount of overhead which can be rightfully allocated to industrial involvement in such projects. A careful evaluation of this situation should be carried out as soon as possible.

At the same time the universities having competence in the fields of cloud physics, weather modification procedures, and related activities should plan to make available academic courses, lectures, seminars, conferences, and graduate programs which could delineate problems, describe current practices, and point up areas where industrial know-how might be effectively applied to solve some of the engineering and scientific roadblocks which now impede progress. Many of these problems appear to be disarmingly simple and it is important that the mistakes of the past are not repeated.

3. A much more effective method needs to be found to allocate funds for research and engineering. This is a problem that is not limited to the subject under immediate consideration.

Too many of the best brains in America are devoted to the never ending task of proposal writing. It is well recognized that proposals prepared for consideration by referees, one's peers or a grants committee, public or private, must be carefully prepared, properly organized, imaginative, attractive and replete with new and innovative ideas to receive a good chance for acceptance.

This means essentially that it must be prepared by the most competent individuals in the group seeking funds. As a consequence, much of the time and ability of our most talented individuals must be devoted to proposal writing rather than in doing the job that needs

the best effort. A certain amount of this type of energy must obviously be channeled into this job to assure that moneys and efforts spent are intelligently utilized.

This places a heavy burden on our universities to do two major jobs. One is to retain and to provide a continuing updating of engineers and scientists who have high competence in other fields but need reorientation. The second is to develop young persons with the depth and breadth of knowledge of an interdisciplinary and multidisciplinary nature as is needed to properly attack the extremely complex and serious problems related to the manipulation of our environment.

In order to achieve the most for our investment, careful attention should be given to the allocation of grants to educational institutions with a minimum of "strings" attached.

If such grants are given to some of the lesser known schools which are trying to build up their competence in the field of environmental science, I believe the money will be wisely invested. A certain amount of chance is involved in making such allocations, but I believe that in most cases the money will be well spent.

4. Atmospheric water is a natural resource of tremendous and vital importance. The provisions of S. 2875, which places primary responsibility for the exploration and eventual management of this resource within the purview of the Department of the Interior, seems to be reasonable and logical.

If an Advisory Committee or Commission is established by the President, I believe they would be properly advised to place the main responsibility for such development within the Department of the Interior as part of the national policy. I believe, however, that many other Departments represented in the President's Cabinet also have important contributions to make and I would expect that each would be solicited for ideas and some active involvement to assure that all groups having competence are properly utilized. As I have mentioned earlier, there is a big job to be done with plenty of work for everyone.

The atmosphere and its proper treatment comes closer to the general public and its basic welfare than any other feature of the planet earth. Air, and the water it contains, is the essence of life. Every effort expended to properly understand these properties which can lead toward their proper appreciation, treatment, and utilization is bound to pay dividends of the first order.

If I may show a bit of impatience—may I plead that it is high time our representatives in Washington forget about empire building and get down to some constructive, cooperative effort. We can no longer afford to waste time in trying to outmaneuver each other at the expense of some possible welfare to mankind. There is enough hard work ahead for everyone, and I feel that we need to push forward with innovation, imagination, and some degree of daring.

S. 2875 holds high promise, since it embodies the provisions and means to do the job for which we have been waiting. Let's all have a "will to do" and get doing.

Thank you, Senator.

Senator ANDERSON. Thank you, Mr. Schaefer. Yesterday we were told that weather modification and weather prediction are almost inseparable. Do you agree that these things are as closely tied as that?

Dr. SCHAEFER. I personally feel that this is not necessarily true for this reason. I think quite a bit of the severe weather is what Dr. Langmuir used to call a emerging dilemma where from a small beginning major things happen.

In a talk before the National Academy in Schenectady, at the dedication of the new research laboratory, he made the statement that some day it will be easier to control than to predict the weather. I feel that there are certainly a number of places where no matter how much information you have, I don't see how you can predict what is going to happen. When you have a convergent phenomenon where you have a lot of things together which point toward an end, then you can predict.

That is the basis of prediction. But if, as an example, a single match can start a major wildfire in the forest, how can one predict that that match is going to be lit at a particular spot at a particular time?

This is an impossible kind of prediction. I think some things in the atmosphere are the same way. A tiny dust storm in the desert might put in the air tiny nuclei to trigger off a small cloud which then, in turn, develops into a large cloud system and is the genesis of a major weather outbreak.

I think these are two separate problems. I personally think that organization has an extremely important role to play in improving their predicting capability. Until they get that job done I don't think they should be involved with anything else.

They have a big enough job to do as it is.

Senator ANDERSON. Doctor, I remember you got into an airplane and rode inside a hurricane one time to try to seed it. Are you still of the opinion it will be possible to do something with hurricanes?

Dr. SCHAEFER. Senator, I feel that this is going at the job the wrong way. I think it is far better to improve our predicting capability so we can detect the initial stages of a hurricane, when we just have a tropical disturbance, a minor one which in the long range will develop into a hurricane.

If we can learn how to predict which disturbances will form a hurricane then those would be the areas where cloud seeding and weather modification can be properly applied.

I believe it is far easier to disturb the smaller systems than one that is full blown. I think it is a waste of time to work on a full-blown hurricane.

I don't see how you can do anything with it. I know when we went into what we called Hurricane King back in 1947, we were just floored by the magnitude of the storm. We were told that this was a dying storm. But it was a massive thing. While we produced a few ice crystals, in terms of the magnitude of that storm I can't imagine we were able to do very much about it.

Senator ANDERSON. You have watched this work for the last 15 years. Some of the work that some of your associates have done has not been too successful. Is there any reason why, in your opinion?

Dr. SCHAEFER. I think this is typical of any science.

You have to make a lot of starts before you find your way through the complex sciences. While I do not want to make excuses for myself or anyone else, I feel that there have been a lot of people doing a very sincere job. Perhaps the biggest problem we have faced is that we have so few people that we don't have time, as often as we should, for the workers to sit down together and talk over their multiple jobs.

I believe that this is one of the most important things that needs to be done. We in the university in New York are making our small attempt to do this sort of thing by the conference we hold, our Yellowstone programs, and so on. I believe much more of this kind of thing needs to be done in the field where the job is, not at some resort area where diversions occur.

I think one needs to get much more in the field where the job lies and consider it right there and try to figure out what goes on.

Senator ANDERSON. Senator Allott.

Senator ALLOTT. Doctor, I have been very much interested in some of your remarks, which go beyond the actual item that we are discussing here, but which I think are well taken regardless of this. One of the things you regret is the time spent in making proposals.

Dr. SCHAEFER. I feel very strongly about this, Senator.

Senator ALLOTT. I think maybe you have a right to be. But you do not offer any alternative to this. Do you have alternatives to offer?

Dr. SCHAEFER. Yes, I do. I think the primary thing is to identify the good people and give them support and identify them once and for all. Because if they have the support they are going to do the job. All the scientist wants is support so that he can get on with the job that he is so excited about, because that is what science is.

Senator ALLOTT. Somebody has to determine and identify these people. This is probably one of the biggest difficulties with our overall research effort in the country today, that they have been identified and research contracts keep going back to the same old shops and the same old men over and over so that new talent is often successfully barred.

I have seen these proposals, as have you, come up, prepared by scientists, slick-paper brochures in which thousands of dollars have been spent in presentations, particularly by the so-called nonprofit institutions—you know what a nonprofit institution is, that is where the profits are divided among the members in salaries—so that there is a great deal to be said on the other side of this problem.

You mentioned at the top of page 7 the lesser known schools. Many of us who are interested in this area and have to deal through appropriations particularly, with the research efforts of this Government, have been trying for years to break this down. Yet we still find that the greatest amount of money is poured into a little 200-mile area on the east coast and into the State of California.

In fact, again AEC has just made an announcement a few moments ago, as an illustration of what I am speaking about, of the last six sites for the proposed bevatron and they included, thank heavens, a Colorado site, but they also suggested that one of the difficulties was that the Colorado site was limited by a lack of depth in scientific personnel.

Now you have to begin at this thing somewhere. One of the places we have to begin is to keep all the money from going where it has been going for the last 25 years. Would you agree with this?

Dr. SCHAEFER. Of course you hit me rather close to home because I live in New York State, which I think is perhaps in the 200-mile zone on the east coast you speak about. But I feel there is a great deal to be said for giving such groups as the National Science Foundation what one might call gambling money where they take chances, sir.

Senator ANDERSON. They are gambling $125 million on Mohole. They are not short of funds.

Dr. SCHAEFER. Of course I can't speak for the overall National Science Foundation program but I know, at least it has been my impression, in the area of atmospheric science, where I have a fair contact, there is always limited money available.

I think, because of this limited money in the areas I am concerned with, there are only a certain number of proposals which can be honored. Now, obviously, any administrator is going to tend to try to have a good betting average. The betting averages are likely to be a little better if established people are encouraged to continue their work.

But on the other hand, I believe that a certain percentage, at least of this should be put out to unknowns. I have in my briefcase a proposal from one of our young small colleges in upper New York State which I am sure would not be approved in its present state. What that means is that I have to sit down with this fellow and tell him how he has to rewrite this. I am sure he has already spent a month on it.

All his spare time has been devoted to coming up with the best thing he could. He has not written any of these proposals before. I know there are certain things you have to say and there are certain things you don't say. There is a certain amount of verbiage that has to be deleted and so on because the people whom this is submitted to don't have the time to wade through all the things that a lot of people think are important.

I just don't have a good answer to you except that if I, for example, as an administrator in a small research center, had a little more money to put out to people whom I have a chance to contact personally, then I think that one could help those young people along to the point where they attain stature and their scientific papers begin to come in so that they are recognized. But it is a tough job, it takes 4 or 5 years. The kind of money I can put out is on the order of a thousand dollars and that is not very much to keep a young fellow going on a project

These are young married people who have a big job to do.

Senator ALLOTT. I realize some of the difficulties in connection with not having the depth of experience or of the length of service that you have had. But it seems to me that eventually somebody has to select to whom these awards will be made.

The National Science Foundation is, of course, by a series of—I don't know what they call them—but they are a series of subcommittees which make the recommendations for the National Science Foundation. It seems to me that in a way you are coming back full blown to the circuit of still having the money poured down the same place it has been poured down for many, many years.

For example, how does a young man who is convinced and knows that he has the capability break through this little wall. The National Science Foundation is not the only one that has to cope with this problem. It exists in NIH, in Defense, a dozen other places, and this is one of the greatest tragedies we have.

I know that in just my casual travels and meetings I encounter people with top scientific capability and I can look them up and find out and I can check with their conferences and find out about their ability. But because they happen to be in some midwestern college they really

never get a crack, a good crack, at some of the research funds in this country.

Dr. SCHAEFER. Senator, I would like to draw one analogy or one illustration of one experience that I had. There is a small teachers college up in northern Nebraska called Nebraska State Teachers College, at Chadron.

Senator ALLOTT. I know it very well.

Dr. SCHAEFER. I am one of the group which passes on proposals to the National Science Foundation. I received this short proposal. It was reasonably well prepared and it had some very exciting ideas. I sent it back immediately. I said:

This is one of the best proposals I have ever read, not because of its makeup but because of the ideas in it.

The proposal was funded by NSF and some fine work was done which unfortunately was terminated by the untimely death of Professor Andrews. I feel that good ideas have a good chance for funding by NSF but raise the question as to whether this agency shouldn't have a few more people to seek out and encourage the presentation of good ideas from some of our lesser known colleges and universities.

I think that this is the primary thing. I feel from what I know of the National Science Foundation, in the area I am concerned with, atmospheric science, that these fellows are highly dedicated individuals who really do a sincere job trying to find out where the good ideas are.

I don't think it is going to make much difference where the person comes from in terms of the allocation of money.

Now I am fairly sure that a limited amount would go to such an individual because he does not have the backup that is necessary to mount a very active program. But I personally think that we have a good mechanism now if such administrators are further encouraged to carry on this kind of money allocation.

Senator ALLOTT. This is only a periphery to the subject we are discussing.

Dr. SCHAEFER. That is right.

Senator ALLOTT. While I do not agree with everything you say, Doctor, I do want to say this: In the long run I think pointing the finger at this question is going to serve a useful purpose, not only in this area but in many, many other areas and I am glad that you did this.

Dr. SCHAEFER. One area, Senator, that must be very carefully considered is the granting of funds for more than 1 or 2 years. They ought to be granted for 3 to 5 years. I think if that were to happen one would find that a great deal of the troubles I speak about would disappear. One of the biggest problems is that you finally get your proposal granted and then you hardly get underway before you have to begin to think of another one, especially if it happens to be a 1-year proposal.

Fortunately, in most cases I know of, the National Science Foundation has adopted a policy of 2- to 3-year grants and I think this is excellent. If it could be 5 years it would be even better.

Senator ALLOTT. Thank you very much, Doctor.

Senator Church?

Senator CHURCH. No questions.

Senator ANDERSON. Senator Jordan.

Senator JORDAN. I have been interested, Doctor, in your colloquy on this with Senator Allott. I agree with the statement that this research money must be more widely dispersed about the country than it is presently. We are a small State with a small university and are stymied because of this lack of diversification in research funds. I am interested in your closing paragraph.

You say this:

> If I may show a bit of impatience may I plead that it is time for our representative in Washington to forget about empire building and get down to some constructive cooperative effort.

Were you directing that to any particular kind of cooperative effort or any particular group of people? To whom are you addressing that remark?

Dr. SCHAEFER. I would say I would direct it to everybody because it is going on everywhere here in Washington. There is such a big job to be done that there should not be this kind of maneuvering in my opinion. Now certainly the time is going to come when we have to sharpen these things up but I don't believe the time is here now. We need everyone we can possibly get. They ought to be doing things in their competence, not trying to do things that are not directly related to their coming activities.

Five years from now, or even 2 years from now, the situation will probably be changed. New alinements will be developed as we find who the groups are that will have to work closely together. I feel very strongly this is not the time for any one group to dominate the field, because it has to be distributed.

We have the same situation in private industry. We have to solicit the help of every conceivable group, the space industry and everybody else. Here is where the great manpower reservoir is. I do some consulting work so I am in touch with these different groups.

They are all groping as to how they can fit into the picture because, after all, they have hundreds of engineers who have to do a job. If they are not designing missiles and airplanes and things of this sort they have to do something else. I think we will find tremendous assets here as soon as adequate moneys are available to begin paying more attention to our everyday backyard problems, and that is what the atmospheric studies really are.

Senator JORDAN. In your opinion the magnitude of the job is great enough that it should transcend selfish interests?

Dr. SCHAEFER. Absolutely, Senator. And I would like to point out that one of the great assets of a State like Idaho is that you have fantastic outdoor laboratories. I spent a month on top of Gigsmore Mountain. It used to be called Looking Glass, and the Priest River is also in Idaho. Here is one of the greatest outdoor lightning laboratories in the world.

You should be developing there. There is a similar place down in Riggins, back in the Seven Devils Mountains area where it looks over toward the Williwaws. These are ideal places. Those of us in the West and in the East, should be joining you folks at Moscow, Idaho, to work together on these. We have to broaden our horizons and discretions.

Senator JORDAN. I appreciate your comment, Doctor. Thank you.

Senator ANDERSON. Senator Moss.

Senator Moss. I take it, Doctor, that you agree with the terms of this bill, that the Secretary of the Interior would be a proper focus to have this kind of cooperative effort built through other departments and agencies and you do feel that they can cooperate in this and that there is no danger of his running off with the program, as it were, to the exclusion of others?

Dr. SCHAEFER. I don't see how he possibly can. There are so many other jobs that have to be done. The consideration of hailstorms has very little to do with getting water in the Colorado River, for example. But there should be the closest of cooperation because things discovered, let us say at Sterling, Colo., or on the Hudson River in New York in relation to hail, might very well tell us better how to transport moisture from the oceans inland.

They might do lots of things which we then would profit from. I have had pretty close contact with the Department of Interior people involved in this work, going back to 1947. That is when I first contacted the Department of Interior through Walter Garstka. He and I sat down at the table in Portland, Oreg., the first time I went west and we discussed this problem in 1947.

Since that time the Bureau of Reclamation has had an interest in this area. This is not some Johnny-come-lately idea at all. They have been very much concerned with this situation. They got involved in evaporation reduction because of this relationship with me. Langmuir and I did some of the early work on evaporation reduction.

It was through my contacts with Walter Gartska and the Bureau of Reclamation that they have now an excellent program going on in this region. So I think that we need to solicit and you should direct, in my opinion, that we get along together and that we cooperate with each other.

I have not seen any desire in the Department of Interior to build a vast empire. Their whole philosophy in trying to solve these problems is constructive. They contract them out to other groups who can help them. They should be urged to continue this kind of policy.

Senator Moss. Thank you.

Senator CHURCH. Mr. Chairman.

Senator ANDERSON. Senator Church.

Senator CHURCH. Dr. Schaefer, one of the things that constantly crops up when it comes to Federal aid for research is the tendency not only to concentrate research activities in comparatively few large centers but the Federal money which has developed an expertise in a given field at a very large center then attracts more Federal money by virtue of the fact that the experts are there.

So these few large universities get larger while other smaller universities scattered across the country are denied Federal funds for the lack of a demonstrable capacity to contribute in the selected fields.

It becomes a vicious circle, it gets worse all the time. I would like to know how you think the vicious circle can be broken.

Dr. SCHAEFER. I think you have a marvelous mechanism in S. 2875 because here you have a plan to spend a lot of money. To me $35 million is a minor amount of money. I think you are going to be dealing with billions before you are very far along.

Now where are the places where much of this money ought to be spent? It is in Idaho, South Dakota, Wyoming, Colorado, New Mexico, Arizona, and Montana and the whole western region. This

is one of the areas that needs the kind of cooperation you are talking about. It is also needed in the middle country area, Nebraska and Iowa. They all have problems of a similar nature.

The pollution we get is not all urban. We get pollution from Denver moving eastward, from New Orleans moving north, and so on. We need to begin to spread out. I think that this is the ideal mechanism. The Bureau of Reclamation at the present time—I am probably going to miss some—have programs at the University of Nevada, at Wyoming, at the South Dakota School of Mines, at Utah State, and a number of small programs are being supported now.

Obviously when you get that kind of support indicated and you have good outdoor laboratories in the region those of us in the East and those in the West are certainly going to go where the projects are.

In fact that is where I spend my summers. I spend my summers in Arizona and Colorado because this is the place where the weather problems of the East arise. I take a good many of my students there. So you have a marvelous opportunity with this very bill to get back to smaller college projects and the Department of Interior, through the Bureau of Reclamation, recognized this and already has a good program going.

I think more of these types of projects, not only in weather modification but in water resources and air pollution control through the Public Health Service, and other agencies, is a very logical thing. I believe it has tremendous potential for the smaller States.

Senator CHURCH. Did you think this imbalance can be adequately corrected without new legislation?

Dr. SCHAEFER. I think it is very necessary to consider this very carefully. I think S. 2875 is a move in that direction. I am sure that the present wording will be modified as you take all the evidence that we are trying to present to you and out of it I hope an outstanding new look will come.

I think that there are tremendous possibilities here that everyone will be very happy about if the job is done right. We are here to really try to help you.

Senator CHURCH. Thank you.

Senator ANDERSON. The Senator from Arizona.

Senator FANNIN. Thank you, Mr. Chairman.

I would like to ask Dr. Schaefer a question. First of all I want to thank you for bringing Arizona and the Colorado River into this discussion. They are very dear to my heart.

We have had a program of weather modification which has been carried on for some years and no doubt will cover what is being done. I am wondering if we are disseminating the information that should be sent out to all the different groups working on these programs. For instance the Salt River project at Phoenix has been doing extensive work on this program for years and years. I remember years ago when they were seeding clouds with silver iodide they used a propane gas furnace to do this with.

At the same time I realize they have stayed on one program. I am just wondering if this is the manner in which this has been handled throughout the country. In other words, have we really disseminated our information properly?

Dr. SCHAEFER. To a certain degree we have in that the community is still so small that when we get together we know everybody by his

first name. This involves even our friends abroad. We just had a meeting of this general kind in Tokyo last May. We have another one coming up on condensation nuclei at our university in another month or so, in May.

The operation at Flagstaff, for example, is now becoming a focal point where we are encouraging people from all parts of Arizona, New Mexico, and other States to come in and see what is going on and join the operation if possible.

I feel that this kind of operation rapidly will get more and more interaction between everyone interested. The National Science Foundation is supporting a hail study this summer at Rapid City, S. Dak. Something like 18 or 20 groups are joining hands to work together for a month.

That means that we are going to be eating and discussing problems and everything else with each other and finding out how others think about our ideas and talking over the problems we have as to whether or not the things we are planning to do have any sense to them. So I think that we are rapidly developing a very good cooperative activity.

Senator FANNIN. Very fine. Thank you.

Senator ANDERSON. Thank you very much, Dr. Schaefer.

Dr. SCHAEFER. Thank you, Mr. Chairman.

Senator ANDERSON. Dr. Bigelow.

STATEMENT OF D. JULIAN H. BIGELOW, PERMANENT MEMBER, SCHOOL OF MATHEMATICS, INSTITUTE FOR ADVANCED STUDY, PRINCETON, N.J.

Dr. BIGELOW. Senator Anderson, members of the subcommittee, the opportunity to appear before this committee of Congress in connection with the problems of weather modification is for me an agreeable study.

I would like first to emphasize that though I was a member of the National Academy Panel and also have had some prior contact with problems arising in the atmospheric sciences I am not a career meteorologist but an applied mathematician with a background in calculational procedures, computing machines, instruments, and methods of experimental measurement, and statistical evaluation of physical phenomena.

During the last 2 years while a member of the Panel, I have made a substantial effort to understand the problems, and present state of weather modification and whatever merit the information I may contribute can have is primarily that of an unbiased scientist looking at these problems from a neighboring field.

To give good scientific counsel to those charged with the responsibility for legislative support of scientific and technological effort, I think it is important to try to gage realistically the facts of the situation, and to estimate the likely and unlikely outcomes. Because weather modification can be viewed as a broad topic, including many important aspects such as violent storms, lightning, atmospheric pollution, and so forth, I shall restrict my remarks hereinafter specifically to weather modification for the purpose of influencing precipitation.

The primary tool which is available today for influencing precipitation is cloud seeding by silver iodide; this is essentially the same tool

introduced by Langmuir, Schaeffer, and Vonnegut for this purpose some 20 years ago.

During this interval, cloud seeding has had its ups and downs related to periods of apparent success and failure in field experiments. As a precipitation influencing tool, its effectiveness has been continually defended and supported—one might say, stubbornly—by individuals and small teams of cloud seeders, some of them commercial operators.

Its use as a tool in scientific investigation of the processes of cloud physics has been pursued by researchers in Government agencies, and under NSF sponsorship and others.

At the present time, there has occurred a remarkable shift in attitude regarding the practical capabilities of this seeding tool to produce increased ground precipitation. So to speak, until a short time ago, the betting odds were against it, now the betting odds are predominantly in favor of some modest but positive success.

The catalyst which caused this shift was not a new and clearer theoretical insight into precipitation mechanism or seeding effects, it was a steady bombardment by these "stubborn men," using empirical facts and experimental data as missiles.

Though the reliable evaluation of the credibility of these data by means of statistical tools has been difficult to the point of despair, it is nevertheless true that the results of such painstaking evaluation of enough raw experimental data have shifted the betting odds. One may say that though scientists pursue a lifelong love affair with theory, those that survive in applied fields learn to recognize and bow to the power of crude facts and data.

We call attention to this situation here and now because we believe it has important implications bearing on the practical problem before us. What we now believe to be the favorable betting odds were not widely recognized and accepted during the last 20 years because the effects which could be produced by seeding were small compared to the prevailing natural variations in atmospheric precipitation.

Therefore, it is safe to say that until we better understand modification tools and their interaction with the vagaries of the atmosphere, the results that may be expected will probably be scattered and irregular—though not necessarily economically insignificant.

A second implication is that for the near future considerable emphasis should be given in any modification program to a close cycle consisting of well planned field efforts, systematic and careful evaluation of results, leading to even better planned field efforts.

I might add that these may well be carried out by men stubborn in their conviction that they will be found right in the end, and propelled by an intimate contact with the human needs involved.

As I see it the weather modification to influence precipitation can—at this time and perhaps for the next 5 to 10 years—be viewed as requiring two different levels of effort: one consisting of a cluster of local efforts, and the other directed at more global objectives in time and space.

The local effort, for which the above close coupled experimental team would, in my opinion, play a key role, would aim to trigger relatively local instabilities in the atmosphere by diligent and locally tailored modification tools such as silver iodide seeding.

It is well known that unless the atmosphere in a local region is already close to precipitative instability, seeding cannot have signifi-

cant effect on precipitation. For this reason, the local modification effort is subject to the whims and variations of large scale meteorological phenomena such as the general circulation, until such a time as we are able practically to modify such large scale efforts.

Consequently the local team cannot be expected to increase precipitation, when, where, and as needed; they will have to be prepared to exploit as best they can the opportunities that chance to come their way. This implies that a flexible and opportunistic approach will be needed, and also for the near future ground management of water will play a key role in conserving and making available the economic benefits that may accure from whatever leverage we presently or within the near future are likely to have.

Thus a near term national program of precipitative weather modification would, in my view, consist of a checkerboard of such local team efforts, each doing the best and most realistic job possible in the associated region.

There is no reason to believe that, for the near future, the techniques and procedures best suited to one region will prove best in another region, so that a unified procedure and comprehensive theory may, for the time being, be unattainable.

However, for all local teams new and powerful instrumentation systems for detection observation, measurement, and evaluation will become necessary, in order that opportunities to modify be properly identified and the outcome evaluated.

In effect, the goal of this instrument system can be viewed as being capable of generating continuous maps whose contours shows the degree of nearness of the state of the atmosphere to modification responsive instability. To accomplish this would require a major, coordinated research and development effort and the large scale data inflow to the instability mapping system would best come in large measure from the Weather Bureau data gathering, forecasting, and general circulation facilities.

Much research and development would be required to make even such an interim operational effort effective. New instruments and particularly dense local observing and calculating systems would have to be developed; also improved modification agents and methods of dispensing them and particularly important new experimental and evaluative techniques for field use. Thus even the local program requires substantial backup in the form of laboratory studies, conceptual analyses, and systems development.

Turning now to a broader and more long-range view of the precipitation modification program, there are many avenues to explore wherein too little is known either in theory or by experiment to permit estimating the prospects. For example, it is known that local instabilities are not the only class and perhaps not even the most important class of instabilities with respect to long-range prospects for precipitation modification; there are in fact known to be instabilities in the general circulation which, if means could be found to influence them, might dwarf the influence for silver iodide seeding on a local scale. A correspondingly impressive possibility resides in the influence of high altitude layers upon radiation exchange extending over vast areas.

On a more modest scale, such basic empirical facts as the distribution of natural nucleants in the atmosphere and their correlation with airborne water transport should better be known. Many other scientific

questions of great practical significance can be listed, quite a few of them being within reach of our present technique.

For these problems and aspects of weather modification I would urge that continuing and expanded effort in the atmospheric sciences should be strongly supported, via NSF, ESSA, and other academic and Government teams.

The more immediate and mission oriented weather modification efforts that we have described as local can and must benefit through scientific knowledge relevant to the atmosphere gained from collaboration and cooperation from every possible source. In many fields and over long spans of time, experience has demonstrated that research and development knowledge is seldom fruitless.

I would like to emphasize that the splitting of the precipitation-modification task into two parts, one local and one near term and the other large scale and more long range which was done for purposes of aiding discussion, is not intended to imply an antithesis between practice and analysis, or between experimentalists and theoreticians.

Rather it is intended to emphasize that two different but complementary missions in precipitation modification could well be carried out in parallel, just as in meteorology there has been a tradition for both synoptic and large-scale mathematical forecasting.

It is a fact that the theoretical insights in each of these areas can and have contributed vitally to the other. As has been indicated, the study of local phenomena such as instabilities can greatly benefit from knowledge of large-scale phenomena such as the Weather Bureau have become increasingly skillful in calculating by means of mathematical models.

But a corresponding fact, not often brought out clearly, is that these large-scale calculational models at present simulate local thermodynamic instability phenomena by averages and other quite gross approximations, and it is exactly to observe and model these that the local dense instrumentation system recommended above are intended.

Thus it may quite possibly turn out that important information can be exchanged.

In conclusion may I say that I would strongly support appropriate legislation along the lines of S. 2875 which appears well suited to advance this important field.

Thank you, Mr. Chairman.

Senator ANDERSON. Thank you, Dr. Bigelow.

You label yourself as an applied mathematician. As such, having knowledge of the computational problems of weather modification, what role do you think computers can and ought to play in this field?

Dr. BIGELOW. I think they can play two different roles, one of which they have not, up to date, played as effectively or as much as I think they should. That role is to take part in an observation system and to compute a probability, depending upon the number of illogical phenomena measured by observing instruments: the probability that the atmosphere is now in a certain state of instability.

In other words, I am suggesting a role which has not been recognized or implemented: to have in the field measuring observing systems, something which continually computes from the parameters we are able to observe, the instability properties of the atmosphere in respect to modification effects.

A second property which has been very well exploited and needs much further exploitation is the calculation of large-scale general models as are now being done in ESSA, the Weather Bureau, which describes the gross and important features of the atmospheric driving terms and atmospheric motion on a hemispheric scale.

Senator ANDERSON. Can you indicate in your view the relative importance of the statistical evaluation techniques and the field experiments of weather modification efforts in comparison to primary mathematical and theoretical approaches?

Dr. BIGELOW. Yes. I think that it is extremely important to recognize that the shift in viewpoint which is presently taking place has been to a considerable extent the result of statistical procedure applied to empirical data. I think that the statistical procedures themselves have been in the past to some extent distasteful to people in meteorology because they do not explain underlying mechanisms.

What they do is enable you to make decisions as to whether or not an effect is being produced in the presence of many disturbing effects. Therefore I think they are vitally important and I think they will play an increasingly important role.

Senator ANDERSON. I think you were consulted on the preparation of S. 2875. What are your views on the scope and time required to carry out the program of atmospheric water resources studies?

Dr. BIGELOW. It is difficult for me to estimate what the time and scope will be, as indeed I think it is for almost anybody. I agree with the remarks that Dr. Schaeffer made about the need for a widespread effort, about the need for a continuing effort, rather than an ad hoc, catch-as-catch-can procedure. Whether the amount of funds appropriate in this form of the bill is the right amount and whether or not the increases are estimated correctly with respect to the evolution in time I would not be able to say.

Senator ANDERSON. Thank you very much. Senator Allott.

Senator ALLOTT. Doctor, I would like to return to the first example you used in which you said computers had not been used extensively as yet in computing the probabilities of certain results. As I understand your statement this would contemplate, of necessity, points for various types of weather and atmospheric observations on a scale which is unknown in this country today.

Do I understand that correctly?

Dr. BIGELOW. I suggest that in order to make effective use of weather modification in the near future one will have to set up some local teams which will be very well equipped with observing apparatus and systems and that within each local team and possibly actually in the field there should be set up a computational procedure which continuously estimates the state of the atmosphere in that local region.

This would be a local computation of 10 miles by 10 miles or 30 miles by 30 miles or 50 miles by 50 miles but the intention would be to determine as best it can the occasion on which that particular cell of the atmosphere is a suitable indicator for modification procedures.

This would mean that the instrumentation, observing instruments and apparatus system for that particular cell might be very much denser than the prevailing observing system throughout the country. in total it might be a small fraction of the prevailing apparatus systems which now exist. But the point would be that if you wish to

modify successfully in a given region there are certain kinds of local parameters which can be logically observed, directly by observing instruments in that region which are subject to insertion in a local model and this can tell you when you are crossing into the boundary of the state of the atmosphere where modification is worthwhile.

I think such a system would greatly enhance the likelihood that those weather opportunities which come across that region can successfully be exploited.

Senator ALLOTT. You stated in your first example of the use of computers to Senator Anderson, the chairman of the committee, the use of computers in determining probability.

Dr. BIGELOW. Yes.

Senator ALLOTT. But since you have to feed detailed data into the computer before you come out with any answers, this would call for various kinds of measuring instruments, atmospheric pressures, all sorts of things on a scale that we do not possess in this country today in any form; or would it?

In other words, aren't you envisioning for this type of operation a great intensification of all weather observation means in the areas with which you so expect to deal?

Dr. BIGELOW. Yes, indeed; in those areas I am. The only reason I am hesitating is that the total weather observation system for the United States, and in fact for the hemisphere, if you count up all the apparatus and equipment in it, is an enormous number.

The distribution, however, over critical regions is quite sparse. What I am suggesting is that we set up dense equipment configurations over those regions where we believe we want to try to exploit weather modification. It might turn out that this would be a small percentage increase of the total.

Senator ALLOTT. I understand that. Thank you very much.

Senator ANDERSON. Senator Jordan.

Senator JORDAN. I have no questions.

Senator ANDERSON. Senator Moss?

Senator Moss. I have no questions, Mr. Chairman.

Senator ANDERSON. Senator Fannin.

Senator FANNIN. No questions, Mr. Chairman.

Senator ANDERSON. Thank you very much. That was a very fine statement.

Dr. Hosler.

Dr. Hosler, you are somewhat well known to the chairman of this committee at least.

STATEMENT OF DR. CHARLES L. HOSLER, DEAN, COLLEGE OF MINERAL INDUSTRIES, PENNSYLVANIA STATE UNIVERSITY

Dr. HOSLER. Yes, sir.

Senator ANDERSON. We are glad to have you back.

Dr. HOSLER. Yes, sir. As I said in the introductory statement here I was tempted to reproduce a statement I made 15 years ago to the day, I believe, before your committee. The composition of the committee has changed except for you, I believe.

Senator ANDERSON. The way things are moving in this world of computers and everything else it is remarkable that you make no change in what you said 15 years ago.

Dr. HOSLER. I would not change much what I said 15 years ago.

Senator ANDERSON. I am sure you would not.

Dr. HOSLER. Mr. Chairman, I want to thank you for this opportunity to express my views relative to the subject matter of S. 2875. I am a meteorologist by profession and have been engaged in teaching, consulting, administration, and research in the field of cloud physics and weather modification for the past 18 years.

Man has manipulated the rivers of water on the surface of the earth for thousands of years. The rivers of water in the atmosphere are more complex and less palpable but are nonetheless manageable. It is not a matter of whether these rivers will be managed, but when and by whom.

This is an age when there seems to even be a consensus that the resources of the earth shall be managed for the greater good and in this world the distribution of water is the overwhelming determinant of those starves and who has plenty.

Why do we hesitate?

It is an accident of nature that we have abundance and others have little. There is no reason why we could not face severe drought in our food-producing areas which could tax our ability to feed our own people and evaporate surpluses now available to others. As the margin of difference between the minimum water required for our economy and its abundance narrows, the frequency of years when the supply falls below the need will become greater and greater and the consequences dire.

We should not wait to exploit what we know about atmospheric water controls and to advance our understanding of the atmosphere on all fronts. I feel certain that what we view as promising techniques today are child's play compared to what can and will be done.

I feel that we, as meteorologists, have been unimaginative and conservative and, above all, inarticulate in expressing our ideas and making known our understanding of the atmosphere. We have confronted one of the most complex and overwhelming of natural phenomena with resources, tools, and systems which are miles behind present capabilities and light-years short of what is required to analyze the problem.

I see no cheap, easy solution to prediction and control of precipitation but I see no insurmountable obstacles if we approach it on a meaningful scale with the tools and talents which are available to our society.

My own immediate experience in weather modification has even centered upon altering the buoyancy of clouds and cloud systems. The natural variability of rainfall in space and time within regions of uplift of air, where rain is produced generally, demonstrates clearly that instabilities exist which are due to small differences in the thermodynamics and microphysical properties of clouds and cloud groups on a scale and of a nature not monitored by existing observing systems.

As a result, the true potential of artificial measures to manipulate on the same scale cannot be assessed and even where the gross features suggest potential, great potential, the lack of real time assessment and diagnosis prohibits intelligent application of the tools at hand, that is, cloud seeding.

We have been greatly encouraged by a study we have carried out over the past 6 years under National Science Foundation support. In this period we have studied in great detail the causes of local variations

in rainfall and shower activity. We were able to relate the reasons for these variations to motions induced by the topography and to determine by measurements that we could, through the release of heat in the clouds by cloud seeding, add buoyancy to the cloud which would counteract some local negative influences, and permit clouds to continue to grow which would have naturally dissipated. In some cases, where nature stopped the clouds just short of reaching sizes capable of producing significant rain, we were able to push the clouds over the barrier nature provided (a stable atmospheric layer) and achieve the development of a shower.

We believe that these experiments have significance beyond the special cases we studied. They indicate that if we can monitor the atmosphere readily and rapidly and pick the times and places, groups of cumulus clouds can be altered and made to affect significantly the circulation over thousands of square miles. Convective bands can be created within large-scale cloud and precipitation systems to alter profoundly the precipitation distribution.

Further, we believe that these so-called mesosystems can alter the energy balance in large-scale systems and affect weather on a national scale. This could be labeled speculation but I would like to meet the meteorologist who would discourage the step-by-step studies which would prove or disprove it.

Many of the most significant precipitation variations in time and space are induced by nature by applying or releasing energy on a scale and of a magnitude well within our capabilities.

We can imitate nature, but only when we are sure how nature is distributing the rain and when we can monitor where and when nature will cooperate. Except on a small scale and for short periods when equipment and personnel from several research organizations have been gathered together, observing nature in action in this respect is now beyond our capabilities with existing funds and facilities.

In order to improve this capability, we need to bring to bear on the problem the talent and techniques of the engineering profession which has so successfully pushed other large-scale projects in our country. With all due modesty, we must state that we are dealing with a problem which is somewhat bigger than the usual engineering project and we can hardly be expected to handle this on the basis of small individual efforts.

The exploratory phases have been handled nicely as small individual projects by individual investigators working in the laboratory, and they have been adequately financed through the National Science Foundation, other Federal agencies, and individual contributions of time and effort. It has been possible to handle some of the experimental aspects in this way.

Other avenues must be pursued on a much larger scale involving far greater financial commitment. The operational techniques, which will be required to bring anything of economic value from weather modification, are completely beyond the capabilities of any presently existing meteorologically oriented organization.

I strongly urge that this committee do all in its power to implement a program which will enable this nation to go down in history as the one which harnessed the rivers in the sky for the benefit of man.

Senator ANDERSON. Thank you very much, sir. I like your phrase "rivers in the sky." That is something we can utilize and remember.

I believe you also talked in the discussion of the weather modification about the program on which S. 2875 is based. Do you feel the bill and the program behind it are appropriate next steps for weather modification work in the years just ahead?

Dr. HOSLER. Yes, I feel they are appropriate in view of some comments made earlier and the qualifications and doubts expressed as to perhaps the amount of talent available to do the job and perhaps the amount of intelligent use we can make of the amount of money requested.

I would just like to say that I feel very strongly that if we approach the problem on an appropriate scale with an appropriate amount of money the talent will come. The talent is available, I feel, in industry and in private organizations in this country. If you want to sit down today and specify the observational network, the computational facilities and data processing facility required in this field I feel if it is within our capability and the technology will rise to the occasion.

I feel that the magnitude of the program projected and the manner in which it is outlined is quite a problem.

Senator ANDERSON. I am glad to have your appraisal of it.

Senator Church.

Senator CHURCH. Mr. Chairman, I have no questions of the witness. I have listened to his statement with much interest. It has not been possible for me to attend all of the hearings on this bill because of the public hearings in the Foreign Relations Committee which I have been attending and which have been occurring simultaneously. Therefore I am not certain whether we have had testimony or will have testimony relating to the possible legal consequences that would follow weather modification.

I think in order to make the record complete we ought to examine this phase of the problem.

I should also like to have access to some testimony on the implications of section 202 of the bill, which reads:

> Activities intended to affect, or determined by the Secretary to be likely to affect, the atmospheric water resources of the United States may be carried on only pursuant to license issued by the Secretary in the same manner as license pursuant to the act of August 30, 1954.

I just seek information as to this particular section of the proposed bill.

Senator ANDERSON. Senator, it is true that the provision may be stronger than we will want in the final writing of the bill. We put it in there for purposes of discussion. If the discussion reveals it is not practical, it can be altered.

I have not such a mind that I can't change it. The Senators who sponsored it are of the same opinion. We want to find out what the situation is. We have had some good testimony on it. On the question of legal liability the Joint Atomic Energy Committee went through that one time and developed the Price-Anderson Act, which tries to make sure certain things can be done. If it can be rewritten in committee it can be written more carefully.

Here we can find out what can be done and needs to be done to have a workable bill. I appreciate your comment.

Do you have any comment, Mr. Hosler?

Dr. HOSLER. I must say from personal experience and observing the experience of others in this room that the minute you embark even

in discussion of a weather modification program you do encounter legal problems and local problems that may actually hamper operations by virtue of the fact that a lot of people just do not understand what you are talking about.

Up in Pennsylvania we have encountered problems. Any weather modification attempts are in charge of the county commissioner in each county in the State of Pennsylvania and in neighboring Maryland they have outlawed any weather modification attempts for 2 years because they feel the droughts in the last few years in the Northeast have been due to weather modification efforts that have been underway in that area.

Of course this is not true but it does not alter the fact that people become quite irritated. So even discussion of weather modification certainly necessitates consideration of the legal aspects of the problem. I think this is of primary importance and in the long run may be a greater problem than the scientific problem of controlling the weather.

Senator ANDERSON. I remember many years ago when this matter came up scientists said they were worried about the legal liability.

Dr. HOSLER. Your bill, S. 222 presented to the 83d Congress, provided that it be patterned after the Atomic Energy Act, which I felt seemed like very sound legal provisions from a purely layman standpoint.

Senator ANDERSON. Senator Allott.

Senator ALLOTT. I have no questions.

Either the first or second witness we had yesterday morning emphasized very strongly that one of the first steps in this, along with the scientific aspects, was that the legal problems in connection with it should start to be studied now by a group of expert lawyers in order that we again can arrive at—I commented on that yesterday.

I don't think there is any question but we have all had experience with this at one time or another in our lives. I think the point that Senator Church makes is a very valid one. You underscored it, too, that it may be more difficult to make real progress in developing legal principles than to make real progress in developing precipitation.

It has occurred to me over and over again, and I may be wrong in this, but as I have listened to the witnesses as we get down the road to a greater scientific capability in this area the more difficult precisely do the legal problems become.

In other words, when you can prove that when the scientists say I am producing rain at this spot, and then the other fellow is in a position to say if you had not produced it at that spot it would have come over to me, it seems to me as you develop a real discipline in this you make the legal problems more difficult. Do you think so?

Dr. HOSLER. By all means. I don't even need to worry about someone saying the rain would have gone somewhere else. If the rain even falls where the man wanted it to fall there are certain people there who will not profit by the fact that the rain has fallen.

Senator ALLOTT. That is all I have, Mr. Chairman.

Senator ANDERSON. We had an example of the agriculture of the country wanting some rainfall and the amusement park not wanting any rain at all.

Senator Moss.

Senator Moss. I have no questions, Mr. Chairman. I have enjoyed the testimony very much.

Senator ANDERSON. Senator Jordan.

Senator JORDAN. No questions.

Senator FANNIN. Mr. Chairman, I would like to ask Dr. Hosler one question. You mentioned industry. Is it difficult to get industry to participate in this program to the extent that it participates in programs such as sea-water conversion and all because of the very nature of the activity involved, the legal complications and the inability for them to be able to recover their investment in future programs or future activity?

At the symposium they had here last year on desalination there were millions of dollars of equipment on display by the leading manufacturers around this country and throughout the world. When we get into this program isn't it rather difficult for industry to participate as it is in one of the other programs?

Dr. HOSLER. I don't think it would be difficult. First of all, now, industry would be doing this under contract with either Federal agencies or universities and would simply be providing the logistics support to obtain observations and process the data.

I would think in order to really do this job it will have to be a multimillion-dollar installation in each case. I would think there would be enough profit in it for industry just to do this as a service.

Senator FANNIN. As a service, yes, but would they take any initiative in developing this as they have the desalination program?

Dr. HOSLER. There is at least one large corporation in this country that is considering on its own a very-large-scale weather modification effort.

Senator FANNIN. I can understand companies such as water service companies that we have in our own State who spend extensive sums on projects of this nature. At the same time the large corporations, unless it would be from the standpoint of contractual activity, do not initiate the activity themselves.

Dr. HOSLER. If they had any more foresight I could foresee where there would be a tremendous market for the type of installations which would be required to monitor the atmosphere and to make the diagnosis of seedability or modifiability and I can see where there might be a worldwide market for such installations eventually.

The ones we are talking about now would be research-type installations and no doubt could be scaled down once we find out what we really need to know, how many of the inputs we really need in order to make the diagnosis and prognosis and make a prescription of what can be done.

I feel there is a market for industry to market the equipment and the data processing facilities and the know how to go out and engineer the weather. There will ultimately be such a market. There would not be this week.

Senator FANNIN. At the present time, though, my question is, "Is industry in this activity to the extent that they should be?"

Dr. HOSLER. No.

Senator FANNIN. Should they be encouraged to get into it to a greater extent?

Dr. HOSLER. If you could see the equipment we use in the field, put together with graduate students and glue and nails and bailing wire,

the space industry and other industries would laugh out loud that we are trying to modify the weather in this way.

My reason for coming down here is to try to amplify the point that we have been shooting at weather modification with a peashooter for years.

Senator FANNIN. I agree with you. I have not observed that industry has been doing as much in this field as they have in other fields.

Dr. HOSLER. No, they have not. There have been a few corporations that have more or less specialized in this field but they are relatively minor.

Senator FANNIN. That is fine. Thank you.

Senator ANDERSON. Thank you very much.

Dr. HOSLER. Thank you, Mr. Chairman.

Senator ANDERSON. Mr. McDonald.

Senator FANNIN. Mr. Chairman, first of all I would like to pay tribute to our witness, Dr. James E. McDonald. We have a meteorology department which we are very proud of at the University of Arizona. The work that is being done through Dr. McDonald has received recognition throughout the country.

We are very proud to recognize Dr. McDonald today. I welcome you to the committee.

Senator ANDERSON. Thank you, Senator Fannin. We are very glad to have him here.

STATEMENT OF DR. JAMES E. McDONALD, PROFESSOR OF METEOROLOGY, UNIVERSITY OF ARIZONA, TUCSON, ARIZ.

Dr. MCDONALD. I am very pleased to be here, Mr. Chairman. I particularly commend the committee for the very idea of holding these hearings and inviting a fairly broad cross section of opinion in the hearing chamber today.

Mr. Chairman, I have prepared a statement which I have submitted to the executive secretary. It is fairly long. I don't believe it is feasible for me to cover it in full by reading it.

May I ask if I might have it then entered into the record and merely hit the high spots in my comments here?

Senator ANDERSON. Without objection your statement as prepared will be printed in the record as if read and you may make a summary of it if you like.

(The statement referred to follows:)

STATEMENT OF DR. JAMES E. MCDONALD

Mr. Chairman and members of the committee, I appreciate this opportunity to express my views on S. 2875 and on national legislative needs in the area of weather and climate modification. I commend the committee for securing a broad cross section of scientific opinion on the important questions we are considering here.

INTRODUCTION

To come right to the heart of one main question before us today, I wish to state that I oppose S. 2875 in its present form. To propose increasing total national expenditures on all aspects of weather and climate modification by as much as a factor of 10 within only a few years may possibly be a wise decision, though it is for me difficult to imagine how that can be done without a fairly large amount of money being spent wastefully. But to propose spending huge sums just on precipitation inducement and just within the Department of In-

terior, an agency that has had almost no past experience in the scientific areas under consideration, seems to me to be quite unreasonable. I shall try to elaborate below the considerations which lead me to this point of my testimony.

GENERAL REMARKS ON WEATHER AND CLIMATE MODIFICATION

I presume that present congressional interest in weather modification legislation is related, at least in part, to the recent release of the National Academy of Sciences' Report NAS–1350 and of the National Science Foundation's Report NSF 66–3. Those reports (especially the first of the two) asked for careful study of how best to proceed in setting up a much stronger national program in weather and modification research and emphasized the importance of considering those fields in very broad scope, not just in terms of the limited area of precipitation enhancement. The speed with which S. 2875 and another pending bill, S. 2916, have been produced betokens encouraging congressional interest in weather modification, yet it seems to betoken slight regard for the Academy Panel's plea for a "thorough study of the administration and support of research and development in weather modification." I would like to urge the Congress to step back a moment from consideration of actual legislation to take more careful stock of present and future needs in Federal support of research and development in weather and climate modification.

I hope that your committee's present hearings and those currently being held by Senator Magnuson on S. 2916 may, in fact, be considered more a matter of stocktaking than of decisionmaking with respect to immediate legislative action. The problems involved are exceedingly complex. The climate of scientific thinking about weather modification appears to be undergoing rather rapid change right now. Hasty legislative action might easily create more problems than it solves. On the other hand, extensive hearings of just the type this committee is now holding will provide an invaluable forum for assembly of the diverse viewpoints that must be woven into plans for a well-conceived national program in this challenging field. Hence all of us are pleased to have this opportunity to speak to you and to other committees now deliberating on these matters.

IMPORTANCE OF MAINTAINING A BROAD CONCEPTION OF NATIONAL GOALS IN WEATHER AND CLIMATE MODIFICATION

Congressional legislation in support of weather and climate modification should, I believe, be based upon recognition that the atmosphere's working parts are so intimately and subtly coupled together that both research and ultimate operational activities must be planned on a basis just as broad as the range of all those atmospheric processes we hope to influence in a beneficial manner.

For instance, some of the cloud modification techniques which (after 20 years of research and testing may now be showing promise in the direction of precipitation enhancement may also play important roles in other modification efforts such as hurricane modification, tornado modification, hail suppression, lightning suppression, and someday perhaps climate modification.

Separating precipitation enhancement from the rest of the spectrum of modification efforts seems to me to be an inherently artificial separation, a separation that would surely reduce the efficacy of the research on all other parts of weather modification. Hence, one of my reasons for being dissatisfied with S. 2875 is that the bill appears to isolate precipitation enhancement as a separate research and development goal (and, at the same time, proposes to support that one activity at a level that, to me, seems rather too high for all of our immediate national needs for research support in weather and climate modification). I concur with those who believe we now need an integrated approach in which precipitation enhancement becomes only one portion of a comprehensive program of study of all aspects of weather modification. In this respect, I would prefer S. 2916 to S. 2875, if I had to choose between the two.

The NAS Panel on Weather and Climate Modification, in its Report NAS–1350, tried to spell out this need for an integrated and comprehensive approach to the wide range of possible opportunities for useful atmospheric modification. The NSF Special Commission on Weather Modification, in NSF 66–3, underscored that basic point. Both reporting groups were trying, I believe, to look not only at immediate needs but also at probable needs as much as two or three decades into the future. Both reports emphasized, therefore, the long-range importance of preparing foundations for effective international programs in weather and climate modification a number of years from now. When I consider any of the

presently conceivable programs of atmospheric modification on an international scale (e.g., hurricane or typhoon modification in international water, modification of Arctic climates through attempts at pack ice removal), I find it impossible to visualize effective programs being prosecuted by any agency that does not have among its personnel a large number of atmospheric scientists specializing in the study of each of a wide variety of aspects of atmospheric modification on both large and small scales.

For instance, Arctic climate modification, which is now under rather active study both in the Soviet Union and in this country, is already generating subtle questions about atmospheric processes ranging from the microphysics and radiation transfer properties of Arctic summer stratus clouds, through the micrometeorology of open versus ice-covered Arctic seas, and on to the dynamics and energetics of hemispheric-scale circulations that govern the heat and moisture transport to and from the Arctic regions. To tackle effectively that fascinating and potentially important problem is going to require a lot of good people with a wide range of talents. Compartmentation of the main effort into too many diverse agencies will not be compatible with optimal preparation for a large modification effort such as modifying the Arctic climate. Needless to add, any agency, pursuing studies in such an area must have immediate access to scientific talent in a wide variety of peripheral areas, and must even have staff competence in certain areas of the social sciences. To speculate in more detail on future international effort in climate modification is probably pointless; but to suggest that the large problems that we may ultimately wish to attack on an international scale can be adequately handled only by an agency or national laboratory with very broad responsibilities and capabilities would seem almost self-evident. This conclusion constitutes a major recommendation of both the NAS Panel and the NSF Commission in their recently released reports.

Perhaps I should interject here that I am something of a recent convert to the notion that serious scientific consideration should now be given to such broad atmospheric modification efforts as those which I have just mentioned. However, I guess I am now almost fully converted, and I agree with those who now feel that it has become important to find some effective means of initiating a very broadly conceived program, with major responsibilities centered in some single organization.

I hasten to emphasize that my conviction that we now need some "lead agency" in the general area of weather and climate modification runs head-on into my strongly held convictions that diversity in support of research should be a first principle of scientific planning. For the latter reason, I would urge that Congress give prime responsibility, but by no means sole responsibility, to some lead agency. For example, I believe that the National Science Foundation should and must continue to be a vital source of support for new ideas and support for individual scientists working in many basic research areas relating to weather modification. Similarly, the frequently reiterated principle that mission-oriented agencies, such as the Bureau of Reclamation or the Federal Aviation Agency, must be given opportunity to support research and development on those special aspects of weather modification directly affecting their missions seems an incntrovertible principle. But it does appear, even to one who prizes diversity of support, the optimal progress in all aspects of weather and climate modification now calls for a substantial degree of centralization of the main effort.

I cannot say to this committee that I regard the Department of the Interior as the logical place for that centralization. The Environmental Sciences Service Administraiton (ESSA) seems to me to be a far more logical base upon which to develop such a national nucleus of weather modification research. An obvious reason for that view is that ESSA has broad background and long experience in all aspects of the atmospheric sciences while Interior has almost none. If someone were to interject that Interior will spend several times more money on weather modification in 1966 than will ESSA, I'd be obliged to stress that I'm not talking about dollars spent but about total staff competence in the atmospheric sciences. Surely ESSA must have, on any reasonable basis of measurement, about two orders of magnitude stronger staff competence in these areas than does Interior. Interior is not equipped at present, nor would it seem logical to change things so as to equip it, to undertake research on modification of all the intimately coupled mechanisms that constitute weather and climate on the broad scale in terms of which the NAS Panel and the NSF Commission have recently made national policy recommendations.

COMMENTS ON SOME VIEWPOINTS RELATIVE TO THE HISTORY OF CLOUD MODIFICATION

Doubtless others testifying before your committee will do an adequate sketch of the general history of weather modification. However, I feel that there are certain facets of that history that are exerting strong influence on present congressional thinking about new legislation, facets of history whose interpretation differs, depending upon to whom one talks.

Specifically, I refer to the viewpoint, held by some persons, that the principal obstacle to past progress in precipitation-enhancement has been a lack of "enthusiasm," a lack of incentive and vigorous drive, a stick-in-the-mud conservatism among certain agencies and certain university scientists. This viewpoint received explicit expression in a hearing on May 21, 1964, before this committee's Subcommittee on Irrigation and Reclamation. I have read and reread the report of that hearing, and I must, in all candor, state that I found it exceedingly distressing. When Dr. J. C. Calhoun, Science Advisor to the Secretary of the Interior, presented what I would regard as a fair and balanced account of the present status of cloud modification with all its myriad uncertainties, he was heavily criticized for a lack of a characteristic that seemed to be given strong emphasis by some subcommittee members, namely "enthusiasm." Subsequently Mr. Floyd E. Dominy, Commissioner, Bureau of Reclamation, was heard, and some of you praised him for his higher measure of "enthusiasm" relative to prospects of rainmaking.

One of you cited earlier testimony given by Mr. Dominy, before the Public Works Subcommittee of the Appropriations Committee, in which he "better pinpointed the enthusiasm" emanating from the Bureau of Reclamation. Of that agency, Mr. Dominy had stated, "No other organization has more incentive, more know-how, and more desire" in the area of manmade rainfall. I scarcely need point out that I, too, admire enthusiasm, but I have read some of the news releases that came a couple of years ago from the Denver office of the Bureau of Reclamation concerning prospects for rainmaking, and I regarded them as examples of deplorably unfounded enthusiasm. Nor could I possibly agree with the suggestion that the Bureau of Reclamation has more know-how in the rainmaking area than any other organization. Today, that Bureau is, indeed, spending more Federal funds in this area than any other agency except NSF, and Reclamation does now have under contract some groups with competence in atmospheric modification techniques; but it is not relevant to equate contractor competence to agency staff competence; nor are dollars spent any reliable measure of values received. The appointment of Dr. Archie M. Kahan as Chief of the atmospheric resources program is a very solid step forward toward assembly of needed staff competence; but I do not see how one could fairly describe the Bureau of Reclamation as a whole, or even the entire Department of the Interior, as possessing extensive know-how in the area of cloud modification.

I emphasize all of these viewpoints (which I know to be shared by more than a few of the country's workers in the atmospheric sciences) because I believe that they bear on the committee's present deliberations on S. 2875. On May 21, 1964, Commissioner Dominy stated to your Subcommittee on Irrigation and Reclamation:

"With the kind of program that we discussed with the Appropriations Committee, starting out with a million dollars a year and as we get it built up over a decade or two, perhaps as much a $3 million a year, we would actually be doing enough cloud seeding and management of the weather, attempt to manage the weather, that if we are succeeding there would be increased precipitation in the Colorado Basin.

Now, a bit less than 2 years later, we find ourselves weighing the desirability of spending up to $70 million per year on that same program.

What has intervened in those 2 years to warrant a more than 20-fold increase in "enthusiasm" as measured in dollars? Presumably the most decisive factor was the appearance of NAS Report 1350, and, in particular, the statements in Report 1350 bearings on prospects of precipitation enhancement.

I cannot speak, of course, for the entire Panel that prepared Report 1350; but I can speak as the member of that Panel who carried out all the analyses of commercial cloud-seeding projects and as the member of the Panel who did the bulk of the reviewing of other (nonoperational) cloud-seeding trials in this country and abroad that constituted the substantive basis of much of the Panel's deliberations leading to our reported findings. So, just speaking now for myself,

I wish to state for the committee's record that I do not regard the available evidence as warranting anything like the enthusiasm for precipitation-enhancement that is implicit in the budgets proposed in S. 2875.

I call attention to the serious disparity between: (*a*) S. 2875's proposal of putting up to $70 million per year, within 3 years, into Interior programs limited solely to the area of precipitation enhancement, and (*b*) the still very ambiguous, highly uncertain, far from "proved" status of even the most promising of rainmaking techniques. We tried to couch our findings in NAS Report 1350 in suitably cautious terms, using phraseology such as "increasing but still somewhat ambiguous statistical evidence" that precipitation can "under certain conditions" be "modestly increased or redistributed." We took pains to stress that "the theoretical basis for reseeding effects is still very crude because we still do not have an adequate understanding of many basically important cloud processes. We warned the reader that our present ignorance is still so profound that "there are few guiding principles for improving the effects of seeding and for extrapolating seeding expectations to different localities." And, clearly aware of one crucial statistical difficulty, we inserted the admonition: "With respect to the operational projects (i.e., the commercial projects), we emphasize that lack of randomization precludes drawing truly decisive conclusions." Only after laboriously working over all of those prequalifications did we assert our conclusion that "we find some evidence for precipitation increases of as much as 10 or even 20 percent over areas as large as 1,000 square miles. * * *"

Now I do regard that conclusion as warranting a new degree of optimism, and I do regard it as calling for substantial increase in spending on research and development in the field of cloud modification; but I fear that we must gather a lot more firm information from good randomized seeding projects before we consider a boost of funds of the sort proposed in S. 2875. I can only foresee undesirably large amounts of wasteful spending from so sudden a rise in spending in an area where knowledge is so uncertain and where good scientific talent is so hard to find.

Our group at the University of Arizona gets all too numerous phone calls from other universities and from research and development firms now eager to get people trained in cloud physics, or looking for people willing to do consulting work in getting some new program going. Some of this is healthy, of course; but, to me, it reveals an already existing shortage of trained personnel that will preclude beneficial spending of any huge increases in Federal appropriations in weather modification within the next few years. And there are signs that the wolves are abroad. Phone calls come from consulting engineers and from firms who know nothing at all about cloud physics but who want to get established scientists into their consulting stables, to aid in garnering fat R. & D. contracts once the big money starts to flow. I have deplored that sort of thing in other areas of science, and I do not wish to see it happen in my own. Not all my scientific colleagues share this concern over getting too much money too fast; but so far none has convinced me that the good outweighs the harm in doing sicence that way. The values of science are higher than those entailed in getting any single mission accomplished with wasteful waste.

FURTHER REMARKS ON "ENTHUSIASM"

It is no secret among scientists in my field that the Weather Bureau has been regarded in certain quarters as being overly conservative relative to rainmaking prospects. I believe it is correct to assert that, in past legislation, Congress has rather explicitly excluded the Weather Bureau from primary participation in certain cloud modification programs. I venture the personal opinion that in the minds of some of you committee members a principal reason for considering putting as much money as S. 2875 proposes to put into an organization that has so little background of experience in the atmospheric sciences (rather than to put the bulk of the research funds into the Weather Bureau and only the operational support and support of engineering technology into the Bureau of Reclamation program) is the belief that the Weather Bureau's record in weather modification is one of negativism—of lack of "enthusiasm." At any rate, some of us think we see rather clear signs of such viewpoints.

I wish to emphasize to this committee that I regard any such viewpoints about the Weather Bureau's past attitudes towards cloud seeding to be quite unfair. The scientifically accessible facts over the past 20 years have, I believe, consistently supported the Weather Bureau's position. Weather Bureau personnel, in all aspects of their work, are continually confronted with the complexity and

the variability of the atmosphere that is at the heart of the big difficulty of reliably detecting real seeding effects. The easy optimism with which some of the earliest of the seeding experiments were "evaluated" is now universally rejected by responsible meteorologists in all camps. When the Weather Bureau officially rejected it, in the early fifties, they somehow earned the name of fuddy-duddy conservatives, a group without imagination. Time has proved that the Bureau position was entirely sound; and 20 years after the 1946 discovery of ice-nucleating techniques we still are so baffled by the complexities of cloud behavior that a large measure of the same kind of caution, the same kind of unwillingness to jump to easy conclusions shown all along by the Weather Bureau, is still very much in order. But, now that NAS Report No. 1350 has assembled evidence, admittedly still weak, that seeding may sometimes produce useful results, one sees the Weather Bureau moving ahead with plans to pursue the problem vigorously. That they did not do so in the past, or that other Federal agencies such as the National Science Foundation did not try to push huge programs in weather modification only reflected the lack of any mandate from the scientific community to do so.

I hope that the committee will reflect carefully on those points of history in thinking about future Federal legislation in the broader area of weather and modification to which NAS Report No. 1350 is addressed.

The key words "enthusiasm" versus "negativism" also obtrude in another sense, strongly relevant to the committee's deliberations. If "negativism" and "conservatism" are the labels that have sometimes been loosely pinned on the Weather Bureau and on many university meteorologists who have remained unconvinced over the years that seeding was an effective means of enhancing precipitation, who have been the main "enthusiasts"? Most, though not all of them, were the operational seeders, those who were doing seeding as a business enterprise. They, in turn, seem to have been a source of steady, low-pitched criticism of the Weather Bureau's "conservatism."

In scientific research, differences of opinion and criticisms are generally salutary in their long-range effects. One might have hoped that the above tension between the "enthusiasts" and the "conservatives" would have led each side to sharpen its arguments, to publish increasingly more conclusive studies, and thus to advance the field rapidly. In fact, the enthusiasm shown by the commercial seeders was expressed almost entirely verbally, at meetings and informal sessions; they published almost nothing in the open scientific literature via the usual channels involving careful scientific review. I think that one can count on the fingers of one hand the number of scientific journal articles published by commercial seeders in the United States for purely commercial projects conducted within this country in the past 15 years. Thus the commercial seeders' enthusiasm for the efficacy of their seeding was not backed up by the type of evidence one expects to be shown in an open scientific argument. They advertised, and they presented unreviewed papers occasionally at meterorological meetings; but with only rare exceptions they did not publish.

On the other hand, after the first few unpleasant instances in which Weather Bureau doubts and caution about the reality of claimed seeding effects led to strong public criticism (above all from Dr. Irving Langmuir, whose eminence gave his criticisms wide publicity), the Weather Bureau seemed to adopt a studied policy of just not opening its official mouth.

Thus the disagreements that should have stimulated fruitful scientific exchanges in the open literature did not occur to any appreciable extent. Non-Bureau meteorologists who shared the doubts of the Weather Bureau could, of course, have played the scientific game of give-and-take with the commercial seeders, except for that crucial fact that the seeders did not publish their results (at least not in any form that could be easily and independently checked). In this kind of a situation, the field didn't move ahead as fast as it might. There was a general lack of conviction among university meteorologists that there was anything to the seeders' unsubstantiated talk about seeding; the few well designed university projects that were undertaken tended mostly to discount any claims of marked seeding effects. The net effect was that most of the university effort went into more basic studies in cloud physics, and very little energy went into design and execution of carefully planned randomized seeding trials of the sort required to get yes-no answers to the practical question of seeding efficacy.

The 1957 Report of the President's Advisory Committee on Weather Control (ACWC) had a fate which seems, in retrospect, both curious and unfortunate. A preliminary draft of that Committee's final report received such thunderous statistical cannonading at a meeting on the University of Arizona campus in

1956 that it took some years for some of the smoke to lift. The net effect was that the moderately optimistic conclusions published in 1957 by the ACWC, relative to winter orographic snowpack seeding were generally regarded with a doubt that was not dispelled by any vigorous rebuttal from the ACWC staff (which was disbanded at completion of the Committee's statutory life). The statistical criticism that seems to me to be the only one that ought to have weighed against acceptance of the ACWC findings is the criticism that the so-called "storm-types error" might have influenced the apparent seeding effects. Another type of error, "seeder-selection bias," was charged, but seems irrelevant in terms of the nature of the seeding projects studied by the ACWC. At any event, the ACWC report did not constitute a major turning point in weather modification development.

The disagreement between the "enthusiasts" and the "conservatives" still continue. NAS 1350 may possibly mark some kind of a turning point, even if not a cessation point, in the disagreements, but it is too clearly to be sure. I note with some surprise that one now hears that NAS 1350 has vindicated the commercial seeders, has shown that they were right all along and that the conservative viewpoint has finally been exploded. First let me say, as the one who analyzed those commercial project reports discussed in NAS 1350, that our difficulties in securing certain of the reports and the difficulties in detecting the real seeding effect in the face of innumerable reporting errors in certain other cases were so great that the commercial seeders might better consider themselves lucky (rather than vindicated) by virtue of the fact that anyone kept pushing ahead with the attempted analyses. But more important is the point that the commercial seeders' nearly complete failure to publish the results in the scientific literature makes it quite absurd (in the scientific sense) for them to now say, "I told you so." For the most part, they simply did not tell the scientific world anything that grew directly out of their seeding business activities.

CONCLUDING REMARKS AND RECCOMMENDATIONS

I have tried to review these facets of the history of weather modification, facets that for the most part have gone undiscussed in the literature, because I believe that the present differences of opinion, even in the Halls of Congress, as to how the Nation's future needs in weather modification research and development should be supported rest squarely on the long-persisting disagreement between the "enthusiasts" and the "conservatives". I have been on the "conservative" side, have received my share of condemnation for my negativism, and see a few places where the latter was deserved. I am now a bit more optimistic about rainmaking prospects, and I now regard it important that we increase our total effort directed toward studying the host of unanswered questions that assume much greater importance once we accept the possibility that useful increases may result from proper seeding techniques. But I am not so enthusiastic that I regard the basic question of the reality of seeding effects as settled in general. We do not yet know enough to say ahead of time whether seeding in a given area under given meteorological conditions will or will not lead to decreases in some downwind areas. We know so little about the inner workings of clouds that a given experimental result can often be interpreted in four or five distinctly different ways. We are just beginning. We have much to learn. Now it does begin to appear to be worthwhile pushing harder.

The atmosphere is a complex system characterized by close coupling of its working parts. Optimal development of a long-range program in weather and climate modification seems to me to require assignment of major responsibilities to a single lead agency, and at present ESSA would seem the logical choice, Interior an illogical choice. The level of support of the Bureau of Reclamation program should certainly be increased, but perhaps by the amounts suggested by Commissioner Dominy in the 1964 hearings, not by anything like twentyfold in 3 years. Mission-oriented modification programs in various other agencies must be supported. NSF must continue its role of supporter of a broad base of fundamental research.

But the principal recommendation that I would wish to make is this: Proposing major new legislation only a month or two after release of NAS 1350 and NSF 66–3 seems to me to be acting too quickly. Surely study and discussion and weighing of alternative possibilities for at least several more months is warranted in a decision that may influence the nature of programs that should continue fruitfully for many decades of future development of weather and climate modification.

It is a challenging objective. We should plan our attack deliberately and in terms of a broad conception of the ultimate potentialities of beneficial modification of atmospheric processes.

So let's not rush too quickly with major legislation. Let's take a long and careful look at all ramifications of this fascinating problem.

Dr. McDONALD. I will begin with listing briefly four points that I would like to get across to the committee and then come back in an attempt to amplify each one as much as time permits.

My main plea to the committee and to the Congress in considering weather modification is to delay any immediate legislative action in the area of weather and climate modification.

I would make the same plea to Senator Magnuson with respect to S. 2916. Both the National Academy of Science Report 1350 and the National Science Foundation Report 66–3 released in mid-January, asked for a careful or a deliberate review of the best way that the Nation might set about to establish a strong and integrated comprehensive program, a national program in weather and climate modification.

I feel that the lapse of only about a month between those recommendations raised on studies extending over about 2 years by a large group of scientists do suggest that Congress would be well advised to have hearings like this, deliberate, but give the whole matter rather more thought.

Secondly, I am opposing the enactment of S. 2875 in its present form in spite of the optimism that is implicit in NFS 1350.

I do believe that your optimism goes far beyond ours. Furthermore I feel that the idea of splitting off precipitation enhancement from the rest of weather modification is essentially artificial because of the very way the atmosphere works, the precipitation processes are mostly related to lightning processes, play a crucial role in tornadoes, hurricanes, hail processes, and the effort to make a huge program centered in the Department of the Interior and solely devoted to precipitation enhancement is just inherently unnatural and it is again not the thing that the two scientific panels strongly recommended.

Both panels urged a unification, an effort at unification into some kind of lead agency where a very broad integrated view of all aspects of weather modification can be considered. I might recall that John Von Neumann, writing 10 years ago in Fortune, emphasized this very point, that weather modification is far broader than just rainmaking.

I think this is what the National Academy of Sciences and the NSF commission have stressed. Furthmore I oppose S. 2875 in that it puts what I regard as an extremely large amount of money in a very short time into an agency that has extremely limited capacity. I stress this to the committee, extremely limited in past competence and extremely limited in present competence in the atmospheric sciences.

I believe that is a very strong basis for questioning S. 2875 and I will return to that.

The third main point that I would like to get across is the idea of the single lead agency recommended by the Academy and the Commission. I must confess this runs counter to ideas that I hold strongly about diversity of support.

Senator Allott asked Dr. Schaeffer questions about this and I agree with the sentiments that lay behind the questions of the Congress that we do need a broad range of divergent industries. Broad support is a good thing.

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I could point out that I got my start in this whole field about 16 years ago as a quite unknown professor at a midwestern university, college as a matter of fact. The State college received a grant at the time only because an agency, in this case the Office of Naval Research, was able to gamble $5,000 or $6,000 on an unknown person.

I am glad they did. I believe in that sort of thing. So I do concur with those who plead for some centralization into one major agency, whatever it happens to be, that has primary responsibility.

I strongly urge the Congress, in whatever legislation it finally passes, to observe the now frequently reiterated plea to keep in mind that the mission oriented agencies need to have a stake in weather modification.

The Bureau of Reclamation is obviously one of those. Also FAA, the Navy, the Army, Agriculture, and so on, and above all the National Science Foundation surely will continue to support the basic studies, the new ideas, and this, I think, has been said to your committee before so I probably do not need to return to that.

But I cannot see the idea of making the Department of the Interior a major agency even in the one area of precipitation modification. I can't see anything like a twentyfold increase over their present budget. They now have about $3 million and S. 2875 proposes an upper limit reaching $70 million in about 3 years.

That seems to me to be about 10 times too large. I do not believe they can spend that in any proper way. I think it would lead inevitably to very wasteful spending and I can elaborate on that if you wish.

The last point I would like to make if time permits—and it is quite well spelled out in my statement so perhaps that may need to be sacrificed for time reasons—is that, looking back at what I regard as some historical aspects that bear very strongly on what brings us here today, it is amusing how my views differ from those you heard first this morning from Dr. Schaeffer.

We use the same words and we use them from a different point of view. I believe there has been this longstanding split between what I would call enthusiasts and conservatives in this field. I examine in my prepared statement in some detail the question of whether the agency that seems to me to be the sensible one for doing most of the work in this field, formerly the Weather Bureau and now the Environmental Science Administration, I question whether the history of this science that we are talking about at all supports the view which I believe is held in this committee, that the Bureau has been a conservative, fuddy-duddy, stick-in-the-mud organization that has been unwilling to get off the chair and get going.

I believe, and I would be happy to elaborate on this if you care, that the scientifically accessible facts over the years have consistently supported the Weather Bureau's position of reluctance to draw the conclusion that rainmaking is a practical—that is, economically significant—reality.

I think the emphasis that the subcommittee of your committee, the Subcommittee on Water Resources and Power, made in the 1964 hearings, one word "enthusiasm," which runs through it like a major threat—I could have counted a dozen repetitions of the word "enthusiasm"—is understandable.

I, too, admire enthusiasm when it is well placed, but I believe putting that kind of premium on enthusiasm rather than putting a pre-

mium on getting good hard facts, diverse opinion, from nonagency representatives and looking at what the available scientific evidence indicates out in the outside world, is a better objective than asking for enthusiasm from interested agency representatives.

Those are the four points that I cover in general in my prepared statement. I have now hit each of them briefly. Let me now go back over some of these in a little more detail and try to flush them out a bit.

The first point about asking that the Congress wait a while, go slow, think it over, listen to more views, try to get a broader picture, stems from my experience in the last year on the National Academy of Science panel that prepared Report 1350.

This is an extremely complex problem. The weather, the atmosphere, the climate are very poorly understood. The interactions of the atmosphere are so baffling to all of us that 20 years after Dr. Schaeffer, accidentally one July afternoon in 1946, discovered the whole technique that we are talking about now; 20 years after that we still can't answer many of the central questions.

If you had the patience I could talk, and so could many people behind me, all afternoon about really detailed points that are at the heart, not peripheral points but at the heart of the processes that govern the prospective rainmaking—how the nuclei works, how a generator works, what is going on in a cloud and so on, overall scales from angstroms to kilometers and perhaps almost astronomical units.

Senator ANDERSON. Are you real sure it was accidental discovery?

Dr. MCDONALD. I have always wondered. I think we should settle this in the Halls of Congress. I have always had a deep, dark suspicion, Senator Anderson, that Vince was using a GE deep freeze which just could not pull the temperature down far enough. That is why he put that dry ice in, because it was not really functioning.

We debated a long time in the Panel and the commission debated a long time and they have asked that a very careful effort be made to see how a broad program can be put underway.

I think that takes more time than we have all together given to the problems.

I was taken aback when I heard in only a matter of days after the release of these reports that "on the ball" Congressmen already had bills ready to go, because I was trying to collect my senses over the conclusions that we finally reached and the switch of positions that we took. So I ask for that delay if at all possible.

Now this matter of the Department of the Interior being an agency which has limited competence in the area I believe needs to be stressed. In the hearings in the spring of 1964, for example—this is the hearings on public works appropriations and the date is May 17, 1965—in questioning one of the Senators, Senator Bible was quite surprised to hear Mr. Dominy point out that only one-tenth approximately of the $1.1 million was being spent in-house in the Bureau of Reclamation.

He asked Mr. Dominy regarding that. Mr. Dominy said, "Yes, sir, as I told the committee last year we do not intend to have a large in-house expenditure. We will have a sharply limited Denver office staff. Dr. Kahan, meteorologist, will work with Mr. Garstka," and so on.

Mr. Dominy himself pointed that out in a memorandum dated September 17, 1965, presented to the Interdepartmental Committee on the Atmospheric Sciences.

There is a memorandum in the appendix signed by the eight or nine advisory board members of the Bureau of Reclamation program in which their closing point, and I quote—

Stongly urges the Bureau of Reclamation to increase its in-house scientific competence in this program by the early addition of at least two more scientists of the Dr. Garstka's level to assist among other things in the continuous evolution of program objective and the valuation of program progress.

The Department of the Interior, as far as I know, has only a few meteorologists and in the Bureau of Reclamation program I am only aware of Dr. Kahan as a meteorologist with background in this area.

I must state, and I had in my prepared statement and I repeat here, a remark that appointment of Dr. Kahan as chief of the program in Denver is a very solid step forward but that still leaves Interior far, far behind ESSA in total competence in the atmospheric sciences.

When you get two scientific advisory boards urging a broad program, integrating all aspects of weather modification, and when you reflect on the inherently coupled way the atmosphere operates, then it is going to be very hard to isolate separate individual parts of the program. You need a broad range of atmospheric scientists and I do not believe that Interior is the place to find them and I think this is simply reflected in past statements in hearings before this committee, where it was stressed that the Bureau would go to the Weather Bureau for competence in this area.

Senator ANDERSON. Doctor, do you object to the amount of money that is now spent in-house?

Dr. MCDONALD. Pardon?

Senator ANDERSON. You want all the money spent on in-house work instead of contracted out?

Dr. MCDONALD. I believe, to start a really big program in precipitation enhancement with a parent organization the leadership coming from the Bureau of Reclamation, where there really are almost no meteorologists and where the upper echelons in that organization are not familiar with the kind of considerations that just inseparably enter into any decision you might make in planning a program, in approving some new move, in making decisions in general, is not wise.

I think you have to have a whole organization that is familiar with the complexities, the variability of the atmosphere. Interior does not have it. So, my objection to S. 2875 is primarily on this idea of going in 3 years from $35 to $70 million as contrasted with statements only about a year ago by Mr. Dominy. If you turn to my prepared statement on page 10 you will actually see the quote from the hearings only 2 years ago. Mr. Dominy was hoping that the Appropriations Committee might give the Bureau of Reclamation a million dollars a year and get it built up over a decade or two to perhaps as much as $3 million a year.

Now S. 2875 proposes going to maybe $70 million rather than $3 million in 3 years rather than in 10. That is a twentyfold increase. I ask where in the past year and a half enough enthusiasm has come to increase this appropriation twentyfold.

I know of only our NAS panel report and I am intently familiar with what is behind that. We spent hours and hours assembling the words to properly qualify our conclusions.

These are to be found quoted in my prepared statement here on page 11. I will not read them now. But I think we did a fairly

adequate job of getting across to the reader that we had a new degree of optimism about precipitation enhancement but the case was not proven.

I notice in the January 21 issue of the New Scientist that our committee is, in fact, taken to task by a British writer, who seems to be quite familiar with the past slow history of weather modification. He takes us to task for having a brave preamble and then he says it is more than disappointing to discover that the panel is unable to answer the straightforward technical question which has been awaiting an answer for 20 years, namely, whether rainfall from clouds can be increased to any significant extent by seeding, and so on.

He goes on to say the panel repeats the somewhat plaintive rigamarole and that we still don't know. That is the case. The panel looked at a lot of data and we are more optimistic but we are not twentyfold optimistic.

The drafters of S. 2875 appear to be roughly twentyfold more optimistic than they were about 3 years ago.

Senator ANDERSON. Doctor, in all fairness, are the jobs comparable? Is what Mr. Dominy was talking about the same thing we are talking about in S. 2875?

Dr. MCDONALD. In that quote he is talking about a 10-year program of seeding in the Colorado River Basin.

Senator ANDERSON. Do you think the job is comparable in S. 2875 and what Mr. Dominy was talking about?

Dr. MCDONALD. No.

Senator ANDERSON. Would you say that was a twentyfold increase?

Dr. MCDONALD. I think the idea in 1966 of concluding that rainmaking is an especially demonstrated reality that we can have a sufficiently large number of seeding programs throughout the United States under S. 2875 to properly spend that kind of money, is just not demonstrated.

The facts do not as yet support that kind of a large-scale approach.

Senator ANDERSON. I understand that approach. I was on the Joint Committee on Atomic Energy where the National Science Board ruled against the construction of the hydrogen bomb. They said it could not be done. You and I know that there are bombs despite that group.

Dr. MCDONALD. Yes. I urge something on the order of $6 or $7 million for the Bureau of Reclamation to find out whether these atomic bombs are worth building. You have to be very careful as to what you say we are doing here.

If it were demonstrated that seeding worked, if this were clear, then this kind of program would be a very different thing. But the problem is still very much a matter of needing more carefully designed randomized projects to answer the basic question.

Senator ANDERSON. I believe we could have demonstrated this if we had the bill 15 years ago but the Weather Bureau vigorously testified it could not be done. They put a scientific panel to work on it and a very fine man edited it.

He was a prejudiced witness and he knew what the verdict was going to be. I forget what the verdict was that I predicted but he had his own convictions. I am not questioning his integrity. He was a very fine man. We were told that it was not scientifically possible to make rain.

Dr. McDonald. I would say 15 years ago; if I had been asked to testify on a similar bill, I would have said even more emphatically that the facts do not at all warrant any such effort.

Senator Anderson. I am one of those who, talking about having enthusiasm, would like to find out if it can be done. We have always been stopped by a group which says it can't be done.

Dr. McDonald. I don't think you need $70 million to find out.

Senator Anderson. I had been trying to work with Admiral Rickover, who wanted to work on nuclear submarines. I agreed it might be done. I believe it has been done but the scientists said it could not be done. If we had taken their word for it Russia would have the only nuclear submarine fleet in existence. But we did not take the scientists' word.

Dr. McDonald. The only way to comment on the question is to remark that for 15 years I have been working one way or another to try to get an understanding that might contribute a little bit to this question. I am still very baffled. So, I am not saying it can't be done. I am saying that to appropriate $70 million in the interest of getting an answer to this question is way overdoing it.

I do not believe that the Nation has, within a factor of 10, enough trained people in the field or attractable to this field to spend $70 million a year just on precipitation enhancement.

Let me give you an example of the sort of thing that has already happened because of the rumors of congressional interest in heavy spending in this area.

A number of people talk somewhat loosely about drawing in engineers. I had a phone call from an engineer who wanted to see me. He was a consultant returning from the manned spacecraft center where he had some other contracts. He wanted to talk to me about a large cloud chamber design.

Someone told him I was one of the few people who had ever done a detailed analysis of this. I asked him on the telephone, "What do you want to know about this?" Presumably he had some detailed questions. It turned out he did not know anything at all about cloud chambers, or cloud physics.

I pursued this with him because I was annoyed that a man would come to talk with me when he had not read any elementary material in the area of cloud physics.

These are the kinds of people who can be attracted with large money. Can we get $70 million worth of engineers and scientists? I do not think so at all. I do not believe this can be done.

Let me illustrate that in another way. At the Institute of Atmospheric Physics we get numerous calls from other university groups and from consulting firms and so on asking us to advise in new programs, asking us to help in consulting programs, and we are just not able to do this. The number of groups that are already looking with futility for trained people in cloud physics is very large.

This being the case, I don't see any possibility of more than somethink like a doubling or a tripling in the area of precipitation enhancement.

If you get more people in all weather modification you can spend more than say $20 or $30 million in a few years on all weather modification, but just precipitation enhancement, I just am too familiar with the shortage of people to see any way of doing that.

I think you might spend some millions very usefully in design and building of new instruments, as Dr. Hosler pointed out. You could put some combustion engineers on improvement of generators and you might well get some chemical engineers on some of these aspects.

You could buy a few more airplanes, you could buy computers and radars, but the problem is, where do you find the people who can intelligently and properly use the radars, computers, and this expensive equipment?

The answer is that there are very, very few people available. You, with your strong interest in seeing this problem go somewhere, are doing the right thing to try to put money into the program to get it going, but $70 million in this one area in 3 years is, if I may say, preposterous to me as a scientist working in the field.

Senator ANDERSON. I am glad to have your view on it. I recognize it is true that it is a large sum of money. But it is not what is authorized by the bill. We have to make appropriations.

When I first came to the Senate in 1948 or 1949 I introduced a bill, the Anderson-Mansfield Act, to provide reforestation, and revegetation of the land in the West. We authorized a large sum of money. It has never been spent. It has never been requested. Only what can be well spent comes from the Treasury of the United States. We hope the same will happen here.

Dr. MCDONALD. It was tenfold more than some so-called experts thought one might spend. That is what I am saying.

Senator ANDERSON. We have had a good many experts who say we can spend this money.

Dr. MCDONALD. I know that.

Senator ANDERSON. On the so-called Anderson-Mansfield bill I think it was 10 times the mount of money that the Forest Service asked to spend. But the Forest Service was not worrying about reseeding, not worrying about revegetation, but the people in the West were.

If you don't need all the money there is no obligation to spend and in many cases they don't spend.

I know that when the space program started there were many people who thought we were spending too much money.

You make money available if it can be spent. That is the only purpose of the bill. What reference did you make to John von Neumann a while ago? You referred to the article in June 1955?

Dr. MCDONALD. Yes.

Senator ANDERSON. I keep it on hand at all times. What was the reference to it?

Dr. MCDONALD. He remarks on page 108 of that issue, June 1955, Fortune magazine, near the bottom of the first column, "But weather control and climate control are really much broader than rainmaking."

I remarked, that essentially is the gist of the NAS panel report and the Commission report. They would like to see a strong, new effort in the whole field of water and climate modification along the lines that Von Neumann sensed 10 years ago.

Senator ANDERSON. Did not Von Neumann favor spending money on weather modification work? Does he not say the ultimate weapon is weather modification and not the atomic bomb?

Dr. MCDONALD. Yes.

Senator ANDERSON. Did he not say we needed computers?

Dr. MCDONALD. Yes.

Senator ANDERSON. Do you think he was wrong on weather modification?

Dr. MCDONALD. I am a recent convert, if I may say, to the view that Von Neumann, in his long-range prediction, is perhaps right. Long-range here meaning probably many decades.

Senator ANDERSON. I am a convert but not a recent convert.

Dr. MCDONALD. I realize that.

Senator ANDERSON. What program do you envision now? You have had practical and very good experience.

Dr. MCDONALD. I think the Bureau of Reclamation program should be supported and increased as one of the mission-oriented agency programs concerned with weather modification. I think their interest does obviously lie in precipitation enhancement. We should hope that the Bureau of Reclamation would support a large amount of watershed studies designed to better evaluate the experiments, because there is this need for evaluation. They should support and do their best, and they are already doing quite a bit, to support engineering research on things like heated snow gages and the snow pillow work they are supporting through the Soil Conservation Service, a large amount of measurement problems peculiar to the mountainous West, and particularly in the mountainous West in winter.

These are unsolved problems of very large magnitude. Perhaps on the order of something like a million dollars per year might sensibly be put into that sort of thing and something of the order of $2 or $3 or $4 million per year might sensibly be put into a few more well-designed randomization projects. These things the Bureau of Reclamation should do.

I don't think you are aware how they are scraping the bottom of the barrel in terms of going out and getting contractors. They already have groups who have virtually no experience. Dr. Batten, in our Department, and I have been asked several times by one university group in Utah to consult with them. We don't have time. We finally urged they come down. We spent all of an afternoon with them. I think it is fair to say we helped them a great deal because they have no meteorologist in this university group and they are designing a Bureau of Reclamation program.

This is true of the State of Washington. Washington has the weather modification board, if that is what it is called in the State of Washington, which is interested in doing work. They have been after us to do consulting at a fee that is, I think, almost embarrassingly handsome but we do not have time for that. There again the University of Washington meteorologists are apparently too busy to help them. Where is the competence to back these groups up? It does not now exist.

We cannot expand. We do not have cloud physicists and meteorologists to do properly the things that are already under contract with the Bureau of Reclamation. That does not mean we cannot get them over a period of time but we will not get them in 3 years with $70 million. We may get them in 20 years with a graduated increase and we should get them because this is only one part of a broad program that looks at the whole challenging spectrum of weather and climate modification with precipitation enhancement as only one portion and one that is intimately related to a large number of the other problems.

And for those reasons, to sum up, because I believe my time is more than up, I regard at present the Environmental Science Administration as the far more logical place to do this.

There may be some point of thinking about an entirely new agency but I do agree that, although we must maintain diversity in the sense of having a lot of other groups that are doing some supporting of weather modification, I think we should have some major agency that has prime responsibility in pushing ahead rapidly on this whole front and I would think that ESSA, and by no means the Department of the Interior, is the logical place.

Senator ANDERSON. You think the Environmental Science Services Administration has people qualified to attempt to increase precipitation?

Dr. MCDONALD. They certainly have more than the Interior Department.

Senator ANDERSON. In that field?

Dr. MCDONALD. Yes.

I would like to stress this point, it may be implicit in some of the things I say in my testimony. Having read the last two hearings that led to the Bureau of Reclamation finding, I have the feeling that you gentlemen are under the impression Mr. Garska is an atmospheric physicist who does know the workings of clouds. I have a statement somewhere that certainly supports that but Mr. Garska is not an atmospheric physicist. I believe Dr. Kahan, essentially, unless he has gotten one of the two master students that the Advisory Board recommended, is still the only person in the Department of the Interior who has any knowledge of these problems. But the Weather Bureau has a number of people, not a large number of people, just in precipitation enhancement.

But I can think of a half-dozen people who are quite familiar with this problem. When you think of the whole problem they may have 10 to a hundred times more people than Interior in the atmospheric science as a whole.

Senator ANDERSON. The primary aim is to increase precipitation. The Weather Bureau has consistently been against modification in the sense of producing precipitation. They do not believe it is possible. It rains sometimes and they still say it is impossible. We thought we should put it with one who believes in it.

Dr. MCDONALD. You would not want them to believe it before the scientific facts demonstrated it.

Senator ANDERSON. Who demonstrated that we could have an atomic bomb?

Dr. MCDONALD. It was demonstrated at Alamagordo. There was no doubt.

Senator ANDERSON. There was a lot of doubt before Alamagordo.

Dr. MCDONALD That convinced a lot of workers

Senator ANDERSON. After it was done. Do we have to wait until after something is done?

Dr. MCDONALD. I strongly urge increased support in these areas; I am not saying I want to stop. I don't believe it is fair to the Weather Bureau—I have hit at this point as hard as I could—to say over the last 15 years that their "conservatism" is fuddy-duddy conservatism. I believe with them that the scientifically accessible facts

just have not supported the conclusion that you could make useful amounts of rain.

Now within the last year the Academy Panel thinks maybe this is beginning to show up.

Senator ANDERSON. I do not think I used the word fuddy-duddy Weather Bureau.

Dr. MCDONALD. It has been my term.

Senator ANDERSON. I have always been anxious to improve the Weather Bureau. It took the position it would not try to modify weather and didn't. We had other people who wanted to try. The Weather Bureau stood as a bloc 15 years ago. The record in the last 15 years would have been different if we could ever get the Weather Bureau people working in the field of weather modification. Scientifically they may be right. Twenty years from now we will probably say it cannot be done. I figure I must have been on the wrong committees. I have been on the Joint Atomic Energy Committee and the Space Committee. I am sure we are doing the same thing here.

Dr. MCDONALD. Again in fairness to the Weather Bureau it should be remembered that already by the mid-fifties they were essentially legislated out of this area. Prime responsibility was given to NSF in Public Law 85–510 in 1958.

Senator ANDERSON. You know why they were legislated out?

Dr. MCDONALD. I am sure you know in much more detail than I.

Senator ANDERSON. They had a mental iceberg on the subject.

Dr. MCDONALD. What you call a mental iceberg I call scientific objectivity about a very complex question. So, I suppose I can't do anything more by repeating that. I close with perhaps one comment on this conservatism. I note at the end of my prepared statement I am rather surprised that as an Academy member who did the analysis on the commerical seeding projects which, in part, influenced us on our changed position with a new measure of optimism but not utter conviction, some of the seeders are suggesting that their position has been vindicated. They have a sort of "I told you so" attitude. I tried to stress in any statement that I will not buy that at all. I was hard pressed to get a lot of their reports. We had trouble securing them from the seeders for various reasons in some instances. In other instances we got plenty of them but they were so loaded with errors that it was an incredible task to sort out the signal from the noise.

To now suggest "I told you so" in view of those facts, plus the fact that the seeders, with almost no exception, did not publish in the open scientific literature the results of American seeding projects over those 15 years, makes out a very hollow claim and one that I kind of chuckle at. They didn't tell us anything over the years.

Senator ANDERSON. The Weather Bureau apparently didn't want to find out. How much do you think the Bureau of Reclamation should have next year to carry out its activities?

Dr. MCDONALD. I agree wholeheartedly to the tune of $6 or $7 million.

Senator ANDERSON. I am glad we got that far along. Thank you very much.

Do you have some questions?

Senator FANNIN. Yes, Mr. Chairman.

Of course I can agree with both of you from the standpoint of this conservatism. I like to see Mr. McDonald press that. Also, Mr. Chairman, I realize without regard to how much money that is appropriated no more would be spent than could be beneficially spent.

I can remember back when I was in a position of calling a special session of the legislature to get additional funds for the university. I don't remember whether you came in to make a plea or not, but I remember quite a few did.

Dr. McDONALD. I would have been for it, anyway.

Senator FANNIN. But I look at it from the standpoint of our own experience in Arizona. I can recall 15 years ago when a professor at the Phoenix College—you probably remember him—was seeding the clouds from a rented airplane and without any equipment. I can remember the equipment that was used by the schools in our State, and the money that was expended, the small amount of money expended for equipment, and I can't visualize that we cannot do a great deal more. I have brought out today: Should we not encourage private industry to get into this field to a greater extent?

I think we are almost in the horse and buggy days with some of this equipment that is being utilized. Also, they call them Rube Goldberg paraphernalia that were used by the Salt River project. We resold some of the equipment. We tried to help them build it. I cannot visualize why we cannot have a program that will be extremely helpful in this field regardless of which agency it happens to go to, if it works with schools, with private industry, and with all the agencies.

It seems to me that S. 2875 comes up with a basis on which this can be handled. Whether it should be modified or whether we should take into consideration the great needs in other areas, needs to be examined. If there are needs in other areas, naturally they should be considered but not to the detriment of a program that is needed in the field of weather modification.

Although I am not in disagreement with you that we should carefully check what is expended, at the same time I feel, from my own experience that there is a tremendous need for money to be spent for modern equipment and for research for equipment that is not available today that could be developed. In the same category, we look at the vast amounts being spent on sea water conversion and for modern equipment that is coming forth in that area. They have made great progress. I feel that we are very lacking in the weather modification field at the present time.

Dr. McDONALD. I agree wholeheartedly on that point on a qualitative basis. It is when we get to this factor of 10 that I bog down. We can spend it, I know. There is never any trouble in spending Federal funds. There are always people ready to spend them.

Knowing the field as well as I do and knowing how many people it takes—it takes people to exploit the expenditure of money. If you have a large number of people in the space program you can spend a lot of money. I am not one those who is overoptimistic about getting a huge increase of people in this field but I agree with the qualitative point that there are many places where we can use engineering assistance, research and development assistance to improve instrumentation.

Senator FANNIN. Dr. McDonald, I certainly commend you for your frankness. You, of course, realize the tremendous need we have in the West for water and the potentiality that would exist for additional supplies through weather modification if it can be successfully brought forth. So I do think that we are in an area where we must gamble some.

Dr. MCDONALD. We must certainly gamble to do a much more thorough check, but on the one random project that has just been completed in the Colorado River Basin, the Colorado State University results have been preliminarily reported by Mr. Grant of Colorado State University and the result is a slight decrease. There are certain stratifications of the data, subportions of the data, that show increases but the overall effect of the Colorado State seeding in the Rockies is a negative effect.

Seven years of seeding at the University of Arizona with a resultant minus 30 percent. Of course, the significant level is not very high. That is, the probability that it just resulted from chance is so great that you can't distinguish this from the zero effect. The positive results are spelled out with some of the negative results in the NAS–1350 report but it is a question of how much you gamble at what time. I want to gamble some, too. I want to gamble a few million, of that order, per year, with reclamation. I do not want to see reclamation made the center of this because precipitation enhancement is too intimately related to all other fields.

For instance, section 202, that I believe Senator Church queried on, probably needs changing. To have the Secretary of the Interior decide what process might be likely to influence atmospheric water vapor, and to require that one get a license from the Secretary of the Interior to do anything that might influence water vapor is really not realistic because you could not seed for lightning or hail or hurricane suppression.

You could not even seed supercooled fog in Salt Lake and Denver because these all influence the precipitation balance and the water budget to some extent. In a sense that it is a measure of how hard it is to decouple these problems. I think the Panel and the Commission recommends that they not be decoupled, that you not take a big appropriation such as S. 2875 asks for and plunk it down in an inexperienced—I use that word advisedly—meteorologically inexperienced organization such as the Bureau of Reclamation.

Senator FANNIN. Dr. McDonald, of course, I remember the pessimism that existed a few years ago. Now even you express some optimism. So I feel we have stayed with this program. If we had dropped it then we would not be in the position that we are today. Now we feel we can attain something.

I think it is important that we continue to go forward to the greatest extent possible for an early culmination of what we have as an objective

Dr. MCDONALD. I agree.

Senator FANNIN. So I go along with your excellent analysis on the expenditure of money, because I don't think we can determine here just what it is going to take or how well it will be expended. That is a determination that will have to be made at a later time.

Senator ANDERSON. I want to say also I think your testimony has been very valuable. You have to have challenges to these ideas to know whether they are sound or not.

We will return at 2 o'clock. We have two other witnesses at that time, Mr. Howell and Mr. Braham.

(Whereupon, at 12:20 p.m., the committee was recessed, to be reconvened at 2 p.m., the same day.)

AFTERNOON SESSION

Senator ANDERSON. Mr. Howell.

STATEMENT OF WALLACE E. HOWELL, PRESIDENT, W. E. HOWELL ASSOCIATES, INC., AND MOUNT WASHINGTON OBSERVATORY, INC.

Mr. HOWELL. Thank you, Senator Anderson.

I am going to make a very unusual request and ask that you accept in the record the statement that I made before the Commerce Committee about 2 weeks ago because I left for a trip to South America the next day, got back Sunday night, and I have not had a chance to prepare a further statement.

However, I would like to make some remarks that will hit the highlights of my previous statement and change it in some respects.

Senator ANDERSON. We will place in the record the paper which you prepared for the Commerce Committee. Also anything about your South American trip that you wish to tell us.

Mr. HOWELL. I will have a word to say on that.

(The statement referred to follows:)

STATEMENT OF WALLACE E. HOWELL FOR PRESENTATION TO THE SENATE COMMITTEE ON COMMERCE, WASHINGTON, MARCH 7, 1966

1. Introduction

I am Wallace E. Howell, president of W. E. Howell Associates, Inc., a private meteorological firm specializing in cloud physics and weather modification, and of the Mount Washington Observatory, Inc., a private nonprofit corporation in New Hampshire. In the past 16 years I have been involved in some 60 odd weather modification programs chiefly concerned with reducing weather modification to a useful practice and applying it in situations where its economic leverage overcomes the uncertainties involved. These operations have been mostly in eastern North America, Latin America, and the Philippine Islands.

I am a professional member of the American Meteorological Society, and hold the society's consulting meteorologist certification, and my company is a member of the Weather Control Research Association, a group of 50 members drawn from governmental, research, and business entities concerned with this field.

I have three points to make before this committee, premised on the start already made on a weather modification program and on its potentialities being such as to deserve national concern. They are—

(1) The importance of a pluralistic approach to a national program of weather modification;

(2) The importance of private initiative in reducing weather modification to useful practice; and

(3) The importance of separating the regulation of weather modification from its operation.

2. The national weather modification program should pursue a pluralistic approach under flexibly coordinated guidance with simultaneous drive toward several coordinate goals

Unless the scientific objectives now in view fail of ultimate realization, we are already committed unavoidably to an undertaking of which the operational, economic, and social magnitude will tremendously overshadow the seminal role of pure science. Science alone is not a sufficient guide. If in testing the scientific foundations we neglect the other foundations of this undertaking, we risk our best chance to build a well-balanced and effective national program.

In the history of science, the pure and applied aspects have always cross-fertilized each other. In weather modification, experience with applications is an important source of ideas and intuitions for basic research. Both of these involve potential direct impact on the social and political communities to an unprecedented degree, for the weather is everybody's. The exploration of applications and impacts is as important as exploration of the pure science itself.

The need for a broad viewpoint in the guidance and development of a national weather modification program is an immediate one.

(*a*) In the area of science, the channeling of adequate support to a few major research efforts should not be allowed to deprive alternative ideas not in accord with the majority view of encouragement.

Ten years ago, the notion that cloud seeding might be effective in cumulus clouds over flat ground through its indirect effect on the dynamics of these clouds was discounted by recognized bodies of scientific opinion: today it is one of the hottest ideas in weather modification. Ten years ago, these same bodies of opinion stressed the necessity for fully understanding the ice-forming action of silver iodide if we were ever to use it successfully for weather modification: today, though little progress has beeen made toward that understanding, the empirical importance of the fact that it does indeed modify clouds is recognized beyond question. These are but two examples of the fact that some of the brightest ideas in weather modification have blossomed outside the garden polts laid out for official cultivation, and some of the most assiduously cultivated plots have so far proven rather barren.

We must, then, nourish the volunteers outside the fence, even though these may at first look rather weedy, and even though it will require a vast expansion of our effort to bring to full fruition those starts that have already blossomed promissingly.

(*b*) Reduction of weather modification to useful practice should encompass many climatic settings, many practices and techniques, and many end uses, through and to which it may be exercised.

The 60-odd weather modification programs I have been connected with have ranged from the subarctic to the Equator, from midcontinent to midocean, from plains near sea level to mountains over 18,000 feet high, from deserts to one of the world's rainiest jungles. The purposes served by the modification have been almost as varied: to fight forest fires, protect bananas from blowdown winds, carry a sugarcane crop through the dry season, supply water to hydroelectric plants, come to the rescue of a city with practically dry reservoirs, help cover a ski slope with snow. Often a single program has involved many different facets. In 1950, New York City desperately needed more water, and asked me to seed clouds over the Catskills. The Nevele Country Club didn't want its guests scared away by the prospect of perpetual rain and sued to enjoin the city. The Palisades Amusement Park offered me double pay to keep rain away. I went ahead in the Catskills, using the seeding occasions to learn all I could about its effects.

Here was a trial of weather modification for one specific purpose—to alleviate shortage in the reservoirs. There are hundreds of uses for weather modification that may be more or less apt, and in the future there may be thousands, and we need to know how to do cloud seeding for other uses as well. This trial was carried out in one particular place—the Catskills—under one unique set of weather conditions. But we need to know how to do cloud seeding in a thousand other places, and in a thousand different weather situations, as well. This was carried out by one particular technique—silver iodide seeding from the ground. But we need to know the effectiveness, for particular purposes, in particular places, under particular conditions, of many other techniques as well. This operation ran into one particular conflict of interests, in one particular legal, social, and political context. But what would be socially, politically, legally, advisable, or possible in any of a thousand other contexts?

These questions call for vigorous exploration through the actual impact of them on people and situations. We cannot hope to be suddenly wise enough to prescribe the shape of a national weather modification program. It will grow. Indeed we cannot keep it from growing. But we can and should encourage and shape its growth at the levels of operational, economic, political, and legal experience in the field.

(*c*) Explicit recognition should be given to the value of international cooperation in both basic and applied weather modification by authorizing support of selected programs through foreign aid and other international channels.

The atmosphere is our laboratory. We cannot easily isolate the phenomena we wish to study. But sometimes we are lucky enough to find a setting where the phenomenon we wish to study is relatively free from interfering disturbances.

For instance, on the west coast of South America there is a natural laboratory for studying sea breeze phenomena free from middle latitude storms, unmatched in the United States and its possessions.

In Colombia, we have used cloud seeding to alleviate damage from local thunderstorm winds. The result is experience, information, and insights applicable to some purely scientific problems and to some problems of reducing weather modification to practice in the United States.

At Bogotá, the capital of Colombia, there is an exceptionally attractive opportunity to study the formation and possible artificial dissipation of ground fog in the context of a useful application to keep the country's principal airport open for commercial use. Knowledge gained there would be immediately applicable to similar problems in the United States.

This story could be repeated many times over. Aside from the assistance given to our neighbors by such endeavors, aside from our leadership in a prime field of international collaboration, aside from the obvious fact that weather management is bound to become an international matter, it is in the immediate interest of our own national program to take advantage of natural and human resources wherever they exist to help contribute answers to the many questions facing us.

(*d*) The diverse interests of the Government, the scientific community, private initiative, and social and political entities outside the Federal Government should all be directly represented in the top advisory board responsible for guidance of the national weather modification program.

In 1957, nearly 9 years ago, the Senate Committee on Interstate and Foreign Commerce recommended the passage of S. 86 in this language:

"Congressmen * * * and Federal agency representatives emphasized the importance of, and the need for, legislation establishing a program of basic and applied research in the field of weather modification.

"Testimony from non-Government witnesses indicated further need for * * * research * * * in both the basic and applied aspects of the program.

"Presently in charge of basic research programs for the Government, the National Science Foundation seemed to be the logical agency to carry out the program.

"Therefore, provisions in the bill would permit the National Science Foundation to execute the program * * *. The National Science Foundation would also be able to arrange with other governmental agencies for handling of the applied or field research aspects of the program.

"It is expected that the National Science Foundation would establish a special commision * * * for * * * formulating an overall research program. This group will recommend which portions of the field should be investigated from a basic aspect, and which should be applied or field research. The National Science Foundation * * * would determine the best possible division of the applied research program and arrange responsibility for this portion of the program.

"Thus, your committee recommends a research program that will yield scientifically verifiable answers to the many questions in the important field of weather modification."

Despite the very evident intent of the Senate committee that basic research should be teamed with applied research, and with two exceptions that I shall note later on, the anticipated program of applied research never materialized. Why not?

Between 1953 and 1957, leadership was provided by the Advisory Committee on Weather Control, composed of six Government members and five members from private life, selected for their sound scientific grounding and for their broad experience in applied meteorology. It was on the basis of their report that the

Senate committee made its recommendation. The breadth and balance of outlook lost when the Advisory Committee disbanded in 1957 has not yet been restored.

You may examine the makeup of the following committees, and I do not know how many others, without finding the name of a single person who has been identified with the application of weather modification to useful ends and scarcely anyone identified with applied meteorology in general:

Committee on Atmospheric Sciences, National Academy of Sciences.
Panel on Weather and Climate Modification, National Academy of Sciences.
Adivsory Panel on Weather Modification, National Science Foundation.
Special Commission on Weather and Climate Modification, National Science Foundation.
University Committee for Atmospheric Research.
Executive Committee for Meteorology, American Geophysical Union.
Committee on Cloud Physics, American Geophysical Union.
Committee on Cloud Physics, American Meteorological Society.
Committee on Weather Modification, American Meteorological Society.

Between 1957 and 1965, the consensus of these bodies that applied research on weather modification was inadvisable and premature effectively blocked the development. Until about a year ago, this consensus regarded the experiences of commercial operations in reducing weather modification to useful practice as being without sicentific value and unworthy of their further consideration. It was only as a consequence of outrageously provocative official disparagement of commercial operators that this situation was finally altered. The belated recognition of the positive results accumulated by commercial operators brought about a complete reversal of this attitude on the part of the Panel on Weather and Climate Modification. In terms of the experience that might have been gained if this recognition had been more timely, the delay has been a costly one.

Restoration of balance between scientific and practical viewpoints in the guidance of official policy is an urgent matter; it should be brought to bear on plans being made now. Indications are against the supposition that balance will restore itself spontaneously: appointment of the American Meteorological Society's Committee on Weather Modification was announced subsequent to publication of the National Academy of Sicences and National Science Foundation reports recommending applied research, yet nobody identified with this activity was placed on the committee. Appointment of a top-level steering committee along the lines of the Advisory Committee on Weather Control could go far toward restoring breadth and balance.

3. The role of private initiative in reducing weather modification to a useful practice and in the exercise of this practice should be given explicit recognition and encouragement

In a free enterprise system, the sum total of private initiatives is the most thorough and the most perspicacious investigator, tester, and evaluator of new ideas. Let us make it our ally in weather modification.

From the beginning, industries and large-scale agriculture having an economic interest in the use of water have held the leading role in sponsoring applied weather modification experimentation. I testified in 1957 at the Senate committee hearings on S. 86:

"There is no danger that sicentific or commercial progress in weather modification will cease for lack of Federal support. From our experience with more than a score of industrial clients, we know the advantages of weather modification are attractive enough to hold and expand the interest of the industries concerned."

Yet the flow of industrial support did slow to a trickle. The reason was one I had not foreseen: not lack of Federal support, but the chill of official disparagement of applied weather modification as being unscientific and premature. How many board chairmen could tell their stockholders they were bucking that kind of advice from the purest of horses' mouths?

Applied weather modification slowed to a trickle, but it did continue to trickle in despite everything. It carried out on its own, as best it could under the circumstances, the 1957 Senate committee recommendations on applied research. And it accumulated the evidence that finally turned the official viewpoint about-face, once the panjandrums of sicence could be persuaded to examine it.

There remains in the private sector an enormous and largely untapped reservoir of interest and concern regarding useful application of weather modification, a reservoir that needs only to be thawed out after its long deep-freeze treat-

ment, a reservoir capable of substantially supplementing and perhaps even outdoing the levels of public support so far mentioned. Here are private dollars ready and able to carry a great share of the load that the taxpayer would otherwise bear. Should not this power be harnessed to the national weather modification program?

(*a*) Those private entities that undertake to integrate their own efforts to reduce weather modification to a useful practice with the purposes and requirements of the national weather modification program should, in recognition of the value to the public of such undertakings, receive compensation in the form of—

(1) Scientific advice for the design of operations in such manner as to yield maximum values both scientific and practical;

(2) Support for such additional scientific operations and/or observations not a normal part of the operational program as may be practical and of scientific value to the national weather modification program;

(3) Evaluation by an appropriate public agency of the scientific, economic, and social results of the operation;

(4) Reimbursement of expenses with respect to periods when operation of the program is suspended for nonoperational reasons, especially for "randomization" of seeding trials; and

(5) Indemnification for legal liability arising out of weather modification operations.

One of the great disadvantages of the past dissociation of governmental and university research from commercial operations has been that the research organizations have spent much time and effort developing equipment and carrying out experimental operations for which equipment and techniques had already been developed by commercial companies, while the commercial operators had not the means of carrying out desirable experimental observations and programs for lack of support for other than the immediate concerns of their operations.

It seems obvious that integration of these two types of operations will bring many advantages to both by making the most apposite facilities and abilities of each available to the other for pursuit of their joint objectives. The results of a questionnaire circulated to industrial entities concerned with the sponsorship of weather modification operations, plus my own conversations along this line, lead to the conclusion that industrial sponsors as a rule will not object to the restrictions that certain of the scientific procedures, such as randomization of operations, will impose on their operations, and will cooperate fully in conforming their operating practices and qualifications to the requirements of an integrated program, provided that there are reasonable compensations, especially in the direction of more rapid perfection of weather modification practices for useful application.

In return, this arrangement will make available to the scientific community a wealth of weather modification experience obtained under adequate scientific control, adaptable to the testing of a wide variety of scientific hypotheses in both basic and applied branches of the work.

There is a further advantage to be gained by making the advantages of these undertakings available to all who wish to undertake them. In this manner, the exploration, on an equal footing as far as considerations of policy are concerned, of all the operational, economic, and social opportunities for exploitation of weather modification will be encouraged, rather than the selection of a privileged few as might occur if only certain private entities were allowed to operate in this manner.

(*b*) Private entities engaged in reducing weather modification to a useful practice should be protected from capricious or arbitrary regulation by State and local governments and from arbitrary or capricious impositions of liability, and should have the benefit of uniform requirements for qualifications and responsibility of weather modification operators throughout the United States and its possessions.

Several townships in Pennsylvania have ordinances forbidding operations intended for modification of the weather, even though expert testimony has established that cloud seeding done within these townships would ordinarily be expected to have its effect in other townships. Also in Pennsylvania, a State law permits the county commissioners of the individual counties to outlaw weather modification activities in their counties, and the commissioners in at least two have done so, despite the fact that counties like townships are too small to contain the expected effects of a cloud-seeding operation. Another State, Delaware, has outlawed all cloud seeding for another two seasons, through September of 1967.

These actions were taken on the mistaken supposition that cloud seeding was being done for the purpose of destroying rainclouds and that it had lead to intensification of the drought, whereas independent studies of the cloud-seeding operation involved have indicated that it probably increased the rain, as reported in the National Academy of Sciences Publication 1350.

Several other States have laws claiming sovereignty over the moisture contained in the atmosphere over these States. Though no case involving these supposed sovereign rights has been adjudicated, circumstances where one sponsor or one weather-modification operator might have operations in one of these States and also in another State upwind of it could lead to difficulties.

In yet another of the States having laws with respect to weather modification, the laws provide for licensing of operators having no professional qualification in meteorology whatsoever, and I know personally of at least one instance where a licensee in one of these States has misrepresented himself as a meteorological expert and sought business as such, on the basis of his holding a weather modification operator's license.

In relation to the Delaware law, I might recount that when I recently had cause to seed the clouds in southeastern Pennsylvania, I had smoke generators operated in parts of West Virginia, Virginia, and the District of Columbia, bordering on Maryland, in such a manner that the expected effect leapfrogged the State of Maryland.

There are many other instances in my personal experience when I have operated generators in one State for effect in another. The indications of a recent Weather Bureau study that precipitation increases appear to extend as much as 150 miles downwind from the intended target underline the interstate character of most weather-modification operations, whether commercial or experimental.

I know of no other field of endeavor where the interstate character of the operation is so obvious, and where it would be so difficult to assure limitation of the effects to a single State. The case for Federal preemption of the right to regulate weather modification activities and to prescribe regulations necessary to assure its conduct in a responsible manner is clearcut.

It seems equally obvious to me that, where we now stand on the road toward weather modification, all operations are in a position to add useful knowledge to our slender store. A public policy that encourages such operation while at the same time providing necessary public safeguards would serve that end.

(*c*) The role of private initiative in reducing weather modification to a useful practice should be explicitly recognized through direct representation of it on all top regulatory and advisory boards having to do with planning and execution of a national weather modification program.

If public policy is to make effective use of private initiative in a national weather modification program through integration of privately supported endeavors with research efforts, it is both fitting and advisable that top-level regulatory and advisory boards have the benefit of direct expression of the points of view involved. Such representation would also measurably increase the readiness of private concerns to take a part in the national program.

4. Regulation of weather modification should be lodged in an independent board, dissociated from all operational interests and representative of a broad viewpoint of public policy

Even though many of the scientific conclusions regarding weather modification are tentative, the principles of science on which the investigation rests are firmly established. In the same sense, even though the form of regulations required for protection of the public interest and advancement of public policy in weather modification can now be only tentatively discerned, the principles on which such regulations are to rest are already firmly established. One of the most basic of these principles is the separation of regulatory from operational functions.

It is unfortunate but true that I and others in the same boat are already caught in ambiguous cross currents involving regulation. Although the recent regulation promulgated by the National Science Foundation purports to be a regulation on weather modification, there is no clear line distinguishing this action from regulation of weather modification, which in my opinion it in some degree effects but which is specifically outside its authority. Yet in raising this question I must plead the matter before the same organization, and indeed before the identical individual, before whom I must also appear if I wish to offer

research proposals for sponsorship by the Foundation. The actual matter is trivial, but it holds the seeds of a thoroughly unsatisfactory situation.

(*a*) The makeup of the board should give explicit recognition to the concerns of the Government, of the scientific community, of social and political entities outside the Federal Government, and of private initiative concerned in the reduction of weather modifications to useful practice and the exercise of this practice.

I have, I think, given sufficient space to the reasons why I believe that the breadth of viewpoint that I believe to be essential in this regulatory body cannot simply be taken for granted.

(*b*) Legislation establishing the regulatory board should preempt to the Federal Government all authority for regulation, including establishment of qualifications and responsibilities of weather modification operators and all questions of sovereignty over the weather.

There is nothing tentative about the present need for Federal preemption of the power to regulate. A power vacuum exists that is being partially filled by inconsistent State and local legislation, in some instances capricious and ill advised. Let me quote the recent resolution adopted by the Board of County Commissioners in Franklin County, Pa.: "Weather modification activities are detrimental to the welfare of the county * * *." And an editorial opinion of this action from the Chambersburg, Pa. "Public Opinion": "The commissioners would have been in a much stronger position if they had been more candid with their public. They recognized the weakness of the State enactment and of any resolution they might pass under its authority, and on a predominantly scientific subject they elected the negative, not the positive approach. It was a sad and weak performance."

(*c*) The authority of the board should extend to the power to resolve conflicts of interest that may arise out of, for example, interference between projects, or out of different objectives within a single area.

At the present time no machinery exists for resolution of conflicts of this sort except where in certain instances they might be intrastate in nature.

Closing remarks

I have the feeling that my neck is now out about a yard, but in closing I would like to stretch it out still farther with some observations on the means of carrying out these suggestions through agencies of Government, even though I lack experience in the legislative field and lack also the courage of complete ignorance.

Earlier I mentioned exceptions to the general lack of Federal programs in applied weather modification. As of 1 year ago, shortly before the results of independent appraisal of commercial operations began to become known in the scientific community, Government weather programs in applied weather modification as listed in the report on this subject by the Committee on Government Operations included an Air Force project with the limited objective of developing a capability to disperse low stratiform clouds and fog, a Forest Service project with the limited objective of mitigating lightning-set forest fires, both of which projects had their origins before 1957; Project Stormfury, a joint Navy-Weather Bureau project to study the possibility of modifying hurricanes; and finally, the only project of a broader scope, the Bureau of Reclamation project with the objective of controlling water resources in various watersheds through the optimum utilization of dams. The last mentioned is noteworthy in that it is the only one that is precipitation-oriented, the only one that has developed a program specifically aimed at taking advantage of capabilities in the field of private meteorology through contract with some of the leading commercial firms—among whom, incidentally, my own firm does not number—and the one that has had to sail most strongly against the wind to get where it is now.

Weather forecasting is clearly the weather man's province. But just as the education of the young is too important a matter to leave to schoolteachers, so weather modification is too important a matter to leave to the meteorologists, especially to those who have for the past many years so exaggerated the false hopes of the periphery of the problem and so completely overlooked false gloom at its heart. The nature of the Federal program designed to encourage and coordinate the exploration and exploitation of a multitude of specific individual situations, with a supporting program of scientific research, and with regulation, greatly transcends the present capability of existing Government agencies, and yet the experience and commitments of existing agencies constitute an important source of strength that should not be wasted. To take advantage of these strengths I suggest the following allocation of functions:

First, an independent Weather Modification Board, perhaps modeled on the Civil Aeronautics Board, restricted to a regulatory capacity; preempting the present authority of State and local governments;

Second, a Weather Modification Advisory Council administratively within the Environmental Science Services Administration but composed of representatives of all the Government agencies concerned with weather modification and of an equal number of representatives drawn from private life; this Council to provide overall guidelines and coordination for orderly development of the national weather modification program, and empowered to direct the implementain of its program through the two agencies next mentioned below;

Third, statutory assignment to the Environmental Science Services Administration of the principal role in basic scientific research in support of the national program, to be accomplished through inhouse, contract, cooperative, or coordimentation of its program through the two agencies next mentioned below:

Fourth, statutory assignment to the Department of the Interior of the principal role in the reduction of weather modification to useful practice not only within the present area of interest of the Bureau of Reclamation and the Office of Water Resources Research but also within an expanded domain covering an applications for useful purposes with authorization to carry out this assignment through inhouse or contract activities and with specific authorization for cooperative agreements with private entities along the lines I have recommended earlier; and

Fifth, authorization for other agencies of the Government to carry out, under the general guidance and coordination of the Council, both researches and applications pertinent to the special missions of these agencies.

Since completing my prepared statement I have studied some of the statements previously made and have discussed my own statement with several persons whose opinions I value highly. As a consequence I will present suggestions differing from those in my prepared statement.

First, I suggest establishment of an independent Weather Modification Board, perhaps modeled on the Civil Aeronautics Board, charged with regulation of weather modification by all agencies public and private, to which the regulatory power of the States and lower political entities be preempted.

Second, I suggest that the major task of formulating and carrying out the national weather modification program should rest with a Weather Modification Commission outside the present Government agencies. Specifically I suggest that the Commissioners should be chosen in equal numbers from public and private life and should give direct representation to a broad spectrum of viewpoints from which the concerns of applications for useful purposes and of our social institutions should not be omitted: that the Commission should be provided with a staff capable of maintaining close working liaison with the entire field of weather modification both here and abroad and of carrying out detailed background and planning studies; that the Commission should be charged with putting the national weather modification program into effect, in part by utilizing the capabilities, suitably expanded, of the National Science Foundation and the National Center for Atmospheric Research, and the several Government departments, each within the domain of its most suitable utilization, and in part by creating its own operating arm to carry out specifically those major programs of field experimentation that have been recommended by the National Academy of Sciences panel report but lie outside the basic research domain of the National Science Foundation.

Third, I suggest that other agencies of the Government be authorized to carry out, under the general guidance and coordination of the Commission, both researches and applications pertinent to the special missions of these agencies.

I am well aware that proliferation of Government agencies poses serious problems and that establishment of a new one is not as simple a solution as it might appear nor something to be taken lightly. Yet I am moved to speak for it. A nonexisting agency obviously lacks a voice of its own, and if anyone is to speak for it he must arise from outside the Government or else speak against his own agency. Also I feel that a voice from without is necessary to counterbalance the tendency I have noted in some agency statements to overaggrandize their roles, somewhat at each other's expense but mostly at the expense of accomplishments outside the Government whose authors have no organized voice. My suggestion for a new Weather Control Commission rests on the following observations.

First, the initial form in which a national weather modification program is cast will be crucial for its future development, and to temporize by allocating

it to an agency not fully suited to the task would be to risk its lasting deformation.

Second, the task transcends the boundaries of existing agencies no less than it transcends State boundaries. It corresponds to an entirely novel relationship between Government and the governed. Its lines to the executive and, especially, to the Congress, should be free from the inadvertent influences that would be unavoidable if the function were appended to those of an existing agency.

Third, in this particular present, where our past imperfect meets the future, and in terms of the actualities of top-level leadership, of depth of commitment, and of breadth of mission, no one of the existing agencies nor all of them together can furnish a home that is both congenial and adequate for the people on whom we should be depending for performance of this task.

Finally, of all the Government agencies that have touched this field in the past, the Advisory Committee for Weather Control provided, in relation to its resources, by far the most constructive leadership and the most creative program. It provided a demonstration of the effectiveness of this approach in organizing the many separate elements, public and private, into a productive national program, that has not been forgotten.

Mr. HOWELL. I have three points that I would like to make before this committee regarding the nature of a national weather modification program. The first is the importance of a pluralistic approach to a national program. The second, the importance of private initiative in reducing weather modification to a useful practice, and third, the importance of separating the regulations of weather modification from its operation.

With regard to the first point, I think I can depend upon the other witnesses here to have made a large part of the point I would like to make, but I would like to try to put a slightly different emphasis on it.

Unless the scientific objectives that are now in view fail ultimate realization, we are committed unavoidably to an undertaking of which the operational, economic, and social magnitude will tremendously overshadow the seminal role of pure science.

Let me compare it to aviation. The aviation industry and private aviation, airlines and the operations of the FAA, all spring from the science of aerodynamics. We have heard many speeches about the science of weather modification. But as I see it, a completely rounded program is going to overshadow the size of the science alone perhaps as much as the whole of aviation overshadows in its operational implications the science of aerodynamics. There is, then, an immediate need in my opinion for a broad viewpoint reflecting all of these implied complications.

Other speakers have already touched on the need for diversification of approaches to these ideas.

For example, the idea of buoyancy, utilizing the buoyancy of clouds as a lever for modification, which Dr. Hosler spoke of, 10 years ago was in disfavor among recognized bodies of scientific opinion. Today it is a hot idea.

So we must be ready to say that some of the brightest ideas in weather modification have blossomed outside of the garden plots laid out for official cultivation and we must look at the volunteers outside the fence even though they look weedy at the present time.

The task of building applied weather modification will require the experimentation over many climatic areas, many different techniques, many different applications. The 60-odd weather modification programs that I have been connected with have ranged over many different climates, from the sea to the high mountains, from the Equator to high latitudes, and I see no way of determining what are the proper

applications for weather modification except to learn by doing in all sorts of places, in all sorts of economic settings, and using all sorts of techniques.

I will come back again to possible international implications of this kind of varietal approach.

Another thing that comes under this heading of diversity is that the diverse interests of the Government, the scientific community, private initiative, and social and political entities outside of the Federal Government should all be directly represented in the top Advisory Board responsible for guidance of the national weather modification program.

In 1957 the Senate Committee on Interstate and Foreign Commerce recommended the passage of S. 86 in language which emphasized the side-by-side importance of basic and applied research. Despite the very evident intent of the Senate committee that basic research should be teamed with applied research and with exceptions I will note later on, the anticipated program of applied research never materialized.

Dr. Haworth, in his testimony before the Commerce Committee, made it very clear why it did not materialize because by the time NSF got the ball the scientific community could not agree on anything about weather modification except basic research.

But when we consider how this scientific community expressed its opinions we find a series of committees such as the Committee on Atmospheric Sciences of the National Academy of Sciences, and the Advisory Panel on Weather Modification of the National Science Foundation. I could read a list of about a dozen other committees, including an extensive list published in the recent Seventh Annual Report of the National Science Foundation, and on all of these committees one can scarely find the name of a single person who is identified with the application of weather modification to useful ends or scarely anyone identified with applied meteorology in general. Thus the breadth of experience that had been brought to the consideration of weather modification through the appointment of the Advisory Committee on Weather Control was lost when that body was dissolved and it has not yet been restored.

I pass now to my second main point, the role of private initiative in reducing weather modification to useful practice.

In the free enterprise system the sum total of private initiatives is the most thorough, the most vigorous, the most imaginative tester and evaluator of new ideas. I feel that it is important to make this an ally in the development of weather modification. From the beginning industries and large-scale agriculture having an economic interest in the use of water have had a leading role in sponsoring weather modification experiments.

I testified in 1957 at the Senate committee hearings on S. 86 that "there is no danger that scientific or commercial progress in weather modification will cease for lack of Federal support. From our experience with more than a score of industrial clients we know the advantages of weather modification are attractive enough to hold and expand the interest of the industries concerned."

Yet the flow of industrial support did slow to a trickle. The reason is one I had not foreseen. Not lack of Federal support but the chill of official disparagements of applied weather modification as being unscientific and premature.

How many board chairmen can tell their stockholders that they are bucking that kind of advice from the purest of horses' mouths?

Applied weather modification slowed to a trickle but it did continue to trickle in despite everything. It carried out on its own, as best it could under the circumstances, the 1957 Senate committee recommendations on applied research.

Mr. Holloman, testifying again before the Commerce Committee, made reference to the verification by the Panel of the results of these commercial operations but he did not mention where the work came from that was thus verified. It came from private initiative.

There remains in this private sector an enormous and largely untapped reservoir of interest and concern regarding useful application of weather modification, a reservoir that needs only to be thawed out in order to come substantially to the support of research and development at the present time.

Here are private dollars ready and able to carry a large share of the load that the taxpayer would otherwise bear. I feel that it should be harnessed to a national weather modification program.

Those private entities that undertake to integrate their own efforts to reduce weather modification to useful practice, with the purpose and requirements of the nation weather modification program, should, in my opinion, be specifically recognized as playing an organic role in the national weather modification program and as such should receive some compensation in the following forms:

First, scientific advice from the most competent bodies available; second, support for additional scientific and/or observational operations not a normal part of an operational program; third, evaluation by an appropriate public agency of the scientific, economic, and social results of the operation; fourth, reimbursement of expenses with respect to periods when operation of the program is suspended for nonoperational reasons, except for random "randomization" of seeding trials; and fifth, indemnification for legal liability arising out of weather modification operations.

This kind of mating between applied developments and scientific research, I believe, can help the task of both. There are many instances where equipment problems have occupied the time of university scientists when they have already been essentially solved by operational cloud seedings. There are many times when operational cloud seeders have done what they could to explore scientific fields because nobody in the universities was interested in their particular problems but these were problems that really belonged in the university field.

Let us get them together, each in its proper role.

Private entities engaged in reducing weather modification to a useful practice should be protected from capricious and arbitrary regulation by State and local governments and should have the benefit of uniform requirements for qualification and responsibility for weather modification operators throughout the United States and its possessions.

I can really think of no other field of endeavor where the interstate character of the operation is so obvious and where it would be so difficult to assure limitation of the effects to a single State.

To my mind, the case for Federal preemption of the right to regulate weather modification activities and to prescribe regulations necessary to insure its conduct in a responsible manner is clear cut. It

seems equally obvious to me, where we now stand on the road toward weather modification, all operations are in a position to add useful knowledge to our slender store.

A public policy that encourages such operations while at the same time providing necessary public safeguards would serve that end.

Finally, under this point the role of private initiative in reducing weather modification to useful practice should be explicitly recognized through direct representation of this viewpoint on all top regulatory and advisory boards.

I think I have already pointed out that such a breadth of viewpoint will not necessarily automatically come about.

My third main point, regulation of weather modification, should be lodged in an independent board disassociated from all operational interests and representative of a broad viewpoint of public policy.

Even though many of the scientific conclusions regarding weather modification are tentative, the principles of science on which the investigation rests are firmly established.

In the same sense, even though the form of regulation required for protection of the public interest and advancement of public policy on weather modification can only be tentatively discerned, the principles on which such regulations are to rest are already established.

One of the most basic of these principles is the separation of regulatory from operational functions. I feel that the makeup of a regulatory board should give explicit recognition to the concerns of the Government, to the scientific community, to social and political entities outside the Federal Government, and to private initiative concerned with the reduction of weather modification to useful practice.

I do not feel that it serves the ends of public policy to give any and every Federal activity automatic priority over any and every private activity because some of the private activities have contributed much more than some of the Federal activities.

The authority of this board, I feel, should contain the power to resolve conflicts of interest that may arise, for example, out of interference between projects, or out of different objectives within a single area.

Going back now to the question of international implications of weather modification, it has been well pointed out in the Panel reports that weather modification is no observer of political boundaries, State or National. But when one comes into the realm of international meteorology, I think we need to consider a parallel in other forms of social endeavor, that the creative and capable leadership in this field of science escalates to the highest fully organized operational level.

At the present time it makes no more sense, to my mind, to consider international meteorology in a continental setting such as South America, which is an area with which I am quite familiar, than it makes sense to consider interstate operation of a weather service in the Federal setting of the United States.

Wherever there is international activity, the political organization tends to be extremely conservative and to lag far behind the achievements of international cooperation and international operation in the field of application.

I drew the parallel the other day that the manager of the Sears, Roebuck in Lima owes no particular obligation to the Peruvian Govern-

ment. He is not an international operator. He is in a sense a supranational operator. It will take a long time, perhaps, before the political attitude toward supranationalism will catch up. But we have an opportunity to achieve that kind of result by operations over a broad area that do not depend upon the competency or the willingness of underdeveloped countries to take an effective hand in it if we can carry out the necessary operations by some such body, perhaps as a civil service group, within the Organization of American States which can do the job competently and effectively without depending upon the political collaboration of underdeveloped countries which are likely to put roads and social reforms about 10 leagues ahead of anything like meterology.

Regarding organizational responsibilities, I agree at most points with the National Science Foundation Special Commission report, but I would like to make more definite suggestions in some places where that report is vague. Numbering them parallel with their NSF numbers, the Special Commission recommends giving support to research and development missions and major but not exclusive planning and implementation missions to any agency of the executive branch.

I suggest this agency be a new and independent Weather Modification Commission.

Second, the Special Commission recommends continuation and expansion of the NSF program primarily through universities and the International Center for Atmospheric Research. I concur, but I suggest wider collaboration with nonuniversity entities having research capabilities, especially intergration with reduction to useful practice.

The NSF report recommends mission-oriented activity within the Federal agencies concerned. I concur.

Fourth, the NSF report recommends separation of regulation from research and development to a degree dependent upon the extent of activity and the degree of regulation, the Office of Science and Technology acting as a sort of superregulator to resolve major conflicts. I suggest the situation already justifies a completely undependent regulatory agency.

I further suggest that major conflicts, if they develop, will involve social, industrial, legal, and practical elements to a degree probably overshadowing the scientific and technological, and a single fully regulatory agency would be better than a two-headed one.

The NSF report also states that whatever regulation is decided upon must be national in scope. I do not see how this can be except through Federal preemption of the power to regulate.

Fifth, the NSF report recommends scientific and public policy views through a standing committee of the National Academy of Sciences and the National Academy of Engineering. I suggest that the public policy aspects of the national weather modification program already extends beyond science and engineering and that an advsory body on public policy should include major representation of nontechnological interest and concern, a breadth of viewpoint too important not to be spelled out.

I am well aware that proliferation of Government agencies poses a serious problem and that establishment of a new one is not as simple a solution as it might appear, nor something to be taken lightly. Yet I am moved to speak for it. A nonexisting agency obviously lacks a voice of its own. If anyone is to speak for it he must rise from outside the Government or else speak for it against his own agency.

Also, I feel that a voice from outside is necessary to counterbalance the tendency I have noted in some agency statements to overaggrandize their roles somewhat at each other's expense but mostly at the expense of accomplishments outside the Government whose authors have no organized voice.

My suggestion for a new Weather Control Commission rests on the following observations:

First, the initial form in which a national weather modification program is cast will be crucial for its future development and to temporize by allocating it to an agency not fully suited to the task would be to risk its lasting deformation.

Second, the task transcends the boundaries of existing agencies no less than it transcends State boundaries. It corresponds to an entirely novel relationship between Government and the governed. Its lines to the Executive, and especially to the Congress, should be free from the inadvertent influences that would be unavoidable if the function were appended to those of an existing agency.

Third, and in this particular present where our imperfect past meets the future, and in the terms of actualities of top-level leadership, of depth of commitment, breadth of mission, not one of the existing agencies, nor all of them together, in my opinion, can furnish a home that is both congenial and adequate for the people on whom we now have to depend for performance of this task.

With regard to the level of expenditures appropriate to this program, let me say that in the recent past I have been seeing in foreign countries a rather horrible case where a program was built up or blown up, inflated, to meet the level of available funds. As a result, the program is in serious trouble. It does not rest on a true capability. It does not have a good objective and the most serious cost of this is not the waste of money, which is replaceable, but the loss of professional self-respect and the loss of the esteem of our colleagues, both professional and nonprofessional. This esteem is hard-earned capital and we have to reinvest it wisely.

The reason behind this, in my opinion, lies not with overfunding, but with inadequately meeting the challenge in leadership to suit the situation.

Using Federal support wisely to engineer leadership and speed the growth of competence is an immediate task of the highest importance and to my mind is the most urgent reason for deliberate speed in creating a weather modification mission.

Let me say with respect to the testimony of my esteemed predecessor, Dr. McDonald, that I believe that the question is not one of leadership. I think Dr. Langmuir would have said it does not matter how big a match you use, it depends on what you light with the match. Some of the agencies here have been holding some pretty big matches but they have not lit much of a fire with them.

On the other hand, I think the Bureau of Reclamation, with a relatively small match, have a pretty hot fire going.

Finally, of all the Government agencies that have touched this field in the past, the Advisory Committee for Weather Control provided, in relation to its resources, by far the most constructive leadership and the most creative programs. It provided a demonstration that has not been forgotten, of the effectiveness of this approach in organiz-

ing the many separate elements, public and private, into a productive national program.

Thank you, Mr. Chairman.

Senator ANDERSON. Thank you very much.

You comment on the use of private entities because manpower is not available. Is there a pool of manpower in private agencies and the universities which could be used to conduct the program so that they could participate?

Mr. HOWELL. There is certainly a pool of manpower that can be used in some parts of this project. Having worked with a number of private industrial organizations, I am very much aware that there are sources collateral, let us say, to those of professional meteorology, which, by adequate leadership in this science, can be brought into effective combination with existing nuclei of professional competence and can serve as seeds for new nuclei.

Senator ANDERSON. Thank you very much. I appreciate your coming.

Our last witness is Mr. Braham.

STATEMENT OF ROSCOE R. BRAHAM, JR., PROFESSOR OF METEOROLOGY, UNIVERSITY OF CHICAGO, AND DIRECTOR OF THE UNIVERSITY OF CHICAGO CLOUD PHYSICS LABORATORY

Mr. BRAHAM. Mr. Chairman and members of the committee, my name is Roscoe R. Braham, Jr. I am a professor of meteorology at the University of Chicago and director of the University of Chicago Cloud Physics Laboratory. It is a privilege for me to have this opportunity to express my views concerning the proposed legislation, S. 2875.

What, by way of experience and background, can I bring to bear on this subject? Since early 1946 my work has been the study of clouds, primarily in field experiments, including cloud modification, as a scientist in Government and at the University of Arizona, the New Mexico Institute of Mining & Technology, and at the University of Chicago.

Over the years this work has been supported by many different Government agencies—Weather Bureau, Air Force, Atomic Energy Commission, Public Health Service, National Science Foundation—private foundations and private university funds. At present I serve, or have recently served as a consultant on weather modification research for the U.S. Army, the Bureau of Reclamation, and the U.S. Weather Bureau.

I am pleased to note in S. 2875 the implicit recognition that weather modification, particularly cloud seeding for precipitation changes, are important and worthy of increased attention and support. I heartily endorse the principle that the Department of the Interior should play a key role in the development of precipitation modification technology.

I also believe, however, that the proposed legislation is unrealistic in its concentration, within that Department, of authority and responsibility for research on a broad front in the atmospheric sciences, training of scientists, and regulation of cloud seeding activities.

Therefore it is my view that enactment of this bill, in its present form, is not in the best interests of a speedy and orderly development

of a program for effective, beneficial utilization of atmospheric water resources. I propose to touch upon these various points in greater depth within this statement.

My views on several broad aspects of weather modification research and the role of Government in organizing for such research were covered recently in a statement before the Senate Committee on Interstate and Foreign Commerce. I will not repeat that material; however, I can provide additional copies of it should you desire them.

It is instructive to discuss the present legislation against the backdrop of a national program in weather modification. The recent report of the National Science Foundation Special Commission on Weather Modification states the elements of a national program in the following way, to which I subscribe:

(1) Strengthened fundamental research in all phases of cloud and weather science.

(2) Development of the technology of weather and climate modification for deliberate intervention in atmospheric processes with consideration for social, biological, and legal aspects.

(3) Provision for operational application of this technology as rapidly as techniques are validated.

(4) Provision for regulation and protection of public interest while at the same time insuring advancement of the state of the art.

Senator ANDERSON. Don't you agree those four fundamentals are pretty well subscribed to by nearly every one in this field? We all want to strengthen research, do we not?

Mr. BRAHAM. Yes, I think this is true. I think our differences in the point of discussion arise from the relative strength we place on the four and opinions as to how applicable today a provision such as No. 3 might be.

Senator ANDERSON. What I am trying to say is that, regardless of whether the Weather Bureau does it or Department of the Interior does it, or a committee of the NSF does it, these are the things we ought to do.

Mr. BRAHAM. That is correct.

ORGANIZATION FOR OUR EFFORT

I endorse the principle that we reaffirm the responsibility of the Department of the Interior for management of water resources throughout all of the United States and that we recognize that this responsibility extends to research and testing operations designed to improve and regulate the yield from atmospheric water resources.

I agree that weather modification studies have reached the point where it is necessary to test existing hypotheses in the context of local geographical and meteorological conditions. The mission responsibility of the Department of the Interior gives them clear motivation for assisting with these tests. But from my view as a scientist, their strengths center around testing and reduction to practice of promising cloud seeding techniques, as opposed to scientific analysis of clouds and weather processes on a broad front. Resources and competence for the latter are to be found in several Government departments and at universities.

We must recognize that present cloud seeding and weather modification techniques are crude and of limited application. Years, maybe decades, of basic study stand between us and the achievement in our quest for a truly usable technology of weather modification. Thus far, most cloud seeding tests have been limited to looking for overall effects. However useful such conclusions may seem, they are of the crudest kind of knowledge.

We must strive to understand why particular tests turn out as they do. Once we have confirmed that a particular cloud-seeding experiment produced changes in precipitation we immediately wonder whether the net effect was the small difference between many large positive and negative effects mixed together. We ponder, too, the outcome of tomorrow's test since tomorrow's meteorological situation will probably differ from today's, and we wonder how we might do even better. The present understanding of basic cloud physics is not adequate to extrapolate the results of a particular experiment to the thousands of other combinations of geography, meteorology, and seasonal situations in which precipitation modification may be desirable.

Moreover, precipitation modification cannot be separated from most other weather modification efforts, for example, modification of severe storms, hailstorms, hurricanes, et cetera, will undoubtedly also affect their water yield.

Therefore, it is essential that we determine the why as well as the yes-no of cloud seeding.

It is my view that development of the science and technology of precipitation modification can only come as fast as there is increase of knowledge over the broad front of meteorology, and development of trained scientific talent in theoretical and experimental meteorology. The universities have a major role in these developments as also do several executive departments.

REGULATION OF SEEDING ACTIVITIES

There appears to be need for some sort of regulatory-licensing legislation to prevent mutual interference of worthwhile research projects, to give a platform for arbitration between sponsors for qualified research projects and commercial cloud-seeding interests, and to give the general public a spokesman in the planning and execution of major weather modifications experiments.

As has been pointed out many times, useful weather modification experiments are likely to be lengthy and are likely to require particular areas to be designated as target and control. This automatically forces the residents in these areas to accept the advantages and/or disadvantages which may accrue to them by virtue of being in the target and/or control area. These points speak for assignment of the regulatory-licensing responsibility to a particular government agency or board.

In my view, it is crucial that this responsibility be vested in a group having no other interests in atmospheric sciences in general and weather modification in particular. The decisions of this regulatory body will be tough enough, without giving to that body the additional handicap of direct association with, or responsibility to, an agency having statutory responsibility or mission interest in the weather modification question.

I support the suggestion of Dr. Wallace Howell before the Senate Committee on Commerce on March 7, 1966, and before this committee this afternoon, for the formation of an independent weather modification board to be charged with the regulation and licensing of weather modification experiments by all agencies, both public and private. All activities concerned, Government and lay public, and private, basic research scientists and commercial operators should have representation on this board.

Senator ANDERSON. May I stop you there. Am I correct in understanding that your objection is not to the licensing but putting it in the hands of the Department of the Interior?

Mr. BRAHAM. Putting it in the hands of any agency having a vested legislative or mission interest in the subject of weather modification.

Senator ANDERSON. That would include the Weather Bureau also.

Mr. BRAHAM. In my view, yes.

Senator ANDERSON. I don't quarrel with you too much on that. I felt personally, and others did feel that you had to have some overall control of the situation. I explained that by my own peculiar experience. I was very much interested 2 or 3 years ago in experiments by Dr. Langmuir and Dr. Schaefer. There was always some private investigator who could upset the experiment by a project in the next-door area. It is true that you can't keep track of what is going on in the experiments except on a controlled basis. Do you subscribe to that in your particular agency?

Mr. BRAHAM. I think the number of cases where one can document that we have been in trouble thus fare are relatively few. However, I think, to the very extent that we are successfully in this quest for an operation and technology, the needs will become ever more apparent and it is time to get on with this aspect of the problem.

Senator ANDERSON. There may be very few, I won't argue that. If you are in a situation where you are trying to demonstrate, you might be interested in seeding clouds in the mountains of the State of Washington and on the other side of the mountain, in Spokane, a private operator can, with his experiment, prejudice your project in that sort of situation. That is the reason I am interested in licensing, to make sure we have an overall policy.

That would give you a chance to demonstrate your project without any interference by some outside source.

Mr. BRAHAM. That is right. If you are one of the few who have been affected it does not matter how many more there are. It is your problem that is important.

INDEMNIFICATION FOR GOVERNMENT-SPONORED RESEARCHER

I think serious consideration should be given to legislation to provide Federal grantees and contractors and indemnification against liability for damage resulting from Government supported weather modification research programs. Thus far this risk has been ignored or covered by insurance. However, to the very degree that our research activities pay off in improved weather modification technology this risk will increase.

We soon will approach the time when growing liability risks will deny university and private meteorological groups the opportunity to contribute to this field. This looms serious when we reflect that a

significant fraction of the scientific manpower in weather modification is presently in these, non-Government, groups.

Senator ANDERSON. I agree very firmly with that latter statement. I recognize we need some sort of protection because it can easily happen that a seeding operation might lead to excessive rainfall which is greatly appreciated by the city of New York, for example, for their reservoir, but no so much appreciated by the operators of a golf course. I think these are very good suggestions. I appreciate them.

If the Weather Bureau were left the responsibility for developing theories on which it might work, would you regard it as proper for the Department of the Interior to be charged with carrying out those theories with testing operations?

For example, this hurricane control you mentioned. Now Interior is not concerned with hurricane control. That is quite plain. But the use of the development for precipitation for the benefit of agriculture and storage of waters in packing snows is very definitely the responsibility of the Department of the Interior and not the Department of Commerce. Department of Commerce is a businessman's organization.

Mr. BRAHAM. I think my response to that would have to stem from this point of view: The major problem ahead of us in the area of weather modification technology at the moment, and I think for the next several years, is really a scientific one.

We need to draw upon and make full use of all of the scientific competence regardless of where it lies. Now, scientific competence, to my way of thinking, extends beyond the academic degrees that people have. I am sure you can go down on skid row in Chicago and find some Ph. D.'s lying in the gutter. You have to have motivation to do something with your tools in addition to having the tools. But combining these in terms of scientific competence, I think we need to use this competence wherever it is found. I think that to the extent the Weather Bureau, Interior, DOD, all of the agencies have an ability and an interest to contribute to these problems we need to welcome their participation.

Once we get to a fully operational technology, then it may indeed be an easier matter to assign responsibilities, but I think at the moment the problem is more nearly a scientific one than an operational one.

Senator ANDERSON. I was thinking of the fact that ESSA has no great responsibility in some of these fields.

To get back to the Atomic Energy Commission: Their research led to a new type of battery, a nickel-cadmium battery which is very reliable. Once it was developed then it became useful to the automotive industry. It was not proper for the Atomic Energy Commission to have control of that battery. It is in the commercial field.

Mr. BRAHAM. And there will be spinoffs It is hard to see what those will be but they will undoubtedly occur.

Senator ANDERSON. You have an interesting paper and I appreciate it very much.

Mr. BRAHAM. Thank you, sir.

Senator ANDERSON. Dr. Kahan, could I ask you a question?

You appear to have been approved by your professional standards by several people participating in this hearing. Do you regard weather predictions and weather modification as inseparable?

STATEMENT OF DR. ARCHIE M. KAHAN, CHIEF, OFFICE OF ATMOSPHERIC WATER RESOURCES, CHIEF ENGINEER'S OFFICE, BUREAU OF RECLAMATION, DENVER, COLO.—Resumed

Dr. KAHAN. No, sir; I do not. I think that there needs to be some very careful examination of the meaning of words when you begin to explore this very point. If an agency is interested in convincing someone that it should have major responsibilities, it can be forgiven for pointing out its strengths. But I think that there have been some things said about the inseparability of prediction and weather modification that do not stand up under really careful critical review. There are forms of weather modification now in practice such as the dissipation of cold fog that should not require an ability to predict very much about the dissipation of that cold fog.

You go out, you seed that fog with dry ice and a hole develops for airplanes to land on the cleared runway; or you seed a low stratus cloud deck and a hole develops therein. You have modified the fog and the cloud beyond any question without any great ability to predict what was going to happen to that fog or that cloud.

The assumption that it would have persisted is generally within the level of predictive skill.

Now, the word prediction has a variety of meanings. To the extent that it is desirable to understand the dynamics of the atmosphere then certainly the more understanding you have of the dynamics of the atmosphere the more enlightened are going to be your attempts to modify the atmosphere. But for any one to suggest that present day-to-day weather prediction techniques are inseparable connected with a weather modification program is something that is not so. We can do a great deal of weather modification on the basis of observation.

Critical observation of the state of the atmosphere, rapidly reported and processed, will permit the intelligent modification under some circumstances.

Now if we look way down the road to that hopeful day when we are talking about influencing the planetary circulation I would agree that it would be very important to have a pretty clear idea of what is going to happen if nothing is done and to compare that with what happens after something is done. But in our interest in being all inclusive on the subject of weather modification, we ought not to lose sight of the fact that what we know how to do right now appears to have some useful aspects. We ought not to get so involved with looking at the broad picture that we forget there are some things that can be done either now or with a little more understanding in the near future. It is these things that I say can be done without great relation to prediction.

The ability to recognize an opportunity for seeding will be very much an observational ability.

I also would suggest that however important prediction becomes, communication between the predictors and the modifiers does not fall apart completely if they are not organizationally in the same agency.

Senator ANDERSON. I am glad you said that closing sentence. I have tried to say I don't care what a prediction is as long as it is available for the people who are going to do the modifying. I do think modification is all wrong in the Department of Commerce.

Do you contemplate any difficulty in finding competent personnel for an expanded weather modification program.

There is some talk about your having two people, something like that, in your Department who are qualified. Do you have more than that?

Dr. KAHAN. We have more than the speaker knew at the time. We hired recently, last fall, three additional meteorologists and we have some vacancies and are considering the hiring of others. I think that when it is clear that the Bureau of Reclamation's program is here to stay, it will be much easier to convince people to make career decisions about joining the Bureau of Reclamation.

I do not think that there is a critical shortage of people to do the job that Reclamation sees as needing to be done. As Commissioner Dominy pointed out in his statement, it is Bureau of Reclamation practice to staff for design and monitoring and not to staff for carrying out the whole task.

Now you can argue the merits of in-house or out-of-house operation. Personally, I believe that in this state of the game, with as much need as there is for capitalizing on wisdom and ideas wherever it can be found, that an organization that is a little poor in-house may actually have an advantage working for it. We are in good communication with the people who know what is known about this field. We have consultants whose qualifications are of the highest. So that is not just a matter of which people come to sit at a desk day after day in the Bureau of Reclamation.

The cumulative wisdom of some people who may not show up in Denver for months on end is still available to us.

While we are on the subject of shortage of manpower, I think it needs to be recognized that we have ups and downs in what we have been talking about in terms of staffing large-scale programs; the amount of money necessary to staff the research interest of the presently identified, qualified meteorological establishment, the men who have the credentials and who have demonstrated an interest. The amount required to do that is perhaps less than is being considered here.

But the job that remains to be done is not entirely a meteorological job. If we are ever to acquire the observing facilities that are going to be necessary to do the job of understanding the atmosphere we have to bring in the skills of people who today may not identify themselves with meteorology at all. My experience has been somewhat different than Dr. James McDonald's in regard to this matter, although certainly I have had some contacts with people whose knowledge of the atmosphere was minimal and whose interest was in capitalizing on the availability of funds.

I have also had contacts with people who had something to offer and an interesting offer, who are not now members in good standing in the meteorology profession.

The job that lies ahead I think is going to require people of this sort and I see no great problem in differentiating between the ones who have a sincere interest in contributing and the ones who are simply opportunistic, looking for where they might make some dollars.

Senator ANDERSON. I think that is very helpful; at least it is to me.

I so often get mixed up in some program of this nature, like saline water. I had some people writing me at one time about that program,

only three men were identified with it. Since I was trying to get some bills passed and hoping to see the project set up, I tried to find out if those two or three men would be interested in coming into the Department. We passed the bill for $200 million. I have on my desk the application of one of these very men.

On this question of in-house work and other types of manufacturing, I was out to the Jet Propulsion Laboratory in Pasadena. They had some pictures made of the last Ranger flight; remarkable pictures. I think the space organization is doing a pretty good job to get the Jet Propulsion Laboratory to take it on. I don't think too much was done in-house in Washington.

I think the Jet Propulsion people have done a fine job and Dr. Pickering has done a good job.

I hope to see this program handled wherever it can be handled.

The committee has asked the Commerce Department for a listing of personnel it has available for atmospheric research. I wonder, Dr. Kahan, if you could give us a similar list of those who are engaged in the Bureau of Reclamation program.

Dr. KAHAN. I would be glad to supply it. As we have testified, the Bureau has arranged for several universities and private groups to undertake projects. They are engaged in Bureau of Reclamation weather modification work and I will list them if that is your desire.

Senator ANDERSON. Yes, we would like to have them all listed; everyone participating in the Bureau's effort.

(The material requested follows:)

PERSONNEL DATA FOR PERSONS ENGAGED IN THE BUREAU OF RECLAMATION'S ATMOSPHERIC WATER RESOURCES RESEARCH PROGRAM

SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY

Richard A. Schleusener: B.S., 1949; M.S., 1956; Ph. D., 1958. Interests: Hydrology, meteorology, weather modification.

Arnett S. Dennis: B.S., 1949; M.S., 1953; Ph. D., 1955. Interests: Radar meteorology, satellite meteorology, weather modification.

Harold D. Orville: B.A., 1954; M.S. 1959; Ph. D., 1965. Interests: Numerical modeling of clouds and local winds, cloud physics, cloud dynamics.

John H. Hirsch: B.S., 1963. Interests: Cloud physics, radar meteorology.

Subcontractors

Thomas J. Henderson: H.S. Interests: Cloud physics, weather modification.

D. Ray Booker: B.S., M.S., Ph. D. Interests: Cloud physics, instrumentation.

UNIVERSITY OF WYOMING

John C. Bellamy: B.S., 1936; Ph. M., 1938; Ph. D., 1946; certified consulting meteorologist. Interests: Meteorology, hydrology, weather modification.

Richard W. Weeks: B.S., 1952; M.S., 1957; Ph. D., 1966. Interests: Electronics, instrumentation.

Merlin C. Williams: B.S., M.S., course work completed for Ph. D. Interests: Meteorology, hydrology, weather modification, instrumentation.

UNIVERSITY OF NEVADA

Wendell A. Mordy: A.B., 1942; fil lic, 1958. Interests: Cloud physics, precipitation physics, weather modification.

Edwin X. Berry, B.S., 1957; M.A., 1959; Ph. D., 1965. Interests: Cloud physics.

John P. Chisholm: B.S., 1946; M.S., 1947. Interests: Instrumentation, radar.

Thomas E. Hoffer: B.S., 1950; M.S., 1952; Ph. D., 1961. Interests: Cloud physics, precipitation physics.

Harold E. Klieforth: B.A., 1949; M.A., 1951. Interests: Synoptic and dynamic meteorology.

Joseph A. Warburton: B.S., 1951; M.S., 1960. Interests: Cloud physics, weather modification.

COLORADO STATE UNIVERSITY

Vujica M. Yevdjevich: B.S., 1936; M.S., 1939; Ph. D., 1955. Interests: Hydrology, hydraulics, water resources.

Walter F. Rowland: B.S., 1954; M.S., 1958, (Ph. D. 1966). Interests: Hydrology, water resource development.

Radmilo D. Markovic: B.S., 1952; M.S., 1964 (Ph. D., 1966). Interests: Hydrology, statistics.

UTAH STATE UNIVERSITY

Vaughn E. Hansen, Pr. D. Interests: Irrigation, water resources.

Duane G. Chadwick: M.S., 1957. Interests: Instrumentation.

Joel E. Fletcher: M.S., 1937. Interests: Hydrology, instrumentation.

Don L. Griffin: B.S., 1965. Interests: Snow measurement, telemetry.

Duard S. Woffinden: M.S., 1965. Interests: Telemetry, radar.

Subcontractor

Robert D. Elliott: B.S., 1936; M.S., 1937. Interests: Meteorology, weather modification.

TAFT COLLEGE

Lawrence E. Peahl: B.A., 1957. Interests: Statistics.

FRESNO STATE COLLEGE

Thomas H. Evans: B.S., 1929; M.S., 1930. Interests: Engineering research.

STATE OF WASHINGTON

Stuart E. Shumway: B.S., 1950. Interests: Meteorology, climatology, weather modification.

Battelle Northwest

James J. Fuguay: B.S., 1950; M.S., 1952. Interests: Meteorology and climatology.

Eric H. Phinney: B.S., 1955; M.S., 1958 Interests: Meteorology.

E. BOLLAY ASSOCIATES, INC.

Eugene Bollay: B.S., 1935; M.S., 1936; certified consulting meteorologist. Interests: Meteorology, weather modification.

David O. Zopf: A.A., 1948; B.S., 1950; M.S., 1951; E.E., 1952. Interests: Systems engineering, instrumentation, weather modification.

Paul T. Willis: B.S., 1959; M.S., 1960. Interests, Meteorology, diffusion.

Robert A. Begun: B.S., 1950. Interests: Instrumentation.

Robert T. Beaumont: B.S., 1947; M.S., 1952. Interests: Snow surveys, meteorology, statistics.

Griffith M. Morgan: B.A., 1955; M.S., 1961. Interests: Aerodynamics, radar.

Carson P. Edwards: B.S., 1962. Interests: Instrumentation.

METEOROLOGY RESEARCH, INC.

Paul B. MacCready, Jr.; B.S., 1947; M.S., 1948; Ph. D., 1952; certified consulting meteorologist. Interests: Atmospheric physics.

Theodore B. Smith: B.A., 1938; M.S., 1940; Ph. D., 1949. Interests: Cloud physics.

John Latham: B.S., 1958; Ph. D., 1961. Interests: Cloud physics, atmospheric electricity.

Chen-Wu Chien: B.S., 1943; M.A., 1949; Ph. D., 1959. Interests: Cloud physics.

Bill C. Ryan; B.S., 1950; M.S., 1964. Interests: Climatology, meteorology.

William D. Bonner: B.A., 1952; B.S., 1954; M.S., 1960; Ph. D., 1965. Interests: Synoptic meteorology.

Millard T. Gannon: B.S., 1938; M.S., 1940. Interests: Instrumentation.

Thomas R. Mee: B.S., 1959. Interests: Cloud physics, aerosol physics.

Alan I. Weinstein: B.S., 1961; M.S., 1963. Interests: Cloud physics.

GEOLOGICAL SURVEY

J. W. Odell: B.S. Interests: Streamflow, hydrology.

SOIL CONSERVATION SERVICE

J. N. Washichek: B.S. Interests: Snow surveys, instrumentation.

FOREST SERVICE

H. C. Fletcher: B.S., 1933; M.S., 1934. Interests: Forest and range management.

Marvin Hoover: B.S., 1938; M.S., 1949. Interests: Forest and range management.

U.S. NAVAL ORDNANCE TEST STATION

Pierre St-Amand: B.S., 1948; M.S., 1951; Ph. D., 1953. Interests: Atmospheric physics.

William G. Finnegan: B.S., 1944; Ph. D., 1949. Interests: Pyrotechnic flares, nuclei studies.

BUREAU OF RECLAMATION

Archie M. Kahan: B.A., M.A., M.S., Ph. D. Interests: Weather modification.

Archie B. Goodman, B.S., M.A., Ph. D. Interests: Weather modification.

Raymond B. Girardo: B.S., 1941; M.S., 1950. Interests: Weather modification, meteorology.

William T. Douglas: B.S., 1940; M.A., 1941. Interests: Weather modification, meteorology.

Richard L. Eddy: B.S., 1956; M.S., 1957. Interests: Weather modification, meteorology.

Ramon C. James: Geol. E., 1957. Interests: Instrumentation, weather modification.

ADVISORY COMMITTEE

Thomas F. Bates: B.A., 1939; M.S., 1940; Ph. D., 1944. Interests: Science Adviser to Secretary of the Interior.

John C. Calhoun, Jr.: B.S., 1937; M.S., 1941; Ph. D., 1946. Interests: Former Science Adviser to Secretary of the Interior.

Earl G. Droessler: A.B., 1942; D. Sc. (honorary) 1958. Interests: Meteorology.

Max A. Kohler: B.S., 1939. Interests: Hydrology.

Walter O. Roberts: A.B., 1938; A.M., 1940; Ph. D., 1943. Interests: Atmospheric sciences.

Verner Suomi: Ph. D. Interests: Atmospheric sciences.

Jack S. Barrows: B.S. Interests: Forest fire research.

William G. Shannon: B.S., 1934. Interests: Conservation, water resources, watershed planning, snow surveys.

Helmut K. Weickmann: Ph. D., 1939. Interests: Cloud physics and modification meteorology.

CONSULTANTS (USBR)

Vincent J. Schaefer: D. Sc. (honorary). Interests: Atmospheric science, weather modification.

Julian H. Bigelow: Ph. D. Interests: Statistics.

Roscoe R. Brahan: B.S., 1942; M.S., 1948; Ph. D., 1951. Interests: Physical and experimental meteorology.

Senator ANDERSON. We will adjourn until tomorrow morning. These papers will be printed and therefore the people who have testified can reasonably revise their remarks if they wish to do so. For myself, I would be very appreciative if anybody who feels compelled to do so would put down on a sheet of paper how he thinks this ought to be organized. I might agree with you. Give us any suggestions you have for this program.

I had the pleasure of one time discussing the food program with former President Hoover. I was trying to run a program. President

Hoover gave me three maps. He put 13 stripes and stars on one picture, and then he had a picture of the Union Jack, and another picture of the French flag. He said:

These are the areas of responsibility. This area has the American flag, that is yours. Don't you ever let anybody in that area go hungry.
You watch it very carefully. Here are the British.

Of course he had a few characteristic things to say about the British I would not want to put in the record. He spoke of them a little bit. He said:

They will get you if they can. They will scrounge around and get some food in these areas and you will find useful things.

Now the French, of course, he was very critical about. But he knew exactly how to organize a program. I don't. I will be very happy to have anybody put down on paper how this ought to be done. If part should stay in the Weather Bureau, the ESSA, part of it go to the Interior, some remain in the Army, some in the Navy, we would like to have your opinion on it. Even if we don't agree with it we will be very happy to have it.

Thank you all very much.

(Whereupon, at 3:25 p.m., the committee was recessed, to be reconvened at 10 a.m., Wednesday, March 23, 1966.)

WEATHER MODIFICATION

WEDNESDAY, MARCH 23, 1966

U.S. SENATE,
SUBCOMMITTEE ON WATER AND POWER RESOURCES
OF THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Washington, D.C.

The subcommittee met, pursuant to recess, at 10 a.m., in room 3110, New Senate Office Building, Senator Clinton P. Anderson (chairman of the subcommittee) presiding.

Present: Senators Clinton P. Anderson, of New Mexico; Henry M. Jackson, of Washington; Alan Bible, of Nevada; Frank E. Moss, of Utah; and Gordon Allott, of Colorado.

Also present: Senator George McGovern, of South Dakota.

Professional staff present: Jerry T. Verkler, staff director; Stewart French, chief counsel; Roy M. Whitacre, professional staff member, and E. Lewis Reid, minority counsel.

Senator ANDERSON. The first witness this morning is Dr. John C. Calhoun, Texas A. & M. College, College Station, Tex.

Dr. CALHOUN. Thank you, Mr. Chairman.

STATEMENT OF DR. JOHN C. CALHOUN, TEXAS A. & M. COLLEGE, COLLEGE STATION, TEX.

Dr. CALHOUN. Senator Anderson and members of the Senate Committee on Interior and Insular Affairs, it is a privilege for me to make this appearance before your committee to speak for favorable consideration of S. 2875.

My name is John Calhoun. I live in College Station, Tex., where I am employed as vice president for programs by the Texas A. & M. University System. The statement which I give today represents my personal view and has no endorsement by nor does it reflect the views of Texas A. & M. University officials.

I have a prepared statement which has been distributed but I prepared it under a busy schedule, so it has some errors in it that I would rather not have appear in the record. I am going to follow that statement but correct it as I go along.

Senator ANDERSON. Fine.

Dr. CALHOUN. In May 1964 I appeared before this committee's Subcommittee on Irrigation and Reclamation to testify for the augmented program of weather modification being proposed for the Bureau of Reclamation. At that time I was science adviser in the Department of Interior and was somewhat cautious in support of weather modification research, because I did not wish to overstate the case for an augmented program.

I am proud to say, however, that before I left Interior in February 1965, I took part in formulating the Department's program for atmospheric water resources and in seeing that it was properly initiated. In the intervening months, that program has had some notable achievements, which I am sure others have described to you or will be described to you by some of the people I see on the program this morning.

The point I wish to make by noting this history is that the program this committee funded in 1964 in the Bureau of Reclamation is a very ample demonstration of the timeliness for applications of weather science and of the wisdom to vest responsibility for research on specific applications with an agency whose purposes take full advantage of the applications.

Because I am neither an atmospheric scientist nor a meteorologist I will leave to others the discourse on the state of knowledge which justifies optimism for producing increased precipitation by modifications in the atmosphere.

The recent reports of the Panel on Weather and Climate Modification, Committee on Atmospheric Sciences, National Academy of Sciences, and the Special Commission on Weather Modification, National Science Foundation, present the case that it is timely to increase substantially our national effort in this field.

I will not repeat statements which have been widely quoted from these reports, some of which were cited by you, Senator Anderson, when you introduced S. 2875.

I would, however, make two points with respect to these analyses which I think ought to be recognized because they are germane to consideration of the steps proposed in S. 2875.

The first point is that it is significant that much of the activity which now permits a positive assessment for increasing precipitation by weather modification has been of the empirical type. The second point is that these results have been the work of research by persons who for the most part were trying, with no apologies to anyone, to increase precipitation.

The first of these points has parallels in other instances of technological advance. One would think by now that we have learned our lesson. Yet it seems that for each new system of inquiry that we undertake, we learn the lesson all over again.

In spite of theoretical computations and deductions and even with all types of models and controlled experiments there is still no substitute for actual observation and experimentation on real situations.

There is no shortcut for the learning that accompanies modifying attempts within an actual system.

Only by attempting modifications do we, in fact, learn about all the parameters which may be applicable to a particular environment or to a particular system of knowledge.

We can learn a certain amount by judiciously observing those modifications which occur naturally. However, it is the modification which we attempt to produce by our own actions that are the most fruitful for our learning. This I consider to be a basic nature of life and it is just as applicable to complex physical systems as it is to complex living systems.

Therefore, if we would increase our knowledge about modifications of the weather, we must indeed attempt modifications. If we would

learn how to apply our modifications knowledge to a given end result we must attempt modifications with that end result in mind.

A planned program which makes use of naturally occurring modifications is a beginning but the inclusion of attempts by which we do our own modifications is essential to the ultimate achievement of success. I would say parenthetically that this same philosophy needs to be applied to other developmental programs in areas of our national interest.

The second point I mentioned is also one which I think we relearn many times; namely, that for the most part applications are successfully found when there is concentrated effort with application in mind. Knowledge about an entire system and its behavior is the concern of the generalist. Such knowledge must be advanced in order that specific applications may be fully understood or may be kept in perspective.

It does not follow, however, that the general system must be understood before the special case can be achieved. Indeed often enough special applications within a system are the foundations for moving ahead with general understanding. Moreover the generalist's concern for the entire system can be a deterrent rather than a spur to understanding specific applications.

Thus, attention to the underdeveloped child or the genius becomes submerged in the general matrix of knowledge about educational processes. Research on problems of water resources remains unattended even while we experience volumes of exotic advance in nuclear and space sciences. That is, they lie unattended until someone takes up a problem with a specific goal in mind.

It is true that atmospheric modifications for the augmentation of precipitation belong to the total set of all weather modifications which are in turn only one part of all atmospheric behavior. One can continue this chain and arrive at a position that, since all nature is a unit, all applications ought to follow from the same set of scientific principles. One would reasonably infer next that all research on all applications should be done by the same group of scientists. This, of course, is absurd.

The atmosphere of course is a resource which has many uses. Not only am I in favor of a program that will increase the water that will be recovered from the atmosphere, I am also in favor of programs that will control lightning where desired, suppress hail, or break up destructive storms.

In my opinion each of these uses should be pursued separately until we have determined how each particular use can be advanced most rapidly and effectively. It is inevitable that the many possible uses of the atmosphere will give rise to interactions just as is the case with other resources.

I don't think it is possible to avoid these interactions among uses of the atmosphere. One argument which has been advanced, and we hear it in many situations, is that we can avoid interactions by placing full responsibility for research in a single governmental agency.

I do not subscribe to this idea because I believe that the interactions among different uses are not a result of our scientific understanding of the matter, but they are a result of what we desire to do in order to satisfy our needs.

The uses are there because we want something, not because we know how to do them.

It is important therefore that we learn first about the possible individual uses of our atmospheric resource. The prospect of modifying it to increase water availability where we want to is one of these and it is a desirable end use so far as our water resources picture is concerned. But this should not rule out learning of our other uses of modifying the atmosphere and these ought to be pursued diligently also.

I would like to stress that in my opinion the legislation proposed in S. 2875 is timely in the senses that it completes a spectrum of technological approaches for meeting our future water resource needs. Our water resources today are in large part a result of our ability to control and handle water after it has reached the ground. We create dams for storage, divert water into new channels, transport it long distances by conduits. Our future water resources rest in part upon grandeur and more visionary systems of redistributing the water after it has fallen.

The proposed Northwest Water and Power Alliance, for example, will distribute water over the entire North American Continent. Hopefully we can also improve the water resources picture by learning to reuse the available water. Avoidance of pollution, better water treatment methods and new purification processes all lead to satisfying part of the growing demand. We will use water again and again as it flows from watershed to sea.

In two ways now we are proposing to extend our acquisition of water beyond surface distribution and reuse. On one end of the hydrogen cycle we propose that, in structures made by man, we will do the job that nature performs when she evaporates water from the sea and reprecipitates it as rain.

The desalting processes that are most attractive are distillation processes. These do in boilers and condensers the same thing that nature does with the energy of the sun and the wind.

What is now proposed in S. 2875 is that we will milk more precipitation from the atmosphere at the locations where it is needed and we will use the carrying power of the atmosphere to distribute water before it falls rather than through rivers and canals after it falls.

Unfortunately our surface storage and distribution system works well only when the water flows downhill. The cost for pumping water uphill to our highest places of need becomes very expensive. Even with desalting transportation is a severe limitation. Atmosphere transport has many attractions therefore from this point of view.

Hence in considering the alternative strategies for meeting water resource demands of the future I don't think we should ignore any possible ways for modifying any part of the entire hydrological cycle.

We have done developmental work on methods of collecting, storing, and moving water. We now know how to design and evaluate large surface water transport systems. Congress has authorized research and demonstration programs with respect to water treatment, pollution control, and the water reuse. Congress has authorized programs for achieving advances in the desalting of sea water.

The one large developmental possibility which remains unexplored is atmospheric modifications. S. 2875 fills in this gap.

The only part of this proposed legislation that gives me pause is section 202 by which the Secretary of the Interior would issue licenses for activities determined to be likely to affect atmospheric water resources. Although at some future date licensing authorities or other regulatory control will be needed for the many conflicting uses of the atmosphere, I believe licensing at this time could detract from developing the technology for these uses.

At this stage of our knowledge there is still need for the kind of empirical activity that brought us to where we are. There is also need for developing other uses which might conflict with water resources use and these ought not to be held in check by licensing provisions.

A clear record should be maintained, of course, of all of the things that we do in atmospheric developmental work so that all modification attempts can be fully analyzed so that we will know what we have done. Such recordkeeping, however, can be accomplished short of licensing. In short, it is not clear to me that licensing is necessary for the successful conduct of a program to develop a technology and to demonstrate its operational use. Consequently, I have reservations about the desirability of this provision.

In summary then, I believe that this legislation is timely in terms of preparing technology to meet our water resource needs. It is also timely in the sense that atmospheric technology is assessed as being ready for the task.

In my opinion it is highly desirable to assign the responsibility for seeking operational methods to increase useful precipitation from the atmosphere to an agency whose goals can immediately use the results. Because of its fine start in this field in the program of the Bureau of Reclamation and because of its overall concern for water resources, the Department of the Interior is the appropriate agency, as called for in the bill.

Although I have not commented on the amount of funds the amounts do not seem to be excessive for the magnitude of the job. I see no conflict between this proposed activity for weather modification and other weather modification activities for hurricane suppression, hail suppression, elimination of lightning or for the other purposes.

Although it is necessary to keep a complete record of all of these activities it is too early to require licensing for carrying on modification experiments in the atmosphere. On the contrary, I think we should encourage many different kinds of experiments by different groups. I wish to thank the committee for its time in hearing me.

I hope I have been able to convey my enthusiastic feeling that the proposed legislation is worthy for favorable consideration by the Congress.

Senator ANDERSON. Thank you, Dr. Calhoun. Did you hear any of the discussion yesterday about section 202?

Dr. CALHOUN. No, sir; I did not. I was not able to be here.

Senator ANDERSON. I tried to explain that we were not particularly wedded to that. We had to propose some system in order to have a nationally controlled experiment. In the early days of weather modification Dr. Langmuir, in cooperation with a Government project, had a project of seeding clouds at Albuquerque. They found out later that when they seeded the clouds at Albuquerque there was rainfall

at Louisville, Ky. We would like to have had a controlled experiment to find out why this was true.

We never knew who was feeding silver iodide into the atmosphere and when or how. What I had in mind was licensing from the standpoint of finding out what other people are doing so that a record can be kept of the experiments. If Interior is not the place for it then we ought to find a place for it. It seems to me there ought to be some control and records kept of the different projects.

Dr. CALHOUN. If I may comment, sir, I agree with you that it is quite essential that records be kept, and that we should be able to have enough information about all the things we are attempting to be able to see how they interact, and analyze the effects for long distances in time or in space.

Now by license I interpret a restriction upon doing experiments until somebody has said yes, go ahead. It is this flavor to licensing that I think would be a deterrent.

Senator ANDERSON. The point of it is to be able to know what is going on and to control what is going on.

Dr. CALHOUN. That is very desirable.

Senator ANDERSON. Surely we don't want to stop people from experimenting as long as they are not spoiling someone else's experiment.

I mentioned earlier in the hearing a project in my State where they had some generators and hired one boy to run them who had not had even an eighth grade education. He looked up in the clouds and said, "It looks like it is going to rain, I will turn the cooker on" and the test would resume. There is not too much science about that.

Dr. CALHOUN. That is a little too empirical to my mind.

Senator ANDERSON. We have had some discussions about in-house work, a criticism perhaps because of the fact that the Department of Interior, through the Bureau of Reclamation, had not the meteorologists it might want. Do you feel it is all right to carry out experiments by contract work with the schools and universities all over the country?

Dr. CALHOUN. It is my opinion, and here I reflect a general philosophy, that a maximum amount of research done by any Federal agency ought to be done through the university itself, private corporations, research institutes, and other nongovernment organizations.

However, I also hold to the philosophy that a Government agency cannot really supervise adequately or understand what is going on completely and direct work through its contractors unless it has within house at least an analytical staff and probably in most cases some research of an in-house nature. My own feeling is that the appropriate balance in Government research and contract research may run something of the order of 20 to 80 percent. But I do think some is necessary.

Senator ANDERSON. I do, too. I do think that the two programs I have been concerned with most, atomic energy and space, have been developed through universities and have been beneficial to the Government. I would not want them to stop.

Senator Bible.

Senator BIBLE. No questions of Dr. Calhoun. I share his enthusiasm for the program. I have heard him many times.

Senator ANDERSON. Senator Moss.

Senator Moss. Mr. Chairman, I appreciate the enthusiasm and concern about this. That was very fine testimony. I appreciate it.

Senator ANDERSON. Senator Allott.

Senator ALLOTT. Doctor, I am sorry that a sudden influx of constituents with problems kept me from hearing all of your statement, but I am informed that a question was raised during the course of your statement concerning where the research should be performed; that is, whether it should be performed primarily in Government facilities, in universities, or other private and quasi-private facilities. I would like to make a short statement and ask you to comment on it.

Recently I had the opportunity of meeting with some 16 or 17 heads of various research projects at the Colorado State University. On this general subject a real concern was expressed by these gentlemen—and I am sure you thought of it although it had never occurred to me before—that when the Government does in-house research or in turn puts it out to private research institutions, the effect is that the Government or its contractor comes into direct competition with the universities who, No. 1, often are capable of this research themselves and No. 2, the Government thereby tends to withdraw from the universities the manpower which enables them to, in turn, produce masters and doctors in the various fields and various disciplines. Therefore when the Government engages in research on an in-house basis it is actually competing with the universities and may destroy the university's capability of providing the new fresh blood of scientific personnel, and to that extent deplete it.

I understand the question was raised during the course of your discussion. Will you comment briefly?

Dr. CALHOUN. Senator Allott. I did not speak to this particular point in my testimony but I will be very happy to comment on it.

It is my own personal belief that university research must go hand in hand—does go hand in hand with the development of graduate students. You cannot do one without the other.

Now if you are going to develop advanced students in a particular area of knowledge you must have access to the experience and to the scientific principles that go along with that area of knowledge. If the Government—which is about the only agency that can support any large-scale experimental work in the atmosphere or the ocean or space—if the Government funds available for this are not somehow made available to universities, this means there is a great big vacuum in the university's access to knowledge and to developing facts which are germane to the development of their graduate programs.

So I am very much in favor of Government funds and programs like this being made available to universities where our new manpower is being developed.

After all, we can talk about the atmosphere and the ocean and all of our other resources but the most important resource we have is people, and our mechanism for developing these people is fundamentally our educational system. We must give this attention while we are doing some of this other work.

Senator ALLOTT. Definite incidents were given to me where to some limited degree, temporarily, the competition of private firms and particularly Government in-house research had to some extent limited the ability of universities to produce new graduate students.

I must confess I should have thought of this a long time ago.

Dr. CALHOUN. It has, sir. I would agree with that.

Senator ALLOTT. But I think it is a very important point which we must keep in mind, when talking about moving ahead on such vast programs as this. I do appreciate your comment to this.

Thank you.

Dr. CALHOUN. Thank you.

Senator ANDERSON. Thank you very much for your testimony this morning.

Dr. CALHOUN. It was a pleasure.

Senator ANDERSON. Dr. Vonnegut.

STATEMENT OF DR. BERNARD VONNEGUT, SCIENTIST, ARTHUR D. LITTLE, INC., CAMBRIDGE, MASS.

Dr. VONNEGUT. Thank you, Mr. Chairman.

Senator ANDERSON. We appreciate having you here.

Dr. VONNEGUT. My name is Bernard Vonnegut. I am the scientist with the Arthur D. Little Co. For over the past 20 years I have been concerned with problems in atmospheric research. My work has been primarily of a scientific nature.

I am grateful for the opportunity this morning to talk. I would like to emphasize what I believe to be the great importance of scientific research if we are ever to have a meaningful system for weather control and cloud modification.

First of all I think it would be well to define what I mean by scientific research. I am referring to studies which I feel must be undertaken to determine how the atmosphere works, how the air moves in clouds, how rain forms in clouds, how storm systems originate.

Now this, while related to the problem of weather modification, I think is somewhat different. There are many experiments that are being carried out that are worthwhile experiments and are necessary to the development of weather modification but that I do not think are the sciences that I am referring to.

For example the experiments in which we make silver iodide smoke or seed clouds from an airplane, these were worthwhile experiments but they are not designed to answer a scientific problem.

They are designed to answer a social problem, an economic problem. I think that it must be stressed that no matter how much activity of this sort is carried out I question that it will provide the basic understanding that we require. So, this morning I am making a pitch for adequate support of fundamental scientific research into the weather, because any structure or technology or cloud modification is going to have to be based on this basic knowledge.

I think it should be emphasized that the research into how the atmosphere works is not a sort of venture that will have a financial payoff for a private organization. In other words, I think that a company would not be justified in spending its own money in research into the atmosphere with the hope of realizing a direct financial benefit.

Although this knowledge is of great value to society and to the country, it is very difficult to see how an individual company can capitalize on it. For this reason I think that essentially the only source of support for basic atmospheric science is from the Government. It is my

feeling that the support has not been adequate in the past and that it should be strengthened in the future.

An illustration of the inadequacy of the support of basic research in atmospheric science is that there have been quite a number of our colleges in this field who are no longer working in the lower atmosphere. It is a fact in the scientific world that it is far easier to get money to study the stratosphere, the ionosphere, the magnetosphere, than it is the troposphere, where the weather takes place.

I think even any effort to speed up the development of the technology of weather modification will have to recognize that the funds must be made available to support a broad program of research.

I think that we have not made nearly the optimum utilization of the resources, scientific resources, that we have for studying the atmosphere. Although the technique or the idea of cloud seeding originated originally in an industrial laboratory, I think it is unfortunate that industrial laboratories have played rather a small part in the development and science of weather.

I think that the people in these laboratories have ideas and techniques for instrumentation that can be extremely helpful and in the future an effort must be made to bring these scientists into the picture.

I know that in some regions of the atmospheric sciences it is necessary that a man have long experience in weather studies and in studies of the atmosphere, but this is by no means universally true. It is possible for a scientist with a good background in physics, chemistry, or engineering to make big contributions to atmospheric studies just in the same way that these men have made great strides and contributions to the field of space sciences.

It is, of course, necessary not only to have funds to support basic scientific research in weather sciences but it is also necessary to have proper administration of these funds. This is, of course, a difficult problem. I feel that Irving Langmuir was correct in a statement that I recall he made that it is impossible to plan scientific research.

About all you can do is provide a favorable climate for it. There are differences of opinion, I know, concerning what a favorable climate for basic research is but I think that one important thing is to have a wide diversity of ideas and approaches.

For this reason I think it would be a very real mistake if we were to attempt to centralize scientific research concerning the atmosphere. It is true, perhaps, that by centralizing a research effort one may increase the efficiency, if there is such a thing, of research.

On the other hand I think that we run a very great risk in having the research, which is essentially an individual enterprise, smothered by a bureaucracy which, in my opinion, inevitably would result. I think that we must recognize now that within the Government we have a rather large number of well trained, very skilled people in the administration of research, in the administration of atmospheric research.

I think that these people have done a good job in the past and they will continue to do a good job in the future. It seems to me that the primary thing is to increase the flow of research funds to the people who will administer and grant support for this work.

Again I think we must recognize that in scientific research one of the most important things is the question that we ask of nature. And if we ask nature a poor scientific question, one that is not adequately

defined, we will not get a scientific answer. In my opinion, while it is of great value to know just how much we can increase precipitation, this information that you can produce a 10- or 20-percent increase is of little value to the scientist in understanding what is going on.

I think that we should recognize that we cannot have double purpose experiments that will answer the social problems of, can we increase precipitation and at the same time yield valuable scientific information? I think it is asking too much of one experiment to do this. While recognizing the need for the rain stimulation experiments and learning by doing, I think at the same time we must be very careful that we furnish adequate scientific support and thank you for the opportunity of making these points.

Senator ANDERSON. That is a fine statement. I am not really sure I understand you correctly. Are you trying to say that we can afford to overlook the possibility of increasing rainfall by 10 percent because we don't understand the scientific ends of it?

Dr. VONNEGUT. No, indeed, sir. I think that we must carry out experiments, it is desirable; I approve of experiments that are designed to find out how much can we increase rainfall. I think we can increase rainfall and I think we should try to increase rainfall.

On the other hand, the growth of the science, in other words, the perfection of the methodology, if we want to understand why sometimes we get an increase of 20 percent and sometimes we get a decrease of 20 percent, when we face problems like that, as I think we will, the scientists are going to be asked why is this so, and in order to answer the question of why this is so, and to avoid failures in the future, it will be necessary to have a lot of background knowledge, basic knowledge of how clouds work, how the air moves in them, how the particles grow, the nature of precipitation forming processes.

The point I am trying to make is that experiments of the sort where you seed clouds and see whether it increases rain or not, while valuable, will not answer the basic scientific questions.

They are not designed as a scientific experiment. I think that it must be recognized that even though such experiments may utilize what we call a scientific approach, even though it may utilize statistics and a lot of scientific apparatus, it is not what we would call a good scientific experiment. It is not the sort of experiment that will provide the type of information I am talking about.

Does that make it any clearer?

Senator ANDERSON. Yes. Thank you, it does. One gentleman from Arizona is saying that, although they had a good program of cloud seeding, the rainfall was less than it had been over a long period of time. Therefore it could be possible that they hit a very dry period and would not have had rainfall at all if they had not had cloud seeding. You do believe it is possible to increase rainfall?

Dr. VONNEGUT. I think, if I may deal with this question at a little length, that the situation now in the scientific world is that everyone believes that precipitation can be increased and agrees that it is possible by cloud seeding to turn supercooled clouds into ice crystals. This is not a questionable thing.

Cloud seeding works and it works every time.

It turns the supercooled cloud into ice crystals. Now from all experiences that we have in science we know that—first of all we know that the cloud seeding changes the number of particles in the cloud by

a hundred or a thousand or even a million. It changes the vapor pressure. Then it changes the temperature. It changes the humidity. Now if treating a cloud in this way did not affect the precipitation and the subsequent life of the cloud, this would be the most startling thing in the world. If it turns out that cloud seeding does not increase or decrease rainfall, but has no effect at all, I will go into a different kind of business.

Senator ANDERSON. I will join you wherever you go.

Thank you very much.

Senator BIBLE. That is a very fine statement. I want to compliment the doctor on it. You say you need adequate funding. What range are you talking about?

The authorization in the bill calls for, as you know, $35 million for the first year, not to exceed $50 million for the second, not to exceed $70 million for the third year.

From then on it seems to be open ended. The bill says such sums thereafter as may be necessary. Is it possible to put an overall price tag on experimental research? I have asked this question several times and most men I have talked to say it is not possible. I don't know. What range are we talking about?

Dr. VONNEGUT. When I see the figures of $30 million or something of this order, it strikes me as being a lot of money and adequate to support a program. This scientific effort I am speaking of will be small financially compared to the overall effort that is being considered here.

The thing that I wish to be sure of is that there is an understanding of the effort for scientific research rather than precipitation. It is a relatively small but vital part of the effort. I think it should be made clear to everybody involved that the scientific effort is to find a reason why things happen. I am afraid, if it is not made clear, we may face a problem in the future of saying, while we spent so and so many million dollars in basic research and scientific research under the assumption that just because there were scientists and scientific apparatus involved, that basic science was being undertaken. It is not a large sum of money I am speaking of, but I think that, in the past, money that has been allotted for scientific research has been used to carry out experiments to see just how much could you increase rainfall.

Now this is a very important social question. In other words, it is a question that must be answered for you gentlemen. It is a question that must be answered for the farmer, for industries who are considering putting money into cloud seeding.

Scientific answers are not going to help them very much at this stage of the game. They want a practical answer. This is a very important social problem but it is not a scientific one.

I think that we can waste a lot of scientists' time if we involve them in this question. In other words, I think there are good important scientific questions that have gone begging because of the enormous pressure to answer this social question.

Senator BIBLE. The thing I was driving at was prompted by hearings we had a year ago in the Appropriations Committee, of which I am a member.

At that time Senator Margaret Chase Smith entered into the record a statement taken from a magazine saying that weather expenses by agencies showed a total of $431 million spent by 17 agencies.

They were listed and the breakdown was inserted in the record. However, Dr. Hollomon questioned the figures and said they were all ranges of weather modification and weather observation and Weather Bureau and National Science Foundation, and so forth.

He asked liberty to submit for the record a table showing the agencies engaged specifically in weather modification, narrowing them down to weather modification.

His statement showed that five agencies for fiscal 1965 spent a total of $4,675,000, rather than the $431 million, for modification research.

I assume that latter figure is approximately a correct amount the Federal Government is funding throughout these five agencies for the specific problem of weather modification. I am just trying to put this into perspective and see if this is the range of figures that we are talking about. I am sure that we are going to be asked, Are these realistic estimates? That is all I am trying to find out.

Dr. VONNEGUT. I think it is true that the portion of weather money that is spent on research is very small indeed. There is a large data-gathering program involved which is necessarily very expensive. I think that if we were to break down the money that was actually spent on what could be termed basic meteorological research that we would find that it was a very small amount indeed.

Senator BIBLE. That is what I was trying to determine.

Senator ANDERSON. Senator Allott.

Senator ALLOTT. I was interested in what I took to be your emphasis on basic research in the first part of your statement. Do you think that NCAR has a capability of contributing greatly in this area?

Dr. VONNEGUT. I do. I think the National Center for Atmospheric Research will fulfill a very useful purpose here and that this is one group that can serve as a central clearinghouse for studies in basic meteorology. I know that my own experience in visits there is that they have been very useful to me in giving me information on work going on elsewhere, exchanging opinions, and we have been most fortunate in the past year in utilizing their flight facility, which has provided us with aircraft to make measurements in clouds.

This is a very special business. Not any airplane, not any pilot will do. It is a tough job. They have been most helpful to us and to other weather scientists who face the problem of getting information.

Senator ALLOTT. You don't know how much of a stimulus you just gave me. You have no idea how much effort it took to get that plane for the National Center for Atmospheric Research.

Dr. VONNEGUT. I can assure you that there are many people who thank you.

Senator ALLOTT. There is one part of your statement on page 2, I would like to refer to. Perhaps it is academic question but you talk about the dangers of bureaucratic control having a siphoning effect on scientific effort. On the other hand we see these popular movements and the next great popular one after space and Appollo might well be weather modification and atmospheric research and so everybody will try to get in on it.

Do you not think—I am sure you agree—that we who are Members of Congress, particularly those of us who serve on the Appropriations Committees, have a particular effort to see that this program is hardened to some extent and that we just don't pass out x millions of

dollars to commissions and bureaus within the Government to undertake research in this area?

If you were sitting in our shoes and had this responsibility to your people do you not agree that you would take a pretty hard look at that angle?

Dr. VONNEGUT. That is a difficult job, administering research. The reason that I have suggested the utilization of existing channels is that, as you know, there is a fair amount of research supported by the Government and there is a fair amount of very good background and basic research supported by the Government.

Now this is done, as it should be done, in terms of people. In other words, when you get right down to it, the scientific effort is generally up to one man and that scientific research is not accomplished by committees. The idea, for example, that I think one can fairly say is responsible for our being here today considering weather modification, is Vincent Schaeffer's discovery of cloud seeding in the laboratory.

Now this was undertaken by an individual following his own curiosity. I think that, to a large extent, supporting basic research is a problem of supporting good people. In other words, it is supporting people who have demonstrated that they can do things in pure science or it is supporting people who give some indication that they will be able to do good work.

It is an individual matter and in the Government presently research funds are to a large extent given out on the basis of small individual grants.

Now this is not efficient but it is——

Senator ALLOTT. Did you say it is not efficient?

Dr. VONNEGUT. It is not efficient. In other words, I have had experience in which I have had a small research grant from a governmental department and this involved getting together with the monitor of the contract and talking it over with him from time to time. He would visit and see what we were doing.

All of a sudden the work was stopped. The reason it stopped was that there had been a decision made in the Government to make things much more efficient. What was done was to give a number of million dollars to one large research corporation so that they could administer these funds in a more efficient manner, and had an overall capability for conducting research.

I think that research is essentially a rather inefficient sort of thing. In other words, it is deceptive. When you look at the research operations, you say, well, this organization is doing fairly well but think what we could do if we really organized it. If it does this well with a poor organization think how well it can do with a good organization.

It has largely been my impression that when research organizations get fixed up and centralized and steered by committees, that the caliber of the work goes down.

Senator ALLOTT. Your answer is partially responsive and partially not. I can see offhand, and I think I can tick off perhaps at least a dozen departments of Government which could, perhaps with some degree of legitimacy, claim an interest and a right to proceed with this. One of the basic purposes of the bill before us, as I understand it, and I think I do, is to try to center some of the responsibility for this program in the Department of the Interior.

I realize they have an individual doing the work and that the results of basic research often depends upon the capabilities of the individual who leads the research team.

It is his constructive thinking, imaginative thinking, that results in the basic research findings. Yet as stewards of the money of the United States it has become painfully aware to us that there is not an inexhaustible supply of money.

Somewhere there must be a happy meeting ground from the point of view expressed by you and the responsibilities of Congress who have to meet not only the demand for research in this very important field—I think all of the Senators here are cosponsors of this bill—but also has to meet this demand in a thousand other areas, not forgetting the approximately $600 million spent by the Defense Department and considerably more will have to be spent for the next jump when you are getting into the field of applied research.

These decisions have to be made. Somebody has to make them. This Congress has to make them. I agree with your premise, and I am not a scientist but I have talked with a lot of them, that the individual must be left a great deal of a latitude as to how he pursues this research.

If I were to tell a physicist, for example, that he ought to do it this way or that way, it would be about the most absurd thing that could occur. On the other hand, if someone who is presumably knowledgeable in these fields, such as the personnel gathered together under the National Science Foundation as one example, does not provide some orderliness to this whole effort we may end up, could well end up in a position worse than we are in now.

It was the intention of this committee to place the basic responsibility within the Department of the Interior, not eliminating the National Science Foundation or any of these things, but rather to try to bring a sense of orderliness out of this whole endeavor.

Dr. VONNEGUT. May I speak to the point you raised of justifying expenditure of funds?

I am very sympathetic as a taxpayer with what you say and I applaud it and I think that the Government faces a very serious problem when it gives out money for basic research and finds out how it is doing, did I get my money's worth?

This is an easy thing to do in the case of a battleship or an airplane. It is delivered to you and you can test it and see whether it measures up to specifications. In research large sums of money are spent and when it is all over people want to know, How did we do? The procedure in the Government now, insofar as I have been able to see, is not a very safe one.

When you get money for research they require the final product which is a report and a certain number of reports are specified and they go to the Government and they are filed away someplace generally and it is a very difficult matter to know whether it is any good or whether it is not.

But the one thing that you may be sure of is that it has to be on good paper and that it has to be pretty impressive.

In other words, you should have probably a hundred thousand dollars for basic research. It seems to me, with my experience with governmental research, that when you have done some research and

handed in your report if some of it happened to turn out fairly well you might want to publish it because this is really what you are supposed to do in science.

Now if you want to publish this, in general I find among the Government departments that they are very leery of giving you permission to publish in the scientific literature which is really what it is all about. I suggest that the government could get much more for its research funds and have a much better idea how it is doing if, instead of asking reports for basic research, they would say, we would like to have the customary end product of scientific research, that is scientific publications. You must publish, or you should publish, so that the best people in the scientific field will go over the work with a fine tooth comb.

They will not be impressed by how thick it is but they will be impressed by what it says, and what it does not say, and whether it is right or whether it is wrong. I think it would be far better for Government, when it gives out money for basic research, to say that we hope that this work will be publishable. However, if it is not, upon written request we will allow you to submit a report in lieu of the published work. It seems to me that this would have a very salubrious effect on research the Government sponsors.

Senator ALLOTT. In basic research, negative reports may be constructive, may they not?

Dr. VONNEGUT. That is right. There should be some piece of paper certainly at the end of it. I think the piece of paper will be much better and much smaller if they are published. When you write a report my experience has been that you can safely say almost anything with the secure knowledge that it is not going to be widely read.

On the other hand, if you publish something, then you are out in front of everybody and fair game and I think this is the way it should be.

Senator ALLOTT. We could carry this on a long time. Your discussion has been very helpful. Thank you very much.

Senator ANDERSON. Senator Moss.

Senator Moss. I don't think I have any questions, Mr. Chairman.

Senator ANDERSON. Senator McGovern?

Senator MCGOVERN. Doctor, do you think this legislation before us, S. 2875, does have the kind of framework that would encourage the type of basic research that you think is desirable?

Dr. VONNEGUT. I think that it has a framework in which such an effort could certainly be fitted. As I understand the bill, there is going to be money available for furthering the technology of weather modification. I think that there is a great deal of latitude in how this money can be used.

This will be largely up to the individuals who will be administering the funds. I can see that, under this framework, a great deal of good can be accomplished. On the other hand I think it could be wasteful. I think much depends on the details and I have spoken in the hope that the scientific end of things will be recognized and that an effort will be made to see that this is supported.

Senator MCGOVERN. But you don't think that the bill is drafted in such a way as to discourage basic research?

Dr. VONNEGUT. No, indeed I do not.

Senator McGovern. The legislation, as you know, authorizes the Secretary to make contracts with a wide range of institutions, organizations, including private firms. Would that meet your suggestion for decentralization and considerable flexibility in the execution of the research?

Dr. Vonnegut. Not necessarily. I think if you have one organization that is responsible for giving out funds in this field that it can very well be dominated by a particular point of view. It will not admit of any diversity. I think that we should guarantee that there are a number of possible scientific approaches.

I think that it could be a very bad effect if the control were so centralized that it could be dominated by one individual or by one school of thought.

Senator McGovern. Thank you very much.

Senator Anderson. I am glad you realize, I know you do, that this is primarily a bill to increase rainfall. That leaves out all the other questions that involve control of hurricanes, and so forth.

Thank you very much, Dr. Vonnegut. We are glad to have your testimony.

Mr. Ramey, we are glad to have you here. We know you are interested in this subject.

STATEMENT OF JAMES T. RAMEY, COMMISSIONER, U.S. ATOMIC ENERGY COMMISSION

Mr. Ramey. Mr. Chairman, I have with me Mr. J. Z. Holland of our Division of Biology and Medicine and Mr. John Reich of our legal division.

The Atomic Energy Commission is pleased to be heard by this committee and I am particularly glad to have this opportunity to speak for the Commission in connection with S. 2875, a bill to authorize and direct the Secretary of the Interior to conduct a comprehensive program of scientific and engineering research, experiments, tests, and operations for increasing the yield of water from atmospheric sources.

I might say it was something like 10 years ago that Dr. Von Neumann, one of my predecessors on the Atomic Energy Commission, had something to say on this subject. As this committee knows, AEC is programmatically interested in augmenting available water supplies.

I refer specifically to the extraction of usable water from the oceans—a program, which, in both national and international perspective—is presently being conducted on a high priority basis by the Department of the Interior and its Office of Saline Water.

The Commission is cooperating to its fullest extent in relation to those portions of the desalting program which engineering and economic studies indicate can advantageously employ nuclear reactors to supply the heat needed for the desalting process.

AEC is dovetailing its knowledge and ideas in the nuclear respects with Interior's plans for the conduct of the desalting program, and I must say that the total cooperative effort has been smooth and substantially effective.

I shall not go into the details of this relationship in the desalting program unless the committee wishes it. I mention it to underscore the complete availability of such assistance as AEC may, in the course of

evolvement of the total research and development effort, be able to provide. At present, I should point out, AEC's programmatic interests, including our interest in the general field of atmospheric sciences and our development of nuclear energy devices for use in unattended weather stations at sea and in space, do not include any direct participation in controlled weather modification.

As the weather program develops, it is very possible we may be able to contribute. If we can, we will to the best of our ability. In this regard, I should point out—as we have called to the attention of the Joint Committee on Atomic Energy—AEC endeavors to contribute to the objectives of the programs of other Federal agencies not only when requested by those agencies based on their formally expressed requirements, but also by developing technology—often to the point of actual demonstration—which other mission agencies can take into consideration in the development of their formal requirements.

This is the sort of cooperation Interior can count on from AEC if this bill becomes law. I should say, at this point, that if Senator Magnuson's bill, S. 2916, becomes law, AEC will similarly extend its fullest cooperation as I have described.

Furthermore, any program to modify any aspect of weather or climate is of interest to us, since many of our activities are subject to weather restrictions. The careful choice of sites, the consideration of climate in the design of facilities, the influence of weather on construction schedules, and the frequent costly delays of important experiments of various types are well known to you.

In a broad sense the Commission has much to gain from an increased knowledge of the workings of the atmosphere.

During the current fiscal year the AEC is spending over $7 million on atmospheric research directly related to our mission, and about $1.2 million for meteorological services.

At least five divisions of the AEC are supporting research and development in this area. Those having substantial programs are the Division of Biology and Medicine, the Division of Military Application, the Division of Peaceful Nuclear Explosives, the Division of Reactor Development and Technology and the Division of Space Nuclear Systems.

This work is most heavily oriented toward predicting the movement and fallout of radioactive contaminants which may be released to the atmosphere by various types of nuclear operations. The studies deal with transport processes throughout the atmosphere, from the local environment downwind of an industrial chimney to the upper stratosphere and beyond.

The action of rainstorms in bringing airborne particles to the ground is an important factor in the fallout picture and is being studied in detail as part of this program. These studies, in turn, are contributing to an increased understanding of some aspects of the physics and chemistry of rainclouds.

We are not conducting research on weather modification as such.

Although none of the following has appeared sufficiently likely of attainment to warrant serious development, various speculative suggestions have been put forward from time to time for using nuclear enegry to affect the precipitation of atmospheric moisture or to modify the weather in some other way.

These suggestions have involved, for example, using heat released by nuclear detonations or nuclear reactors to weaken the wind circulation of a hurricane, to create a cloud blanket over the Arctic Ocean and thereby change the global heat budget, or to cause moisture to rise over coastal mountain ranges and thus provide increased precipitation in the arid interior.

Even more speculatively, suggestions have been advanced as to the possibility of modifying the climate of large parts of the world by diverting ocean currents, damming straits, or opening new channels for the seas. If such vast earth-moving projects are ever to be undertaken, nuclear energy could well play a part in their execution. However, serious consideration of such schemes must await much more complete knowledge of the mechanisms of operation of the global atmospheric circulation, as well as many other factors.

The point of bringing up these seemingly fanciful proposals is that the sources of energy are available or becoming available and the technology can rather rapidly be developed to make quite radical changes in our environment. It is our lack of understanding of the ramified consequences of such acts that restrains us most severely.

Even man's production of atmospherically contaminating by-products, though unintentionally, have a strongly interrelated effect on efforts to modify the weather beneficially. To cite a strong example, the "Report of the Environmental Pollution Panel, President's Science Advisory Committee," issued by the White House in November 1965, states under the head "Climatic Effects on Pollution":

> Carbon dioxide is being added to the earth's atmosphere by the burning of coal, oil and natural gas at the rate of 6 billion tons a year. By the year 2000 there will be about 25 percent more CO_2 in our atmosphere that at present. This will modify the heat balance of the atmosphere to such an extent that marked changes in climate, not controllable through local or even national efforts, could occur. Possibilities of bringing about countervailing changes by deliberately modifying other processes that affect climate may then be very important.

AEC is, of course, happy that nuclear power reactors, which are becoming commercial, do not contribute to atmospheric pollution. If carbon dioxide does threaten to create a global weather problem, the increasing use of nuclear power will certainly contribute to the alleviation of this problem.

In the field of water resources, as indicated above, the Commission has a very close working relationship with the Department of the Interior. Our water desalination program is another method of providing fresh water to areas of the world where it may be in short supply. Here again, in the very long term, side effects must be anticipated. Irrigation and cultivation of large areas which had previously been deserts can be expected to lead to modifications of climate. With increased evaporation, cloudiness might increase, extremes of temperature become more moderate, and other climatic changes might occur.

Senator ANDERSON. Mr. Ramey, I have been following what the Atomic Energy Commission is doing in desalination. I think it is an extremely commendable job, and I wish to commend you on it.

Mr. RAMEY. Thank you, sir. We have had excellent cooperation with the Interior Department, as I have indicated. We think we have a very well balanced program and we would like to go ahead with some hardware projects in the next few years.

Senator ANDERSON. You are making very good headway. I commend you for it.

Mr. RAMEY. Another aspect of our work which has potential application to the conservation of water resources is the AEC's Plowshare program, or peaceful uses of nuclear explosives. An example is the use of such explosives to connect sources of water currently lost by runoff to naturally existing storage reservoirs, or aquifers. Other examples are the creation of craters to collect water which is excess at certain times of the year, and the digging of water conveyance ditches.

The AEC has close working relationships with other Federal agencies interested in meteorology and the atmospheric sciences. In fact we rely on other agencies to provide many of our needs in these fields.

The Environmental Science Services Administration (ESSA) of the Department of Commerce performs certain work under contract to the AEC. ESSA furnishes routine meteorological information as well as specialized atmospheric diffusion forecasts to support the test programs at the Nevada Test Site and the National Reactor Testing Station in Idaho. Several laboratories within the Institute of Atmospheric Sciences of ESSA derive a substantial part of their funding from the AEC. These laboratories do fundamental research in atmospheric turbulence and diffusion in addition to providing much of the information necessary for forecasting radioactive fallout levels.

Mr. Chairman, you may recall that Dr. Marka, then of the Weather Bureau, provided some very objective testimony in the fallout hearings in 1957 and 1959.

Our relations with the Department of Defense in the area of atmospheric sciences are varied. The Air Weather Service of the U.S. Air Force carries out part of our high-altitude sampling program under a contractual arrangement similar to that with ESSA. Jointly we are developing improved air sampling equipment. The Defense Atomic Support Agency (DASA) conducts a complementary sampling program, the data from which are used by the ESSA group and our own scientists in their evaluations of global atmospheric radioactivity. We have many mutual interests and frequent contacts with the various Defense agencies in the areas of fallout, blast propagation and radiation effects in the upper atmosphere.

Similarly the Commission has many mutual interests and close working relations with the Public Health Service of the Department of Health, Education, and Welfare in the fields of radiological health and air pollution.

The National Science Foundation and the Atomic Energy Commission have many joint interests within the sphere of atmospheric sciences. Research programs at several universities receive funds from both agencies in an effort to combine excellent basic research with the adequate attention to the problems of greatest interest to the Commission. To the extent that our future needs may involve applications of knowledge in areas which we cannot now clearly identify, we are in a real sense dependent on the continuing support of basic science by the National Science Foundation.

I might add also, Mr. Chairman, we don't have any problems of issuing research reports and getting them published in the literature.

With respect to weather modifications, we are convinced that the public interest requires Federal planning and Federal control. Frag-

mented tinkering with the atmosphere by various local groups for special, individualistic purposes could create a heavy imbalance of social and legal problems in relation to the small overall gain in knowledge and other benefits for the common good.

Now, AEC is not in a position to recommend the assignment of the program contemplated by S. 2875 to any particular Federal agency. With respect to all the significant aspects of controlled weather changes—whether the objective is to extract water from the atmosphere, to prevent rainfall, or to disperse hailstorms or hurricanes—we recognize that they are significantly intertwined.

There are two features of S. 2875 that appear to us to serve particularly worthwhile purposes, and I would like to comment on these very briefly.

As we understand it, the bill provides, in effect, for the protection of the public and those participating in the program, in connection with injuries, losses and damages that individuals may suffer while progress for the many is being pursued under such a program. This is done by a broad allusion to the Atomic Energy Act of 1954, as amended, with the intention, as we read it, to incorporate in the bill by reference the concept of indemnification against the consequences of nuclear incidents as embodied in the Atomic Energy Act. This concept—an imaginative but well-considered, pioneer treatment providing for specific protection, in advance, of the public and of those engaged in the nuclear activities by means of a Government indemnity mounted on a base of available insurance—bears the distinguished name of the senior Senator from New Mexico in hyphenated association with Representative Price of Illinois.

The Price-Anderson Act has, in our judgment, enabled the present successful stage of AEC's cooperative power reactor demonstration program and, indeed, contributed invaluably to the progress of the whole reactor developmental effort.

We have not yet thoroughly thought through whether the Price-Anderson Act can most usefully be adopted in whole for the weather program, as contemplated by S. 2875, or whether a modified or entirely different system would more advantageously suit this program. We are convinced, however, that it is realistic and wise to treat this important subject. And we will be pleased to offer the services of our lawyers, if you wish, to assist in any deliberations respecting the utilization of our Price-Anderson concept.

The other feature of the bill that strikes us as particularly apt is the requirement for Federal licensing of weather manipulation. As in the case of the indemnity feature, the bill alludes to AEC's licensing procedure—which we in AEC have endorsed for our own purposes during the initial and present stage of the program to encourage widespread participation in the development and utilization of atomic energy for peaceful purposes. We believe appropriate Federal licensing control of weather modification activities would also be highly desirable, whether or not the licensing procedure parallels AEC's. In this regard, too, we will be happy to make available the knowledgeable services of our staff.

We have had considerable experience in developing licensing procedure and practices to enhance the utilization of new technology for industrial and other peaceful purposes. Considerations of health and

safety have always been preeminent in connection with our regulatory planning and activities. We have also endeavored to maintain an appropriate separation between AEC's developmental programs and AEC's regulatory division. Some things we have had to learn the hard way. We would be happy to pass along the results of our experience to any agency which is assigned the new mission contemplated by this bill.

Again, may I say that we appreciate this opportunity to appear before this committee in connection with its consideration of the important subject covered by S. 2875.

Thank you, Mr. Chairman.

Senator ANDERSON. Thank you, Mr. Ramey. I want to thank you for getting up the report promptly. It has been very helpful to us. I am glad to see you comment about licensing. There were many people who thought that section of the atomic energy bill would be difficult to administer because it might hamper the development process. Has it worked out that way? It has not been a hindering device, has it?

Mr. RAMEY. No, sir, as a matter of fact, it is thought to be one of the several measures that was absolutely essential for private enterprise for privately and publicly owned utilities to undertake the prototype and commercial development and operation of nuclear powerplants.

You may recall in the 1950's and 1956 and 1957 the utility company people, for example, Commonwealth Edison of Chicago, which is a rather farsighted private utility, indicated that they thought they had to have a licensing control and indemnity protection which the Commission and the Joint Committee on Atomic Energy thought had to go hand in hand in order for a commercial industry to get established.

Naturally enough, a licensing process and the indemnity provisions do provide for redtape to some extent and we have to be constantly alert to means of improving our licensing program. In this connection the Atomic Energy Commission last year, at my suggestion, appointed a panel of distinguished attorneys and members of the utility industry, the atomic equipment industry and people outside to review our program and make recommendations.

This panel, which we call the Mitchell Panel, came up with some recommendations and the Commission about 6 weeks ago started putting into effect some expediting procedures that do away with some of the redtape that was established but which would at the same time protect public safety.

Senator ANDERSON. Then they built a second plant and now they are talking about a third plant.

Mr. RAMEY. Yes, sir, they have announced a third plant that they intend to construct under our licensing procedures.

Senator ANDERSON. Thank you.

Senator BIBLE. That is a very fine statement. I compliment you on it. I appreciate the emphasis you put on public indemnity. The experience of AEC will aid us in contending with some of the pitfalls that we might have in the field of weather modification.

Thank you very much.

Mr. RAMEY. Thank you, Senator Bible.

Senator ANDERSON. Thank you very much, Mr. Ramey. Thank you for your offer of help. I am sure you can help us a great deal when we come to drafting the legislation.

Dr. Mordy.

Senator BIBLE. Mr. Chairman, it is my privilege and pleasure to introduce to the committee Dr. Mordy. Dr. Mordy is a meteorologist, a very worldwide known cloud physicist, if that is the correct designation of his work, in the field of weather modification.

He came to the University of Nevada about 6 years ago, founded the Desert Research Institute, is the present director of the institute. We feel they have done outstanding work in the field of weather modification.

He has performed ably and well. He was recently appointed as vice president of the University of Nevada. That he deserves. He has a presentation with pictures that will be most interesting to the committee.

It is my privilege to introduce Dr. Mordy.

STATEMENT OF DR. WENDELL A. MORDY, VICE PRESIDENT, THE UNIVERSITY OF NEVADA

Dr. MORDY. Mr. Chairman, I appreciate very much the opportunity you have afforded me to testify before your committee to present my views on the need for support of weather modifications activities and to lend my support to the objectives outlined in Senate bill 2875, as introduced by Senator Anderson.

For the background of the committee, my field of specialization is cloud physics. I have been active in this field since 1947 when I became associated with one of the early groups working on weather modification problems in Hawaii.

In the years that followed I have been involved in cloud physics research work in Australia and Sweden as well as in this country. I am now director of the Desert Research Institute which has an active program in weather modification. The support for our program is derived from both public and private sources. The primary sources have been the Nevada State Department of Conservation and Natural Resources, the National Science Foundation, and the Bureau of Reclamation.

During the past several months there has been a great upsurge in discussions about the future of weather modification. These discussions have been derived from three primary events which have been the subject of much of the testimony before this committee and the Commerce Committee. These events are the entrance of the Department of the Interior as a major participant in weather modification research, the issuance by the National Academy of Science of their report on weather modification research, and the report of the Special Commission of the National Science Foundation on weather modification.

As I have read these reports and listened to the testimony, both before this committee and the Commerce Committee, it has struck me that certain facts have escaped the emphasis they deserve, or have been somewhat confused in the testimony.

The first is that there has been a tendency to talk about weather modification on a global scale, to talk about the international problems

which may result from large-scale weather modification experiments, and to anticipate prematurely, I believe, some of the problems which lie in all probability rather far in the future.

It seems to me that for the moment when we speak of weather modification we are mainly speaking of cloud seeding. Other suggested schemes for weather modification have yet to be proven. It seems unlikely to me that any of them are near the point which would justify congressional hearings or special appropriations beyond those already appropriated for basic or exploratory research.

The second point which has bothered me has been the tendency to overemphasize, in my view, the interdependence of cloud seeding and weather modification on weather forecasting or the global weather observation systems. Cloud seeding has advanced from its beginning in 1946 to its present level of achievement without requiring similar progress in weather forecasting. As a meteorologist I cannot help but agree with those who have testified that that an increase in the general knowledge of meteorology will contribute substantially to the progress in weather modification. But I believe it is a distortion to feel that nothing can be done in weather modification until we can more accurately predict the weather.

The reasoning which lies behind the suggestion that forecasting precedes weather modification is that without prediction we otherwise will not know what the effects of cloud seeding or weather modification are. In terms of increasing precipitation and measuring the results of cloud seeding, I believe that we can now show evidence that weather forecasting, while useful, is not essential to observing and measuring the results.

The third point which I believe needs additional emphasis is that the reports from the National Academy of Science and the National Science Foundation are more favorable than earlier reports, but they continually emphasize the need for more statistical design and analysis. Yet in them the one piece of evidence on the effectiveness of cloud seeding which has won universal acceptance is the cold fog dispersal possibility. Curiously, no one has asked for statistical evidence of this possibility. This can be seen with your own eyes.

I call your attention to the chart which sits on the chair over here which shows a hole in the cloud over the Reno Airport a year ago this January, produced by seeding with dry ice. It is like a spot on a white tablecloth made with black ink. I don't think anyone questions that the dry ice affected the clouds in this case.

The reports of the National Academy of Science and the National Science Foundation have been welcomed by all of us in the field of cloud physics. We have felt that they were long overdue and represented a great stride forward in the general understanding of the problems involved in weather modification.

Nevertheless, there are many of us who feel that the statements are overly conservative and dwell on many factors which are peripheral to the needed central emphasis on cloud seeding. Cloud seeding works. The results are not "ambiguous" as the reports indicate. Rather, they are limited and imperfect because of the scale of effort mounted thus far in this country and resistance in some quarters to more extensive effort.

Today we see that resistance fading away, and it appears to be time to get on with the job.

I would like to show you some new evidence of cloud-seeding effects which has been collected very recently with the help of the increased support for weather modification in the past 3 years or so. In 11 consecutive tests, dropping dry ice in supercooled stratus clouds over the Lake Tahoe area, snow fell. The clouds were from 3,000 to 6,000 feet deep; the snow fell from the seeded areas of the cloud where no other snow was falling.

How did we know that it would not have occurred otherwise? Because we had good radar control from three locations; positioning our aircraft within 50 feet, determining the wind velocity which carried the seeding material along in the cloud, and detecting the precipitation which resulted.

Moreover, the control and precision of these tests was so good that we literally produced desired patterns in falling snow in the clouds. These patterns were detected by a radar and photographed. Photographs attached to this testimony show a letter "R" Morse code, (. — .) written over Reno, produced in such a cloud on the 23d of last month, the photograph of the radarscope off the Meeks radar. We dropped ice for a mile, stopped for a mile, went 2 miles, stopped for another mile and then seeded for a third time. What you see there is a radar return from the snow which fell in that particular seeding experiment. This occurred on the 23d of last month. I can assure you if you don't like the letter "R" we will put some other letter up there for you. We are not agreed in the Institute whether the "R" is for reclamation, Reno, or research, but they are all related.

These results were possible because of the availability of expensive radar equipment on the surplus market. They were possible because we had been able to mount a large research program at the University of Nevada with increased funding available, primarily from the Department of the Interior. It was possible also because we have been able to put together a team of 25 specialists, engineers, meteorologists, and technicians, and an engineered system of observations which heretofore we could not afford. I hope they suggest the kind of thing that can be done in the future when this country is ready to make a bigger commitment to the cloud seeding and weather modification effort.

In regard to the bill before you, I have three statements I should like to make:

(1) This bill is timely and comes on the heel of the two reports which have been referred to frequently in these hearings—National Academy report and the National Science Foundation report, both of which recommend a strong increase in the activity aimed at increasing our water supplies by cloud seeding and weather modification.

(2) The bill represents the scale of effort in funding required to move forward in this field. Up to this time public spending for weather modification has been such that the projects have been characteristically small. Most of them have been funded with a few tens of thousands of dollars, and in only a few instances two or three hundred thousand dollars. Such projects are extremely useful in identifying problems in planning and in carrying out pilot scale programs, but in weather modification, as we have seen, they have not produced definitive results. Often they have been hit-or-miss pro-

grams consuming long intervals of time with very limited and often inconclusive data.

If the funding contemplated in S. 2875 becomes available, integrated observational systems will be possible, designed to do the task of verification and designed to increase systematically our knowledge of cloud physics.

Thank you, Mr. Chairman.

Senator ANDERSON. Thank you, Dr. Mordy. I think this illustrates why you bear the good reputation that you do. I am glad to see you indicate some work that you were able to get done with these increased funds from the Department of the Interior.

There has been much discussion about in-house capability and contractor work. I think you have demonstrated it is possible to contract the work on a pretty good scale. Is the educational field providing an adequate number of qualified scientists in this field of cloud seeding?

Dr. MORDY. Not for the scale of effort that we would like to see mounted in this country. I think there has to be a great increase in the support of meteorological programs in the universities. As soon as we got our team together we began to have offers from the physicists from some of the other institutions who would like to have some of our people.

This is characteristic of science nowadays as you are well aware. Along the increased program in weather modification, we must have an increase in the educational possibilities for young people in this field.

Senator ANDERSON. What do you consider a reasonable size areawise for a strong field experiment?

Dr. MORDY. This all depends on your objectives, Senator Anderson.

Senator ANDERSON. My whole objective is cloud seeding to increase precipitation.

Dr. MORDY. You can do this in terms of the present situation if you want to determine the potential of the cloud seeding. This can be done in a relatively small area. If you want to show it is possible to produce a 10-percent increase in rainfall over several hundreds or thousands of square miles you would go about your business differently.

I think there is need for both kinds of experiments and I think there should be some very large scale experiments mounted. I am not sure that the universities are the ones to do this.

We have seen evidence that private enterprise is making a very great contribution to this work. It is particularly true, I think, that the contractors under the Bureau of Reclamation have made great strides in the last 2 or 3 years because they are able to do things in areas where it is not convenient for universities to work.

Senator ANDERSON. I am glad to hear you say you think private enterprise should have a substantial part in these projects and also opportunities for universities to contract this sort of work.

Do you think in those two fields we can get enough people to do a real job?

Dr. MORDY. One of the things I could comment on as far as people are concerned, is that our program has taken in at least 50 percent of young people who have had no contact with weather modification activities before they joined us.

One of these is one of our best people, who was president of the Sierra Research Corp., Buffalo, N.Y. He likes to live in Nevada. You may not understand that but it is true. So, he came to Nevada because he wanted to live there and he joined our group. He is an electrical engineer and a former instructor at MIT.

His contribution in this field has been as great as anyone that we have. We have been able to attract a number of people into the field as a result of the increased funding. I believe we will be better able to do that if the program moves forward.

Senator ANDERSON. Senator Bible.

Senator BIBLE. I want to compliment Dr. Mordy on an excellent statement and again repeat my high respect for the wonderful work he is doing in this field. The one question that I have and one which I have asked the good doctor about before is brought to my attention forcibly by his statement that he has put together a staff of 25 people at the University of Nevada who are working in this field.

Now I would think that one of the real problems that you have is in assuring those people that they are going to be able to stay there for a reasonable number of years, at least, and that they are not going to be dependent upon annual fundings, the indefiniteness, I should say, of annual fundings. Does this pose a problem?

What I am trying to say is that if the Congress authorizes this at the suggested level and funds it, say, at maybe half that level for a year or two and then the funding drops off, it seems to me that that poses a terrific practical problem to anybody attempting to run research institutes in this particular field.

Dr. MORDY. Yes, it is a very real problem and all the people in this room who have been concerned about maintaining a group of specialists on problems know what uncertainties do to their ability to hold a group together.

For that reason we have found it desirable to seek support from a number of different agencies in the Government so that if one program weakens we are not too badly damaged.

This has been the practice of a number of universities in this regard. There is a real need, in this kind of program, to mount it over a sustained period of years so that we really can get about our business and can commit ourselves to a program in which there is a large investment in money and a large investment in people, that we can in fact plan some years in advance. Some things take a good many months to put together. If you do not have those months laid out ahead of you you are very wary of entering into them.

Senator BIBLE. I appreciate that comment. I think I asked the same question of Commissioner Dominy when he appeared before the Interior Appropriations Subcommittee last year as to whether or not it was possible to indicate the term of years for this particular project. He, of course, said it was difficult but at least it should go forward for a period of 10 years.

Dr. MORDY. I would say 10 years in a program like this is a minimum.

Senator BIBLE. A 10-year program is a minimum program for something of this kind?

Dr. MORDY. Yes.

Senator ANDERSON. Senator Allott.

Senator ALLOTT. I have no questions. Thank you for a very fine statement.

Senator ANDERSON. Senator McGovern.

Senator MCGOVERN. Dr. Mordy, it is my understanding that there are six or seven educational institutions that have contracts of one kind or another with the Bureau for weather modification. Is there a satisfactory exchange of information among these institutions so that each one reinforces the work of the other?

Dr. MORDY. There has been excellent cooperation and it has been stimulated by the Department of the Interior.

We had a meeting in Paige, Ariz., a few months ago in which all the contractors with the Bureau of Reclamation sat together for 2 days and exchanged information on their programs.

Similarly the Bureau has given somewhat different missions to each of these institutions to perform in the weather modification program. Because of the difference in the missions we each have something to benefit from in our discussions, we have something to learn from our discussions with the other groups.

I think all the programs are excellent, the ones I have seen.

Senator MCGOVERN. There is one in South Dakota Dr. Sloizen is conducting.

Thank you very much.

Senator ANDERSON. Thank you for your testimony.

Dr. MORDY. Thank you, Mr. Chairman.

Senator ANDERSON. Mr. Bollay.

STATEMENT OF EUGENE BOLLAY, PRESIDENT, BOLLAY ASSOCIATES, DENVER, COLO.

Mr. BOLLAY. Mr. Chairman and members of the committee, I am Eugene Bollay, a meteorologist and engineer who has been engaged actively in the field of weather modification for 15 years. I have been in the field of meteorology for 30 years.

I am president of E. Bollay Associates, Inc., which performs weather modification research principally for Government agencies.

I welcome this opportunity to present my views on the legislative proposal in S. 2875, which, if enacted, will significantly affect and advance the management and production of the Nation's water resources. It is essential, I believe, that water in lakes and rivers as well as water in the sky and ocean be considered in the same context—as an important natural resource. In S. 2875 recognition is given to the fact that water—any water—is a natural resource just as are, for example, mineral resources.

Weather modification for increasing the yield of water from atmospheric sources is but one important facet in the total effort on weather modification and climate control.

Thus I suggest that it is equally important for other committees in the Senate and House to recognize and encourage or direct other mission oriented agencies in the Government to fully exploit the potential benefits that weather modification and climate control can provide in fulfilling their assigned responsibilities. There must be full cooperation between Federal, State, and local government agencies, because after all, weather is everybody's business.

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Areas of weather modification which are of necessity of great interest to specific agencies, which are most immediately apparent are:

Elimination of supercooled fogs at airports—Federal Aviation Agency and Department of Defense.

Modification of "warm" fogs—FAA and Department of Defense.

Lightning suppression—Department of Agriculture.

Hail suppression—Department of Agriculture.

Hurricane modification—Department of Defense and U.S. Weather Bureau.

Severe storm modification—U.S. Weather Bureau.

General circulation modification—U.S. Weather Bureau.

We must recognize at the beginning that what we are seeking to do is to change the efficiency of nature's process in order to create a better environment for all mankind. The breadth and complexity of the problems involved will cut across many fields of science and technology and each will require its own special competency and dedicated effort of those who are to solve the problems. This approach to weather modification will automatically insure healthy scientific competition which is so essential to the national interest.

The history of weather modification in this country is typical of the developments of many technical fields. The initial effort was in response to defense requirements. This was followed very shortly by university research (sponsored largely by NSF) and by experimental projects supported by industry to meet its specific problems. It is clear that the time has now come for a coordinated national program to broaden and hasten the development of scientific knowledge and to apply the accumulated knowledge specifically to the welfare of mankind.

And this requires the highest level of national coordination and support—preferably in the offices of the Science Adviser of the President.

The basis for S. 2875 is a recognition of the need for increased water sources form the atmosphere. The proposed legislation would incorporate within the same agency both operative and regulatory functions. Separation of powers is a recognized principle of our law.

The development of administrative law shows that in such situations a conflict of interest eventually develops. No one can serve well as both judge and prosecutor. It would be my suggestion therefore that the regulatory provisions of this bill be separated and made the subject of another bill. I propose that the Federal Government establish a board or a commission that is separate and independent from any operating branch of the Government, much like the Civil Aeronautics Board or the Federal Power Commission. In the absence of such a board and during the interim period that is involved in establishing such a body, to avoid confusion and to insure continuance of existing programs without interruption, I suggest that the responsibility for such regulatory activities remain with the assigned responsibilities of the National Science Foundation; where it was placed after careful deliberations under Public Law 510, on the basis of the recommendations of the President's Advisory Committee on Weather Control, in 1957.

Another area of equal importance is the problem of liability. S. 2875 recognizes the need. I strongly urge that the necessary legislation be passed at the earliest opportunity to protect the individuals as well as the Government agencies who are engaged in such efforts.

Mr. Chairman, I concur in those portions of the conclusions of the two recent reports by the National Academy of Science and the Special Commission of the National Science Foundation which urge that an incerased national effort be initiated. To me, S. 2875 is the first realistic step in this direction.

In conclusion and summary, I recommend that:

(1) The Interior Department be the responsible agency on the Federal level for those aspects of weather modification related to increased precipitation as part of its responsibilities in managing the national water resources.

(2) That other mission oriented agencies who might benefit from weather modification effort be encouraged to formulate their plans and requirements and apply for support from Congress.

(3) That a separate and independent regulatory board or commission be established dealing with, among other things, licenses and legal problems.

(4) That suitable legislation regarding liability be enacted at the earliest moment.

(5) That the NSF be encouraged to expand its research activities and to continue its present responsibilities in this field.

(6) Let it be recognized that the industrial sector of meteorology and the research groups at the universities and other research centers be encouraged to continue as a dominant force in the national program in weather modification.

(7) Coordination between Government departments be carried out through the offices of the Science Adviser to the President.

I wish to express my thanks to this committee for giving me the opportunity to state my views in relation to this proposed legislation.

Senator ANDERSON. Mr. Bollay, I want to thank you for being here and for presenting those views concisely as you have and with specific recommendations on what you think should be done.

The committee is very happy to have you appear here today. You have had a long and illustrious record in meteorology and weather modification. Mr. Bollay was in the Office of Naval Research when Project Cirrus was carried out.

The Office of Naval Research was the basic sponsor of this program with the Army, Air Force, and Weather Bureau working on it. Mr. Bollay pioneered in supplying weather modification to hydroelectric programs with the organization of North American Weather Consultants in 1950.

I know you were a consultant to Capt. Howard Orville and the President's Committee on Weather Control, which filed its report in 1957. You were consultant and member of the National Science Foundation Committee on Weather Modifications. You prepared a design study for the National Science Foundation on an optimum weather modification program which served as the starting point for the expanding Bureau of Reclamation program.

You are now working on Bureau of Reclamation atmospheric water resources programs in Colorado and the Pacific Northwest. We like

the type of witness you are and we appreciate very much your being here.

As one of the early pioneers in this field you have seen this activity swing through several cycles. Do you think we are now embarked on the proper course at the proper speed?

Mr. BOLLAY. I think we have made a good start on this, Senator. I think by implementing the bill that is now before you for discussion we can really go ahead.

I should like to state one feeling if I might as to the character of the program, the nature that the program should really take. The job ahead is to a large extent an engineering effort. It requires all the scientific skills in the universities and research centers. It does not require 10 million meteorologists. It takes engineers, mathematicians, applied mathematicians, meteorology experts, it takes such organizations as NCAR. Senator Allott, I might say NCAR has provided the flight facility to our organization for the work in Colorado.

NCAR is permitting us to use the magnificent computer which is the right size for our operations. The State University of Colorado at Fort Collins is assisting us with this in the calibration of our generators.

We are having nothing but excellent cooperation on the scientific level and research level in Colorado and in the Northwest.

Senator ANDERSON. That is very fine. When you go back to your headquarters in Boulder we want all the advice you have and keep it coming to us.

Mr. BOLLAY. Thank you, Mr. Chairman.

Senator ANDERSON. Senator Allott.

Senator ALLOTT. Mr. Bollay, I am very happy to welcome you to this committee. Your work is very widely known. We are proud of your efforts in Colorado. Like the chairman of the committee I cannot help but compliment you upon the conciseness of your statement.

In our work we have to deal with so many millions of words that it is very pleasant to run across a statement which is concise and unequivocating.

Mr. BOLLAY. Thank you, Senator Allott.

Senator ALLOTT. I am very happy also to learn of your close association with NCAR, the way that the plane has turned out. When we made the justification for it everybody was convinced that this plane was just going to be another private passenger plane for the wanderings of people in NCAR. I got the personal assurance of Dr. Walter R. Roberts as to how it would be used and I am very pleased to receive this double assurance this morning, not only that it is being used the way it is supposed to be used but that it has been of inestimable help.

Last week I had an opportunity to talk with some of the research people with respect to weather modification at CSU and I believe this whole effort represented the kind of scientific endeavor which is most fruitful and will be most fruitful to our country in the long run.

I am very glad to welcome you to this committee.

Mr. BOLLAY. Thank you very much. If I might make one short statement, and I would like to direct this to Senator Anderson, I am convinced that the problem of weather modification and climate control will be the next big central problem that will face the scientific community. Senator Anderson, who has been a pioneer in putting central problems that face this country in sharp focus, I am looking at

you anxiously to make sure that you put this one in sharp focus and give it the proper concentration. I know you can do it.

Senator ANDERSON. Thank you. I will do the very best I can. You are very kind. Thank you for being here with us this morning.

Mr. BOLLAY. Thank you.

Senator ANDERSON. We have another pioneer in this field with us today, Mr. Elliott. You are welcome because we know the work you have done as a pioneer in the field of weather modification and your operations for the Southern California Edison Co. represents the earliest commercial endeavor to increase snow pack and runoff. We are happy to have you here. You will make a fine contribution, I am sure.

STATEMENT OF ROBERT D. ELLIOTT, NORTH AMERICAN WEATHER CONSULTANTS, SANTA BARBARA, CALIF.

Mr. ELLIOTT. Thank you, Senator. I would like first, if I may, to offer for the record a statement by the Weather Control Research Association. I shall not read this but I would like to enter it into the record with your permission. The Weather Control Research Association is a group of interested individuals who have been interested in weather modifications since 1951, meeting twice a year.

It includes such people as the Southern California Edison Co., the University of Nevada, North American Weather Consultants, E. Bollay and Associates, Howell, and that sort of people.

Senator ANDERSON. Without objection it will go into the record at this point.

(The document referred to follows:)

STATEMENT OF POSITION OF THE WEATHER CONTROL RESEARCH ASSOCIATION

The Weather Control Research Association has been in existence since 1951. It is composed of people interested in all phases of weather modification. Private and Government organizations are about equally represented. Our members come from private utilities, public utilities, water supply agencies, irrigation districts, universities, research institutes, State governments, local governments, Federal agencies, private weather consulting firms, and private industries active in weather research and cloud seeding operations.

The field projects and research efforts of people represented within this organization have provided the basis for the optimism expressed in the recent National Academy of Sciences report, "Weather and Climate Modification Problems and Prospects."

1. REGULATION AND LICENSING

In the broad field of weather modification, we feel it is urgent that a separate, regulatory, or licensing commission should be established, independent of any operational or coordinating government groups. The reason for this is that mission-oriented agencies overregulate those projects which are in competition with their own activities. This separate regulatory board should be adequately funded to provide realistic monitoring of the effects of weather-modification activities.

2. UTILIZATION OF PRIVATE MANPOWER IN BOTH PLANNING AND OPERATIONS

It is important that manpower in the private field, where many years of experience have been accumulated, be used in hearings on legislation and in the planning and the formulation of any national programs.

It is also important that experienced individuals be utilized fully in carrying out the programs.

These points are stressed because a great many new people will be needed to carry out the contemplated, large-scale weather modification programs. If past mistakes and wasted effort are to be avoided, however, we must continue to draw heavily on the experience of the people who have actually developed our present knowledge and refinements of technique.

3. UTILIZATION AND ENCOURAGEMENT OF PRIVATE INDUSTRY AND LOCAL GOVERNMENT

The Federal policy should encourage industries, utilities, local government, and private water users to continue the valuable work which has produced positive results in the past. This group has much to offer based on their long experience in this field. Industry will rise to the occasion if given the continued opportunity to develop broad imaginative programs in weather modification.

4. LEGAL ASPECTS

We recognize the need for and encourage the passage of Federal laws designed to strengthen, encourage, and promote scientific field research and operational programs performed by professional-level persons and groups. Such laws should afford protection to the public from unqualified cloud seeders acting without regard to the best interests of the community, and, at the same time, these laws should afford protection to legitimate operators by defining liability and by the provision that litigation be handled uniformly at the Federal level.

The conflicting provisions of present State and local regulations now unjustly harass weather modification activities and only Federal action can resolve this problem.

The Weather Control Research Association is greatly encouraged by the recent findings of the National Academy of Science and the National Science Foundation. We appreciate the effort in Congress to realize the values to be derived from weather modification and we stand ready to help if called upon.

Mr. ELLIOTT. Mr. Chairman and members of the committee, I am pleased to appear before you today to present my views on the needs in the field of weather modification.

I am Robert D. Elliott, president of North American Weather Consultants, a private meteorological firm that has been active in weather modification programs for over 15 years. I am also president of Aerometric Research, Inc., our research affiliate, which performs meteorological research of various types for government and industry. I have served as a member of the President's Advisory Committee on Weather Services and as a consultant to the Advisory Committee on Weather Control. In the American Meteorological Society, I was appointed to the board for certified consulting meteorologists when that board was founded in 1958 and, currently, I am coeditor of the Journal of Applied Meteorology.

During the past 15 years North American Weather Consultants has conducted over 130 project-years of cloud-seeding operations, primarily for hydroelectric generating utility companies in western mountain areas, but also for irrigation districts, counties, and farm groups. Many of these projects were conducted over a long series of years. Because of this, and because of the scientific manner in which the projects were caried out and reported on in the scientific literature,[1] [2] both the Advisory Committee for weather control in 1954–57 and the Panel on Weather and Climate Modification of the National Academy of Sciences in 1964, reevaluated a number of our project results. In both cases this reevaluation contributed consider-

[1] 1954: Elliott, R.D., and R. S. Strickler: "Analysis of Results of a Group of Cloud-Seeding Projects in Pacific Slop Watershed Areas." Bulletin of the American Meteorological Society 35, pp. 171–179.

[2] 1963: Elliott, R. D., and J. T. Walser: "Abrupt Shifts in Seasonal Runoff Relationships as Related to Cloud-Seeding Activity." Proceedings of the Western Snow Conference, 1963, pp. 99–108.

ably to the modicum of optimism shown in their appraisals of the effectiveness of cloud seeding in mountain areas.

It is worth mentioning that three private companies, all under the management of professional meteorologists qualified by long experience in the weather modification field, contributed all of the commercial project data reevaluated by the Academy of Sciences. It is important to make the distinction between this group and the more numerous and frequently changing population of "rainmakers" possessing little or no technical competence that so often preempt space in the news media.

In order to portray for you what is meant by a long-term watershed weather modification project, I shall review the salient features of the one being conducted by North American Weather Consultants for the Southern California Edison Co. high in the southern Sierras. This program is in its 16th year, and is the longest continuous program in the United States, if not in the world. It relies for seeding primarily upon six remote high-level silver iodide smoke generators which are mounted on towers to remain above the snow level and are controlled by radio. These generators are mostly at about 7,000 feet elevations, but one is at 10,000 feet elevation. They contain a season's supply of fuel and silver iodide. When weather conditions are right, the meteorological center at North American Weather Consultants' headquarters in Santa Barbara calls the powerhouse at Big Creek, and after examining telemetered reports from a 10,000 feet elevation weather station in the target area, orders certain generators to be started. The powerhouse dispatcher pushes the appropriate buttons on a panel, thus sending coded signals to the chosen generators ordering them to turn on. When lit, they automatically return signals to the powerhouse which indicate by red lights above each button that the transmitted orders were obeyed. The reverse operation is performed on turnoff.

Such a pushbutton automated system could be established in any high mountain area where access is a problem and where it is desirable to produce the modest increases in runoff which have been indicated in the Academy of Sciences' report.

Economic value of cloud seeding to increase water resources.—It is our feeling that we have already tested on the free market the economic value of cloud seeding. The fact that long-term private projects exist is adequate proof. However, it is interesting to consider the fact that calculated benefits to the total economy far exceed that to our clients. For example, extra water produced by hydroelectric generation passes downstream for reuse by farmers. Some of the extra moisture even benefits cattlemen in mountain range land. We estimate that benefits to the total economy due to the extra water we have produced in 130 project-years amounts to about $1 billion.

Senator ANDERSON. I am glad to get that figure in the record.

Mr. ELLIOTT. I will be happy to give you a breakdown, Senator.

Senator ANDERSON. I am happy with that figure.

Mr. ELLIOTT. However, we do not pretend to possess all of the answers required to mount an operational program that will fully realize all of the indirect as well as direct benefits. There are many puzzling features which require intensive and expensive field research. Private industry cannot find justification in the fraction of the total benefits which it receives to make such an investment. Even though their

portion of the benefits greatly exceed the actual cost of operations, the potential cost of liability suits makes this type of research investment a business strategy having little appeal.

I believe that the Federal Government can reasonably take on this task on the basis of the potential benefits to the Nation as a whole. The research can also increase knowledge and with more widely disseminated knowledge will come a reduction in public uneasiness and the threat of suits.

Research in weather modification.—We have had rather extensive experience in field research having been participants in two out of the three "orographic" cloud seeding tests conducted in the United States. These were the Santa Barbara and Elko projects, the latter of which is still underway. And I might add that we are working with the Desert Research Institute on that project. Our research affiliate, Aerometric Research, Inc., conducted, under a National Science Foundation contract, a 5-year storm study, which included 3 years of extensive field sampling of storms entering central and southern California during the seasons of 1959–60 through 1961–62.

The National Academy of Sciences report cites several of our scientific publications on this project in support of their contention that more work needs to be done along the lines of establishing water budgets of storms and of orographic precipitation systems.

As pointed out in the National Academy of Sciences report, such information is required to assess the full consequences of artificial stimulation of precipitation, including possible downwind and other indirect effects. In my view, this water budget approach is analogous to the determination of diversions from a river by means of stream gages below and above the point of diversion. The difference is that the airstream is being sampled for its water content in vapor, and solid form, as well as that in liquid form; with changes in the form occurring along the stream.

If this exemplifies the type of field research that is desired, and I believe that it does, then in my judgment the approaches employed at present are too fragmented, with many field projects being started on too small a scale. I believe that a single adequate field test of cloud seeding, employing these bulk-physical measurements instead of the statistical spot-sampling techniques now employed, would cost in the millions, rather than in the hundreds of thousands.

This does not imply that I favor establishing a single "crucial" experiment which would hopefully answer once and for all the various questions that need answering. This is the unrealistic opposite extreme from fragmentation; unrealistic because cloud seeding applied in different areas and in different seasons, produces different results.

I believe there should eventually be 5 to 10 large-scale field research projects in the United States.

Regulation of weather modification.—As more and more weather modification programs are started there is bound to be a proportional increase in the number of scientific, legal, social, and economic conflicts. We have already observed several cases of ill-conceived and hastily enacted restrictive legislation on a State or local level which have prohibited or severely curtailed well-designed scientific weather modification programs which could have been of great economic benefit to the area.

Conflicts could arise between private operational projects and Government sponsored research programs. Research programs should be protected from contamination, there is no question about that. On the other hand, a long duration privately financed project, especially one which has added to our fund of knowledge, should not be arbitrarily terminated to make room for a new research program in that area.

With the injection of multimillion dollar Government expenditures into the field of weather modification, many new people will be attracted to the field in general. Unfortunately, some of these individuals will not have the educational background, experience, or ethics necessary to make a meaningful contribution to a national weather modification program. For these reasons it is essential that a national licensing and regulatory board be established. Because it must arbitrate between the conflicting needs of one Government agency and a private program or different Government agencies, it must be completely separate from any operating agency of the Government. This would be in the tradition of the ICC, FCC, or CAB.

I therefore recommend that section 202 be replaced with the following:

All treatment of cloud formation on air masses having the purpose of modifying the precipitation, or cloud cover, from the natural process may be carried on only pursuant to license issued by the Weather Modification Board. The Board shall issue licenses to all applicants meeting the professional requirements and other requirements determined as being necessary by the Board, and shall provide for the monitoring of licensed projects and for conducting special investigations and studies which the Board deems necessary in the proper regulation of weather modification.

The Board shall conduct hearings and arrive at judgments in cases of conflicts, either between private parties, a private party and a government agency, or between government agencies.

The permanent staff and its expenses shall be supported by funds appropriated annually, and equal to $250,000 in the first fiscal year.

The Board is empowered to make contracts with private organizations, or universities to conduct any special projects deemed to form a necessary basis for performing the Board's functions. It is also empowered to confer and negotiate with State authorities or agencies concerned with the regulation of weather modification within their State.

Coordination and the national weather modification program.—It must be recognized that, due to the multitude of potential benefits of weather modification, no one Federal agency should have sole control of all Government activity in this field. A pluralistic approach is not only desirable, but necessary if we are to develop all of the phases of weather modification.

I believe that now is the time for instituting a broadly based national program which recognizes the mission of the Department of the Interior in developing water resources on a national basis. This national program should also recognize the mission of the Environmental Science Services Administration and the Weather Bureau in developing means to ameliorate severe storms that cause loss of lives and property. It should recognize the role of the National Science Foundation in supporting basic research, particularly in theoretical, numerical, laboratory, and limited field studies. The Department of Agriculture's Forest Service has a role in developing means to reduce lightning strike fires which destroy millions of dollars worth of timber.

It should also recognize the mission of the Department of Defense

in investigating the military applications of weather modification such as fog and cloud dispersal methods.

A comprehensive program should further recognize the need for, and provide for, the coordination of Federal efforts in weather modification, under some type of an interagency coordinating committee which will insure the continuous exchange of information and provide for interagency agreements on the pooling of facilities and expertise where this is called for.

I submit then section 101 be reworded to read:

In formulation and execution of the comprehensive program, the President shall establish an Interagency Weather Modification Coordinating Committee. Members of this Committee will be drawn from all Government agencies having recognized weather modification missions. Each member of this Committee may request advice and participation in their weather modification programs of any agency members that have scientific or engineering competence related to such programs, and all such Federal agencies are directed to participate in such programs on the basis of interagency agreements.

Advisory committee on weather control.—It is believed the time is now ripe to establish an advisory committee on weather control, similar in structure to that which served President Eisenhower, with representatives from private industry, the universities, and Government. This committee would serve in an advisory capacity in the formulation of a national weather modification plan, and, after its formulation, in periodic status reviews.

Operational programs and matching funds.—In the event that the Federal Government wishes to commence operational projects, there are several practical matters of organization worth considering.

To date, the only purely operational programs in the United States have been operated and financed by private enterprise or, in a few cases, by local government bodies. The electric utility industry, for example, has shown that they are willing and able to finance a seeding program on watersheds which are primarily controlled by them even though other water users downstream would also benefit from an increase in runoff.

But what of the water users on a river that is largely controlled by the Federal Government? In the Western States, many of the rivers are controlled by federally constructed and/or operated multipurpose dams. In these cases, no one group of water users can or will wholly finance a seeding program, and the organizational problems in instituting a cooperative program are very difficult, even though the majority of the water users may desire such a program. In cases like this, the Government can provide the needed organizational focus and also provide matching funds to finance such a program.

I therefore suggest a new section be added to S. 2875 following section 102:

The Secretary may provide matching funds for any approved programs of weather modification on a watershed above federally sponsored dams, reservoirs, regulating or diversion works, provided a request for such a program is initiated by the local water-users of said watershed.

Manpower requirements.—There is a small nucleus of people technically qualified to conduct field programs in weather modification. These are to be found primarily among those groups who conducted the operational programs reevaluated by the Academy of Sciences and among the several universities now engaged in field studies. It is

upon this nucleus that the needed manpower must grow. Additions will come through involvement of others in these activities, especially that of advanced students in the universities. Others will be drawn into the field from bordering disciplines.

The interdisciplinary character of the undertaking is quite evident, the principal ones being: meteorology, engineering, and cloud physics. I place cloud physics last, even though it undergirds the whole field, simply because, for the time being, the most needed development is in the other two sectors.

The role of the Bureau of Reclamation in starting programs in the several western universities and in supporting active field experimentation in the watersheds of concern to it is indeed commendable and serves the double purpose of attracting promising talent to the field as well as advancing our knowledge. It should be noted that they started their program when the climate was less optimistic that at present.

Conclusions.—I shall briefly summarize my thinking on the subject of this bill. It seems that the technical objectives of the bill are well aimed and that major, coordinated Federal support of weather modification research and operational projects is not only timely but overdue. I suggest that coordination of such a program should be exercised by an interagency coordinating committee, and that regulation of all weather modification activities should be done by an independent board. Specific suggestions for obtaining the technical objectives of the bill include provision for matching funds with local water users for operational programs where appropriate, and research emphasis on large-scale physical evaluation programs. The emphasis should be placed on making the fullest use of existing skills and facilities rather than developing duplicate or competing installations.

In conclusion, I want to thank this committee for the opportunity to express the convictions I have developed over the past 15 years and to present my ideas concerning the form which a national weather modification program should take.

Senator ANDERSON. Mr. Elliott, I like your presentation very much. The thing I like about it best is that when you found something you did not like in the bill you proceeded to suggest language of your own. We may not like your language either but it is a starting point from which to work something out. I appreciate it very much. It is a very good idea and we will benefit from it. Do you have any rough ideas as to the possible precipitation increase in the San Diego-Los Angeles area?

Mr. ELLIOTT. The San Gabrielle watershed, which is controlled by the Los Angeles County Flood Control District, is an area in which we are now and have been conducting a program for a number of years. actually serving as consultants to the Los Angeles County Flood Control.

It is a very interesting area. We have been employing an evaluation technique there which is rather new and involves obtaining hourly measurements upwind in the area.

Senator ANDERSON. You do think there has been an effect from this cloud seeding?

Mr. ELLIOTT. Yes, sir, I do. As a matter of fact it is more like 20 or 30 percent and I believe that the mountains in southern and central

California are peculiarly located in a climatic region where weather modification is actually more effective than it is in the higher mountain areas.

Senator ANDERSON. We value very much the experience you have brought to this hearing today. We appreciate it and thank you for it very sincerely.

Mr. ELLIOTT. Thank you, Mr. Chairman.

Senator ANDERSON. We meet again at 2 o'clock.

(Whereupon, at 12:30 p.m. the subcommittee recessed, to reconvene at 2 p.m. the same day.)

AFTER RECESS

(The subcommittee reconvened at 2 p.m., Senator Frank E. Moss (Utah) presiding.)

Senator Moss. The subcommittee will come to order. Senator Anderson unfortunately cannot be with us this afternoon. We will continue with the hearing which has been very interesting and very productive up to now and I am sure the witness this afternoon will add to the fine information that has been provided to us.

Our first witness this afternoon is Harold Wilm, chairman of the policy committee of the Interstate Conference of Water Problems, Syracuse, N.Y.

We are happy to have you, Mr. Wilm.

You may proceed, sir.

STATEMENT OF HAROLD G. WILM, ASSOCIATE DEAN AND DIRECTOR, THE WATER RESOURCES INSTITUTE, SYRACUSE, N.Y.

Mr. WILM. Mr. Chairman, my name is Harold G. Wilm. I am associate dean and director of the Water Resources Institute, State University of New York, located at Syracuse, N.Y., and also a member of the executive committee of the Interstate Conference on Water Problems.

Speaking for the conference, our executive committee acts in response to resolutions adopted by the whole conference at regulatory scheduled national meetings.

As you are aware, the conference consists of one official member from each of our States; each is an official at a comparatively high level of State government. With respect to the pending bill, S. 2875, the executive committee has no specific resolution upon which to base a statement. I can, however, express the great interest of the conference and its member States in assisting to alleviate water shortages by all feasible means including, if possible, weather and climate modification. I would like to express the hope that, in implementing S. 2875, the Secretary of the Interior will actively enlist the advice and help of State governments and of research organizations and institutions within the States. Because the Secretary is the Chairman of the President's Water Resources Council established under the Water Resources Planning Act of 1963, I am confident that he will employ this new mechanism for achieving coordination and cooperation among the Federal agencies that are interested in water problems, as well as working with the States and interstate bodies.

I might interject that I have been noticing that other witnesses before this committee have, in general, neglected to mention the Presi-

dent's Water Resources Council as a mechanism for achieving interagency cooperation. It seems to me that this is a very excellent mechanism. The authority for such activities is well embodied in sections 101 and 102 of the bill before you.

Now I should like to step out of my role as a representative of the interstate conference and to speak as an individual and as director of the college of forestry, water resources institute. As you know, we in New York are very deeply concerned over water shortages caused by the drought of the past 4 years, as well as over problems of water quality and water pollution. The State itself and agencies within the State—including our water resources institute—are actively interested in any programs which may lead toward the solution of these problems. As to the bill before you, S. 2875, I might raise two specific questions. First, have the science and art of weather and climate modification yet reached a stage which would warrant such a great stepup in Federal support for research and development in weather modification from $7.2 million in fiscal year 1963 to the more than $35 million proposed by the bill to be administered by the Secretary of the Interior? Second, among the numerous Federal Cabinet members, is it logical for the Secretary of the Interior to be the administering officer?

As to the first question, up to the recent past I have entertained serious doubts. In spite of extensive research and tests of various kinds, it has still remained uncertain whether, on a practical scale, the "seeding" of various kinds of air masses can achieve favorable results. On a partly conjectural basis there would seem to me to be two major disturbing factors: (1) the air mass to be seeded must be in a condition in which it can be made to produce precipitation, (2) the "dosage" or intensity of seeding has to be applied to the airmass in sufficient, but not too great, quantity to induce precipitation. There is no question as to the soundness of the scientific principle involved, or of its application to weather modification; the main question is one of control; if the wrong air masses are seeded, or insufficient dosage is applied, little or no effect may be expected. If, on the other hand, the dosage is excessive in any particular air mass, it is possible that precipitation may actually be suppressed or the clouds partially dispersed.

I might interject at this point that in earlier years I put in quite a lot of time, myself, in making studies of various cloud-seeding tests. In one particular set of tests I studied, including quite a large number of separate attempts, there was a distribution of apparent effects of the cloud seeding from quite strongly minus to quite strongly plus which, to a scientist, would normally infer complete random distribution of the effects with a mean somewhere around zero. Even then, much more so than now, I am led to suspect that that greater variation in both directions and magnitude of the apparent effects may have been at least partly due to the inability of the people doing the job to predict what dosages should be applied to these particular airmasses.

In some cases they may have gotten no effect because they put in too little. In other cases, they may have actually suppressed precipitation. This means, of course, a much more precise knowledge is needed of the kind of clouds that are passing by that you attempt to seed, the concentration of ice particles in them, and from such information the intensity of dosage needed to produce precipitation.

Based on this argument, then, we need to acquire much more knowledge of air mass characteristics and behavior, and methods for appraising these characteristics, both basic and applied, done by many agencies and coordinated in some effective manner.

Two circumstances lead me to favor passage of this bill providing for stepped-up Federal support and leadership in weather and climate modification. One is the favorable, though conservative recommendations of the National Science Foundation's special commission, and of the National Academy of Sciences Panel on Weather and Climate Modification. The first recommendation of the National Academy Panel (p. 22 of their vol. I: Summary and Recommendations) calls for the increase of financial support to at least $30 million per year. This, of course, conforms quite closely to the first-year level of authorization recommended in your bill. The other circumstance is the very difficult experience undergone by New York State and the other States of the Delaware River Basin, with the effects of the persistent drought in that basin last year.

Several times during late 1965, air masses traversing this general region dropped rain elsewhere than the headwaters of the Delaware River Basin, upstream of the greatly depleted reservoirs of New York City. I am sure you can visualize the very weird situation we were going through, rationing water violently in New York City so that they were using actually a quarter billion gallons per day less of water than they ordinarily used, and intentionally holding back water in the New York City reservoir rather than releasing it down the river in order to hold the salt back at Philadelphia.

And in the midst of all these measures, with the New York City reservoir standing very low, only one-third filled, with great banks of mud showing above the little remaining pools, at that very time, in one commission meeting, the district engineer in charge of the Army flood control reservoirs down in that region asked for permission to release water from a reservoir quite low down in the Delaware River Basin because the meteorological situation had altered it to such an extent that they were afraid that possibly there might be floods and they would have too much water in the reservoir to control the floods.

So, in the Adirondacks there was rain, in the lower Delaware there was rain, but above the New York City reservoirs there was hardly any rain at all. One is led to conjecture whether, with more comprehensive knowledge of principles and techniques, it might have been possible to induce more rain to fall on this strategic watershed.

Now for a few words on jurisdiction. As a principle, it is my general view—shared, I am sure, by the members of our interstate conference on water problems—that jurisdictional decisions in matters such as this should be left to the wisdom of the legislative and executive branches of the Federal Government. As a suggestion, however, it does seem appropriate for the Secretary of the Interior to direct this program because of his position as chairman of the President's Water Resources Council. It is also appropriate because the Department of the Interior has a broad understanding of the practical problems of weather modification and the dynamic need for their solution. The Department already is conducting a program of applied research, through the Bureau of Reclamation. As to the more basic and esoteric aspects of weather research, I am confident that the Secretary will

enlist the services of other organizations and agencies, as provided in title I of the bill before you.

Mr. Chairman, I have been listening with great interest to the witnesses before me. It may be noticed that my statement intentionally contains no reference to sections 201 and 202 of the bill, to provide for licensing and indemnification. While really we have no recommendations in this respect at all, I might comment that it is my own very deep feeling that judgments or decisions on matters, policy matters, of very great import to many different kinds of people, are best vested in a group of men rather than a single man. By similar arguments, the regulations of the activities of a great many people perhaps may be best handled by a group of men rather than a single man.

Again, although I have not included it in my testimony, it occurs to me to suggest that the committee may wish to propose the President's Water Resources Council, a body, a group of men rather than a single man as a controlling body. This kind of arrangement provides not only breadth of wisdom, but by bringing an agency to bear on policy and establishing regulations, it tends to take off the tremendous burdensome feeling of responsibility in applying regulations to people whose whole lives are affected by the decision.

It has been a pleasure to have the privilege of expressing interest in S. 2875, as well as endorsement of the provisions of the bill for greatly increased support of such a comprehensive program by the Federal Government, through both direct and cooperative research and other activities.

Thank you, Mr. Chairman.

Senator Moss. Thank you, Dean Wilm. We appreciate very much your coming to share this statement with us and make our record.

You, as many other witnesses have done, have referred to the figures in the bill as an amount of money that we appropriate.

You, of course, recognize that that simply is setting a ceiling which is not to be exceeded, which is a policy that this committee follows on, I think, all legislaiton that we endorse, whether it be for the building of a dam or the purchase of a piece of land for a park or whatever else. We set a ceiling on the amount of money that can be spent.

We, of course, put that at what we think is a reasonable figure but very seldom do the Appropriations Committees of the Congress come up to our ceiling. It is usually something else, something less. So, I do not think that we need to have great worries that this program will be accelerated too fast from the present level.

I am sure the Appropriations Committees and the entire body of the Congress would look into that very carefully. The pressures on Federal expenditures and competition of all of the functions of the Federal Government are such that I think it will keep it in range.

But it is a good point to raise. This does authorize a ceiling at least of a pretty high amount to begin with.

I appreciate your comment about the problems that we have had so far in knowing whether we are seeding too much or too little. We do not know and we have made a lot of guesses which it seems to me is a good recommendation for the accelerated research that we need now so as to learn the precise amount of cloud seeding necessary for a critical cloud cover to be productive for us.

I understand that you had quite a good deal to do with the preparatory work leading to the passage of the Delaware River Basin planning bill as a representative to the interstate conference. Is it not true that virtually every State is concerned over water problems, not just the West and New York, and is it not true that the development of methods of increasing rainfall would be almost universally useful in the United States and, as a matter of fact, all over the world?

Mr. WILM. Yes, sir; of course it is true. It has become only sharply realized in the East that even we are not blessed with more water than we need.

Senator MOSS. That is what we out West consider one little ray of sunshine in the very severe water problems of the East. We think that finally many of the folks in that area have been awakened to what we have been talking about all along and what we have lived with all our lives and that it is now much easier to get attention given to water conservation and water resource development and storage and all of these things that are, of course, the basic lifeblood of the West.

If we could induce just a moderate addition to our rainfall we could very considerably change the economic and social fabric of a large area of our country. Is that not true?

Mr. WILM. I am sure it is. Of course when you get into a situation such as the Delaware Valley, which is highly developed and with a concentration of population, it is not really so much a question of expanding population and building up of industry but of saving what we have.

Senator MOSS. If we could find how we could change the direction somewhat on these movements of the air masses to better rainfall location that would better conditions. You are pointing out that you had a reservoir in the lower part of the Delaware Valley where permission was asked to draw it down some because it was too full to offer the flood control safeguard needed.

At the same time you had reservoirs in the upper part of the Delaware Basin that were pulled out down to a critical point for water supply.

Mr. WILM. Yes. It is my hunch that the clouds that had gone by those reservoirs were just close enough to have wanted to drop the rain, and if they had gotten even a little nudge they would have done so, if we had but known how to give the nudge.

Senator MOSS. Thank you very much, Mr. Wilm. We do appreciate your testimony and the fine work that you do with the interstate commission.

Mr. WILM. Thank you.

Senator MOSS. Our next witness will be Mr. Stuart E. Shumway, Secretary of the Weather Modification Board of the State of Washington.

We are glad to have you, Mr. Shumway. You may proceed, sir.

STATEMENT OF STUART E. SHUMWAY, SECRETARY, STATE OF WASHINGTON WEATHER MODIFICATION BOARD

Mr. SHUMWAY. Mr. Chairman and members of the committee, my name is Stuart E. Shumway. I serve as secretary of the State of Washington Weather Modification Board and Meteorologist for the

State of Washington, Department of Conservation. It is indeed an honor and privilege for me to appear before this committee today.

Ever since the initial weather modification experiments were conducted by Drs. Langmuir and Schaeffer, back in 1946, the State of Washington has been vitally interested in the development and control of the atmospheric water resources.

Although Washington was preceded by a few States in enacting statutory regulations in acknowledgement of the reality of man's ability to intervene upon the natural weather processes, our State legislature has fulfilled this requirement by passing a truly enlightened and comprehensive Weather Modification Act.

Mr. Chairman, I have a copy of the Weather Modification Act with me and with your permission I would like to have it entered into the testimony if it would be useful to you.

Senator Moss. Yes. We would like to have it. How extensive is it? Could it be reprinted or should we put it in the file?

Mr. SHUMWAY. It is about eight or nine pages.

Senator Moss. Well, it will be inserted in the record.

(The document referred to follows:)

CHAPTER 245

(H.B. 195)

STATE WEATHER MODIFICATION BOARD

AN ACT Relating to weather modification and control; establishing a board, defining powers and duties; making an appropriation; providing penalties; and declaring an emergency

Be it enacted by the Legislature of the State of Washington:

SECTION 1. As used in this act, unless the context requires otherwise:

(1) "Board" means the Weather Modification Board;

(2) "Operation" means the performance of weather modification and control activities pursuant to a single contract entered into for the purpose of producing or attempting to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding one year; or, in case the performance of weather modification and control activities is to be undertaken individually or jointly by a person or persons to be benefited and not undertaken pursuant to a contract, "operation" means the performance of weather modification and control activities entered into for the purpose of producing, or attempting to produce, a certain modifying effect within one geographical area over one continuing time interval not exceeding one year;

(3) "Research and development" means theoretical analysis exploration and experimentation, and the extension of investigative findings and theories of a scientific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials and processes;

(4) "Weather modification and control" means changing or controlling, or attempting to change or control, by artificial methods, the natural development of any or all atmospheric cloud forms or precipitation forms which occur in the troposphere.

SEC. 2. (1) There is established a weather modification board to consist of the director of conservation, who shall be the chairman and who shall exercise no vote except in case of a tie vote, nine members all appointed by the governor, including a member of the faculty of Washington State University, a member of the faculty of the University of Washington, one member to be a person experienced in, and actually engaged in the commercial production of horticultural products, three members to be persons experienced in, and actually engaged in the commercial production of other agricultural products, and three members representing the general public. Members appointed to represent horticulture, other agricultural products, and the general public, shall each represent a different congressional district in order that each congressional district of the state shall be represented by one such appointee. The term of office of each member

of the board appointed prior to March 3, 1961, shall be four years, except that the first terms of office of such appointed members first taking office shall expire, as determined by the governor at the time of their appointment, one each at the end of the first, second, third and fourth years after March 3, 1957. The term of office of each member appointed to the board as an additional member because of this amendatory act shall be four years, except that the first terms of office of such appointed members first taking office shall expire, as determined by the governor at the time of their appointment, two at the end of the first year after March 3, 1961, and one each at the end of the second, third, and fourth years after March 3, 1961. Any member appointed to fill a vacancy occurring prior to the expiration of the term for which his predecessor was appointed shall be appointed for the remainder of such term.

(2) Members of the board shall receive no compensation for the performance of their duties under the provisions of this chapter; but each member shall be reimbused, to the extent allowed by law from funds available for the administration of this chapter, for expenses necessarily incurred in the performance of his duties.

(3) A majority of the members shall constitute a quorum for the transaction of business. As amended by Sec. 1, Chap. 154, Laws of 1961.

SEC. 3. In the performance of its functions the board may, in addition to any other acts authorized by law:

(1) Establish advisory committees to advise with and make recommendations to the board concerning legislation, policies, administration, research and other matters;

(2) Establish by regulation or order such standards and instructions to govern the carrying out of research or projects in weather modification and control as the board may deem necessary or desirable to minimize danger to health or property; and make such rules and regulations as are necessary in the performance of its powers and duties;

(3) Make such studies, investigations, obtain such information and hold such hearings as the board may deem necessary or proper to assist it in exercising its authority or in the administration or enforcement of this act or any regulations or orders issued thereunder;

(4) Subject to section 7, of this act, appoint and fix the compensation of such personnel, including specialists and consultants, as are necessary to perform its duties and functions;

(5) Acquire, in the manner provided by law, such materials, equipment and facilities as are necessary to perform its duties and functions;

(6) Cooperate with public or private agencies in the performance of the board's functions or duties and in furtherance of the purposes of this act;

(7) Represent the state in any and all matters pertaining to plans, procedures or negotiations for interstate compacts relating to weather modification and control.

SEC. 4. The board shall exercise its powers in such manner as to promote the continued conduct of research and development activities in the fields specified below by private or public institutions or persons and to assist in the acquisition of an expanding fund of theoretical and practical knowledge in such fields. To this end the board may conduct, and make arrangements including contracts and agreements, for the conduct of, research and development activities relating to:

(1) The theory and development of methods of weather modification and control, including processes, materials and devices related thereto;

(2) Utilization of weather modification and control for agricultural, industrial, commercial and other purposes;

(3) The protection of life and property during research and operational activities.

SEC. 5. In the case of hearings pursuant to section 18 of this act the board shall, and in other cases may, cause a record of the proceedings to be taken and filed with the board, together with its findings and conclusions. For any hearing, any member of the board or a representative designated by the board is authorized to administer oaths and affirmations, examine witnesses and issue, in the name of the board, notice of the hearing or subpoenas requiring any person to appear and testify, or to appear and produce documents, or both, at any designated place.

SEC. 6. (1) The board may, subject to any limitations otherwise imposed by law, receive and accept for and in the name of the state any funds which may be offered or become available from federal grants or appropriations private gifts, donations or bequests, or any other source, and may expend such funds,

unless their use is restricted and subject to any limitations otherwise provided by law for the administration of this act and for the encouragement of research and development by a state, public or private agency, either by direct grant, by contract or other cooperative means.

(2) There is established an account in the general fund to be known as the "weather modification board revolving account." All license and permit fees paid to the board shall be deposited in such account. Any accumulation in this account in excess of five thousand dollars shall revert to the state's general fund.

SEC. 7. (1) In administering the provisions of this act the board shall utilize, and the director of conservation and development shall furnish, such clerical and other staff services and material and office space as are required by the board in the performance of its functions involving internal operations of the board. The director of conservation and development, however, shall not be obligated to incur any expense in complying with this subsection beyond the amount of funds lawfully available for the payment thereof.

(2) The expense of complying with the requirements of subsection (1) of this section shall be paid only from the "weather modification board revolving account," hereby created, upon the presentation of a claim therefor approved by the director of conservation and development. Such claims shall be audited and paid in the same manner as other claims against the state.

SEC. 8. Except as provided in section 9 of this act, no person shall engage in activities for weather modification and control except under and in accordance with a license and a permit issued by the board authorizing such activities.

SEC. 9. The board, to the extent it deems practical, shall provide by regulation for exempting from the license, permit and liability requirements (1) research and development and experiments by state and federal agencies, institutions of higher learning and bona fide nonprofit research organizations; (2) laboratory research and experiments; (3) activities of an emergent character for protection against fire, frost, sleet or fog; and (4) activities normally engaged in for purposes other than those of inducing, increasing, decreasing or preventing precipitation or hail.

SEC. 10. (1) Licenses to engage in activities for weather modification and control shall be issued to applicants therefor who pay the license fee required and who demonstrate competence in the field of meteorology to the satisfaction of the board, reasonably necessary to engage in activities for weather modification and control. If the applicant is an organization, these requirements must be met by the individual or individuals who will be in control and in charge of the operation for the applicant.

(2) The board shall issue licenses in accordance with such procedures and subject to such conditions as it may by regulation establish to effectuate the provisions of this act. Each license shall be issued for a period to expire at the end of the calendar year in which it is issued and, if the licensee possesses the qualifications necessary for the issuance of a new license, shall upon application be renewed at the expiration of such period. A license shall be issued or renewed only upon the payment to the board of one hundred dollars for the license or renewal thereof.

SEC. 11. The board shall issue permits in accordance with such procedures and subject to such conditions as it may by regulation establish to effectuate the provisions of this chapter only:

(1) If the applicant is licensed pursuant to this chapter;

(2) If a sufficient notice of intention is published and proof of publication is filed as required by RCW 43.37.140;

(3) If the applicant furnishes proof of financial responsibility, as provided in RCW 43.37.150, in an amount to be determined by the board but not to exceed twenty thousand dollars;

(4) If the fee for a permit is paid as required by RCW 43.37.160;

(5) If the weather modification and control activities to be conducted under the authority of the permit are determined by the board to be for the general welfare and public good;

(6) If the board has held an open public hearing in Olympia as to such issuance. As amended by Sec. 2, Chapter 154, Laws of 1961.

SEC. 12. A separate permit shall be issued for each operation. Prior to undertaking any weather modification and control activities the licensee shall file with the board and also cause to be published a notice of intention. The licensee, if a permit is issued, shall confine his activities for the permitted operation within the time and area limits set forth in the notice of intention, unless modified by the board; and his activities shall also conform to any conditions

imposed by the board upon the issuance of the permit or to the terms of the permit as modified after issuance. As amended by Sec. 3, Chapter 154, Laws of 1961.

SEC. 13. The notice of intention shall set forth at least all the following:

(1) The name and address of the licensee;

(2) The nature and object of the intended operation and the person or organization on whose behalf it is to be conducted;

(3) The area in which and the approximate time during which the operation will be conducted;

(4) The area which is intended to be affected by the operation;

(5) The materials and methods to be used in conducting the operation.

SEC. 14. (1) The applicant shall cause the notice of intention, or that portion thereof including the items specified in RCW 43.37.130, to be published at least once a week for three consecutive weeks in a daily newspaper having a general circulation and published within any county in which the operation is to be conducted and in which the affected area is located, or, if the operation is to be conducted in more than one county or if the affected area is located in more than one county or is located in a county other than the one in which the operation is to be conducted, then in a daily newspaper having general circulation and published within each of such counties. In case there is no daily newspaper published within the appropriate county, publication shall be made in a daily newspaper having a general circulation within the county;

(2) Proof of publication, made in the manner provided by law, shall be filed by the licensee with the board within fifteen days from the date of the last publication of the notice. As amended by Sec. 4, Chapter 154, Laws of 1961.

SEC. 15. Proof of financial responsibility may be furnished by an applicant by his showing, to the satisfaction of the board, his ability to respond in damages for liability which might reasonably be attached to or result from his weather modification and control activities in connection with the operation for which he seeks a permit.

SEC. 16. The fee to be paid by each applicant for a permit shall be equivalent to one and one-half percent of the estimated cost of such operation, the estimated cost to be computed by the board from the evidence available to it. The fee is due and payable to the board as of the date of the issuance of the permit; however, if the applicant is able to give to the board satisfactory security for the payment of the balance, he may be permitted to commence the operation, and a permit may be issued therefor, upon the payment of not less than fifty percent of the fee. The balance due shall be paid within three months from the date of the termination of the operation as prescribed in the permit. Failure to pay a permit fee as required shall be grounds for suspension or revocation of the license of the delinquent permit holder and grounds for refusal to renew his license or to issue any further permits to such person.

SEC. 17. (1) Every licensee shall keep and maintain a record of all operations conducted by him pursuant to his license and each permit, showing the method employed, the type of equipment used, materials and amounts thereof used, the times and places of operation of the equipment, the name and post office address of each individual participating or assisting in the operation other than the licensee and such other general information as may be required by the board and shall report the same to the board at the time and in the manner required.

(2) The board shall require written reports in such manner as it provides but not inconsistent with the provisions of this act, covering each operation for which a permit is issued. Further, the board shall require written reports from such organizations as are exempted from license, permit and liability requirements as provided in section 9.

(3) The reports and records in the custody of the board shall be open for public examination.

SEC. 18. (1) The board may suspend or revoke any license or permit issued if it appears that the licensee no longer possesses the qualifications necessary for the issuance of a new license or permit. The board may suspend or revoke any license or permit if it appears that the licensee has violated any of the provisions of this act. Such suspension or revocation shall occur only after notice to the licensee and a reasonable opportunity granted such licensee to be heard respecting the grounds for the proposed suspension or revocation. The board may refuseto renew the license of, or to issue another permit to, any applicant who has failed to comply with any provision of this act.

(2) The board may modify the terms of a permit after issuance thereof if the licensee is first given notice and a reasonable opportunity for a hearing re-

specting the grounds for the proposed modification and if it appears to the board that it is necessary for the protection of the health or the property of any person to make the modification proposed.

SEC. 19. Nothing in this act shall be construed to impose or accept any liability or responsibility on the part of the State, the board or any State officials or employees for any weather modification and control activities of any private person or group, nor to affect in any way any contractual, tortious or other legal rights, duties or liabilities between any private persons or groups.

SEC. 20. Any person violating any of the provisions of this act or any lawful regulation or order issued pursuant thereto shall be guilty of a misdemeanor; and a continuing violation is punishable as a separate offense for each day during which it occurs.

SEC. 21. There is appropriated to the director of conservation and development, for the biennium beginning July 1, 1957, out of the general fund in the state treasury, the sum of one thousand dollars for the purpose of paying expenses incurred by him in complying with subsection (1) of section 7 of this act.

SEC. 22. There is appropriated to the state weather modification board, out of the general fund in the state treasury, the sum of one thousand dollars for the purpose of carrying out the provisions of this act.

SEC. 23. This act is necessary for the immediate preservation of the public peace, health or safety, support of the state government and its existing public institutions, and shall take effect immediately.

Passed the House February 12, 1957.

Passed the Senate March 12, 1957.

Approved by the Governor March 23, 1957.

Mr. SHUMWAY. Further evidence of this State's active interest is manifest in one of the world's longest continuous privately supported cloud seeding operations sponsored by the wheatgrowing interests in the semiarid eastern portion of the State.

Beginning with the final report of the President's Advisory Committee on Weather Control in 1957, evidence has been steadily accumulating in support of the committee's contention that the Pacific Northwest is one of the most favorable areas in the United States for the stimulation of precipitation from supercooled, orographic clouds. Despite the undisputed superiority of this area for such experimentation, we were unable to attract the necessary Federal funding and consequently the personnel required to initiate the requisite field research program.

We tried the Weather Bureau. We approached the National Science Foundation. Both efforts to interest Federal support and participation were unsuccessful.

Therefore, in 1962, the State of Washington Department of Conservation, in cooperation with the city of Seattle Department of Lighting, undertook a limited operational research program in the Upper Skagit River Basin in northwest Washington to test this hypothesis:

Cloud seeding with ground based silver iodide generators in a region of favorable climate and topography can be demonstrated to be economically feasible.

At this point we did find a friend at the Federal level. Dr. Pierre St. Amand of the Earth and Planetary Sciences Section, Naval Ordnance Test Station, China Lake, Calif., wished to field test a pyrotechnic cloud seeding material they had developed. He was impressed with our area and agreed to cooperate with us.

The results from the two winters of cloud seeding operations, inadequate funds and personnel notwithstanding were most encouraging. As in inevitable, however, the answer to the initial hypothesis posed a multitude of new questions. This demonstration, nevertheless, was seriously considered by the Bureau of Reclamation and has resulted

in the State of Washington becoming engaged in the Bureau's atmospheric water resource research and development program.

This choice by the Bureau of Reclamation of the Pacific Northwest as an area for the conduct of a substantial field experiment corrects a serious shortcoming in the national weather modification research effort. Certainly this region, best known for its rainfall, offers the potential for a high rate of learning from research in cloud and precipitation physics. The justification for this shortcoming is, obviously, the absence of an acute political and economic urgency to meet the rising demands on the water resources in this type of region.

Our State's reputation as that place where it rains all the time brings to an advocate for the development of an atmospheric water resource in Washington the accusation of "carrying coals to Newcastle."

Even without resorting to a reminder that nearly half of the Evergreen State is classified as semiarid, a substantial rejoinder is practicable.

Admittedly the humid two-fifths of the State which lies west of the Cascade Mountain divide receives an area average in excess of 70 inches of precipitation per annum. However over 85 percent of this generous potential water supply falls during the 7 months, 7 winter months, October through April.

Were it not for the extensive, high elevation watersheds in the Cascade and Olympic Mountains, with their capability to intercept and impound a large portion of this unseasonable precipitation in the form of snow, western Washington would be forced to rely upon large quantities of artificially stored water during the summer months.

One of the most valuable components of this State's water resource is the existence of over 40 million acre-feet of water locked in storage in the form of ice in glaciers. The Cascade and Olympic Mountains in Washington contain 80 percent of the glaciers in the United States, excluding Alaska.

These glaciers, collectively covering approximately 135 square miles of rugged high mountain terrain, contribute an average of 1 million acre-feet of water every summer to sustain streamflow in what otherwise would be a low-water period.

At the present time, these ice reservoirs are operating at only half of their capacity of 200 years ago. This represent an ominous average decline of 1 percent every 4 years. One of the aims of the State of Washington atmospheric water resource program is to design dependable engineering techniques which may be applied to reverse this trend. Particular emphasis will be directed toward those glaciers along the eastern slopes of the Cascade Mountains which nourish the arid portion of the State.

Although the State of Washington's interest in weather modification and control encompasses the entire gamut of promising techniques for ameliorative adjustments to hazardous weather conditions, such as hail and lightning suppression, fog dispersal and so forth, our overriding natural advantage lies in the development of the atmospheric water resource.

Being near the source and at the center of the North American Continent's principal water vapor distribution system, we are assured of a dependable supply of precipitable water at the time when it is most susceptible to stimulation techniques and also amenable to management for later beneficial uses.

Since our primary interest is directed toward the development of a supplement to our water resources, we believe the realization of this objective can best be achieved through cooperation with an agency well qualified in water resource management.

Similarily we believe the development of the other phases of weather modification and control should be the responsibility of that agency most closely associated with the interests to be served by the modification.

We have examined S. 2875 closely. It is our conviction that this legislation meets the general and specific need of assignment of the responsibility and establishment of a principal agency to develop the Nation's atmospheric water resource.

Our experience in the State of Washington of numerous attempts over the past 9 years to obtain Federal assistance to advance what we feel to be a desirous scientific program of benefit to the entire Nation illustrates the need for S. 2875.

This committee and Congress has recognized the need for a coordinated program in this field in legislation enacted in recent years.

We wish to urge that the committee act favorably on S. 2875 so that its benefits to the Nation may be made available at the earliest possible date.

Thank you very much for the opportunity to appear before this committee today.

Senator Moss. Thank you, Mr. Shumway. We appreciate the very fine testimony. You are correct in saying that we think of Washington more often as a State that gets all the water rather than a State that has an arid section, although I have visited the eastern part of your State and know that you do have problems of insufficient rainfall in a good part of the State.

It is a sort of half and half area. I think you point out a very notable fact that this ought to be a good laboratory, where a section has a great deal of rainfall, obviously caused by some atmospheric and ground features, and a section that is very arid.

Out of that perhaps we can find some of the answers.

Could you indicate your ideas for expanding your operations in Washington if there is no expansion of the Federal program?

Mr. SHUMWAY. You mean the expansion of the Bureau of Reclamation program?

Senator Moss. You were describing to us what you have been able to do just on the State level. You said you got a little help. You found an angel or two who helped you but the State has been going ahead with the program. Suppose we were not able to get a bill here to appreciably expand the Federal effort, what further do you think your own State would be able to do?

Mr. SHUMWAY. We have had a lot of difficulty doing what we have done already. We were forced to stop what we were doing primarily because of lack of funds until we got the Bureau support.

Now we have quite a large-scale program scheduled to start later.

Senator Moss. Is one of the limiting factors to a State program that you are confined to a relatively small area, whereas if you had a national program, the sampling stations, testing, and so on could be much more widely dispersed?

Mr. SHUMWAY. Not in this particular region. You are confined pretty much to the Cascade Mountains and a short distance down wind.

All this lies within the State of Washington. We could conduct a large-scale program in the State of Washington without having to go out in other areas.

Senator Moss. Have you encountered any legal problems in connection with the work that the State has been doing, in experimenting in this field?

Mr. SHUMWAY. We have not had any legal problems. We have had some public relations problems because we were working in an area where it rains so much.

Senator Moss. Have you been concerned about possible legal liability being asserted against you?

Mr. SHUMWAY. No. If the operation is conducted properly I don't think that there is any possibility of damage. We operate on post and target areas in the wilderness area in the North Cascades. There is nobody living in that area at all.

Senator Moss. The bear and mountain sheep are not very litigous, I take it?

Thank you, Mr. Shumway.

Senator Jackson, the chairman of the full committee, is here now. He may have some questions.

Senator JACKSON. Mr. Shumway, I regret I was detained at another meeting. I do want to compliment you for your very fine statement. I agree wholeheartedly with you that our State presents a wonderful opportunity for experimentation in this area. I think a lot of people fail to realize that we have rainfall varying from about 7 inches to about 200 inches at times over the Quinault, on the coast. Many people think of it as having plenty of rain but, as you mentioned in your statement, over half of the State is semiarid and in some parts of the State truly arid. I think what you are doing in connection with your current studies is and can be extremely helpful to a national project. I think you are demonstrating that there is a potential in all of the States, in most of the States anyway, of water availability that, if properly marshaled and directed, can be put to better use than is currently the case.

What is the State budget at the present time?

Mr. SHUMWAY. We were spending about $8,000 a year of the State's half and the city of Seattle, Department of Lighting, was furnishing the personnel to turn on and off the generators. Their share was substantially more than what the State was putting up.

Senator JACKSON. Then you received funds from some of the private groups, didn't you, in connection with some of the experiments?

Mr. SHUMWAY. None other than just the Bureau of Reclamation funds that we have now.

Senator JACKSON. I see. But previously did you receive money from any private groups?

Mr. SHUMWAY. Previously we did not receive anything other than the State funds.

Senator JACKSON. Mr. Chairman, I want to congratulate Mr. Shumway in this very helpful and very practical and very useful statement.

Senator Moss. He has made a very useful statement. We appreciate it, Mr. Shumway.

Thank you very much.

Mr. SHUMWAY. Thank you, Mr. Chairman.

Senator Moss. Our next witness and apparently our final witness is our old friend Spencer M. Smith, Jr., who is the executive secretary of the Citizens Committee on Natural Resources.

We are very glad to have you, Mr. Smith. We look forward to hearing from you. You appear often before this committee and you always make a great contribution.

STATEMENT OF SPENCER M. SMITH, JR., SECRETARY, THE CITIZENS COMMITTEE ON NATURAL RESOURCES

Mr. SMITH. Thank you, Mr. Chairman.

We have been concerned since our inception with the need for and importance of a sufficient supply of high quality water. This concern we believe is basic to any one of our interests no matter how varied or ramified they may be.

Our past activities in support of wilderness, national parks, balanced recreation uses and the general preservation of scenic beauty are directly relevant to any and all programs, which seek to provide a quantity of high quality water.

Not only is there a direct relationship, for few parks or other natural areas could survive without a sufficient quantity of water, clean water, but there is also an indirect effect, when water shortages become so egregious that various types of construction are mandatory in order to satisfy the water demands.

It is this orientation, therefore, that has occasioned our deep interest in this or any other program that has the potential of adding to our needed and often crucial water supplies. We do not purport to be scientists fully acquainted with all of the technical features that would be embraced by a program of weather modification; we do respect the work and attitude of scientists dealing in this and other areas—in fact the board of directors of our own committee find a variety of scientific areas well represented.

By the same token a respect of scientific inquiry, scientific procedures and scientific results are not necessarily proof positive of the resolution of any and all problems under a particular scientific investigation.

History is replete with occasions where the intelligent layman has been the forerunner of scientific accomplishment. It has been comparatively recent, for example, that scientists were of the opinion that weather modification was well beyond the ability of man, or at least sufficiently removed so that man's activities in this area were minimal.

The senior member of this very committee urged a serious investigation of such a program early in the 1950's but until very recently such an urging went for naught.

I am reminded of a personal experience of a few years ago, when I had the great good fortune to be guided through the Thomas Edison home of Glenmont in Llewellyn Park, West Orange, N.J., by the inventor's young son, Theodore Edison.

On two walls of the study were letters by distinguished scientists of Europe proving beyond a shadow of a doubt that illumination could not be achieved by the use of electricity. This was later to have cause Mr. Thomas Edison to remark that he was interested in em-

ploying scientists for a variety of purposes but not for discovery or invention because they inevitably told him that it could not be done.

For a number of years now the burden of scientific information to the untrained layman like myself, has indicated that the subject of weather modification was fanciful and had little potential in reality.

Mr. J. Herbert Hollomon, Assistant Secretary of Science and Technology, of the Department of Commerce, supports such a conclusion when he indicated:

> * * * that the United States at present lacks a broad, systematic, and comprehensive program to extend and exploit available scientific knowledge in the field of weather modification. To date, our efforts have been fragmentary and subcritical, far below the size and quality for effective work.

While this stated realization by the Department of Commerce has cheered our own hopes no end, it should be pointed out that the reason for our lack of such a program was due to the reliance of the policy makers in the Department of Commerce on the scientists who said, It couldn't be done.

In fact it appears to those of us not totally knowledgeable or sophisticated in this area that the very group that has been reluctant to embark on such a program is now aware of the program potential, and they are now devotees of the entire concept.

There are a number of us who are not charmed by the so-called change of the old order and are not convinced, especially by the testimonly of Mr. Hollomon, that there is a full appreciation in the Department of Commerce of the possible fruits of weather modification upon water resources.

If, as Mr. Hollomon has stated here in his objections to S. 2875, the bill fails to take into account the close link between weather modification research and weather prediction research, then he in turn fails to see the implication of weather modification to the entire water resources program that has been taking shape over the last decade.

Quite candidly we have not been persuaded that the relationship between the research of weather prediction and weather modification is as integrally interwoven as Mr. Hollomon contends.

We do not necessarily accept the criteria for research as one of creating mathematic models and the use of high-speed electronic computers as "* * * fundamental to any systematic attack on the problem of weather modification."

It is not our position that any research program should rule out this procedure but to the extent this system has been tried, it is our impression that the number of variables to date have been unwieldy and nonproductive.

On the other hand the breakthroughs that have been made have resulted from ampirical efforts—or cut and try. To rule out this procedure again would appear to us to cast one's lot with a process that is yet to be productive and to reject on that has had limited success.

Mr. Holloman has apparently found the function of mathematical modeling as the basis for linking weather modification and weather prediction. While we are not unsympathetic to the similarity of research procedures, we feell it is even more important that the relationship of the results be considered. It may very well be impossible to divorce weather modification from weather prediction research if Your concept of research is singular and inflexible.

Mr. Holloman's testimony does remind one that weather prediction has been considered historically as a resources and activity oriented service. Doctors initiated the Weather Bureau originally in the Surgeon General's Office of the Army because of the impact of weather on health.

It was later transferred to the Signal Corps of the Army because of the vital role weather played in military campaigns. Perhaps, even because of the turn toward more peaceful activities, the Bureau was then transferred to the Department of Agriculture where again the role of weather prediction was closely allied with farming activities.

When the need for aviation navigation became a significant problem, the Bureau was transferred to its present place in the Department of Commerce. Since that time, however, the aviation activities have been transferred out of the Department and now reside in the Federal Aviation Agency.

This leads one to the conclusion that if weather modification and weather prediction are as inseparable as it has been claimed then it would appear logical to transfer the activities of the Weather Bureau, with all of its functions, to the Department of Interior.

If this was fully implemented, it would seem to be in accord with first, the idea of gathering together under one authority the water and natural resources of our country and second the historical position of orienting the Weather Bureau function to serve an area of critical need. The latter is evident in the case of the critical posture of our water resources.

It is true that the executive branch has been consolidating similar programs, wherever possible, under a single Department authority. With this we concur.

The best evidence of this is the Executive order transferring the Bureau of Water Pollution Control from the Department of Health, Education, and Welfare to the Department of the Interior. When this transfer was undertaken there was no presumption that the Public Health Service would not continue to perform their very important role as protectors of public health, whenever and wherever the occasion arose including the area of water resources. The efforts of the Congress and this committee in particular, as well as the executive branch have been fostering a greater consolidation of the activities relating to water resources in the Department of the Interior.

As we stated at the outset, we are primarily concerned with any program that has the potential of adding to the quantity and quality of the water resources of this country. We support therefore S. 2875 as the best vehicle, that to our knowledge has been proposed, to effect such a program.

We feel that the limited successes in weather modifications in the past have resulted from actions quite apart from Government programs and we feel the opportunities for experimentation and success in the Government will be better carried out under the provisions of S. 2875 than they have been heretofore. Additionally, we feel that placing this responsibility for weather modification in the Department of the Interior is justifiable in terms of the relationship between this program and the responsibility of water resources of that agency.

Finally, we believe this measure is in accordance with the President's efforts to consolidate the principal duties relating to the water resources of the country in the Department of the Interior.

I want to thank the committee for this opportunity to offer our views on this important legislation.

Senator Moss. Thank you very much, Mr. Smith. That is a very fine statement. It indicates that you have been following rather closely the testimony that has come in before this committee and are familiar with what we have in the record so far. I, of course, applaud your suggestion that we consolidate resource management to the maximum degree in a single department where it can be considered in all of its related functions. Then it can be evaluated effectively rather than having different agencies where there may be conflicts or overlaps or just plain noncommunication on problems.

Since weather modification does have many ramifications—the principal one we have been talking about is being able to develop it as an additional water resource—it seems very logical that it ought to be in the department that is in charge primarily of water resources management at this time and may increasingly gather jurisdiction in this area.

One of the witnesses earlier yesterday or the day before talked about having rivers in the sky. I think this now begins to emerge as a good description of what we really have. We have been managing our rivers on the surface of the earth for quite awhile and are getting fairly well along with that, but now we have rivers in the sky to manage and these rivers ought to be managed by the water resources agency that has the responsibility for developing and utilizing this most precious of all natural resources.

So, I have found your testimony refreshing and heartening. I would think that it underlines our need to greatly accelerate our efforts. We have been moving along at a snail's pace so far and in a sort of haphazard way. It now is time that we concentrate and make an organized and scientific attack on the problem.

Mr. SMITH. This is our position. We are very anxious, of course, as we said at the outset, to do anything, support or sponsor or anything that can add to the quality of our water resources. We strongly support this. We are very hopeful that this bill will be successful in the Congress because the Department of Interior, now with the statutory authority given it by the Congress, is moving further and further into acquiring other responsibilities so far as water resources are concerned. This seems to us to be a logical place for this activity.

Senator Moss. Thank you very much.

Chairman Jackson.

Senator JACKSON. I want to compliment Mr. Smith, too. I think your next to the last sentence really put the finger on this when you said finally you believe this measure is in accordance with the President's efforts to consolidate the principal duties relating to the water resources of the country in the Department of Interior.

Mr. SMITH. Yes.

Senator JACKSON. I think your approach is a sound one because the Department of Interior is in a better position to tackle this problem from the standpoint of quality and quantity of water.

Mr. SMITH. That is right.

Senator JACKSON. I thought your statement was very much to the point and I want to commend you.

Mr. SMITH. Thank you.

Senator JACKSON. Thank you, Mr. Smith.

Senator MOSS. Thank you, Mr. Smith.

This completes the list of witnesses who are scheduled to appear.

I would like to point out that all of the evidence that we have here in the record will be printed and that everyone who appeared as a witness will be furnished with a copy of this record but in addition if there are any others who were not witnesses and would like to receive a copy when it is printed, if they will just leave their names with one of the members of the staff, you will be furnished with a copy.

This is an inquiry to try to gather and bring together as much information as we can and therefore we hope that this record will be very widely examined and critically examined by experts in the field and by laymen and by everyone else who will take the time and the interest to apply himself to this a bit in this field.

Therefore I make this announcement about the printed record because after that is done, it is time for the committee to sit down and start thinking about the problem and we still will accept any sort of written comments or information that we can get on the subject. We have some communications that will be included at this point.

(The data referred to follows:)

STATEMENT OF LOUIS J. BATTAN, PROFESSOR OF METEOROLOGY AND ASSOCIATE DIRECTOR, INSTITUTE OF ATMOSPHERIC PHYSICS, THE UNIVERSITY OF ARIZONA, TUCSON, ARIZ., AND PRESIDENT, AMERICAN METEOROLOGICAL SOCIETY, BOSTON, MASS.

Thank you for the invitation to submit a statement relevant to S. 2875 a bill dealing with weather modification. The American Meteorological Society has a vital interest in this matter and as president, I would like the record to show our desires that research efforts in weather modification and the atmospheric sciences in general be substantially enlarged. Secondly, as a scientist who has been actively engaged in research in cloud physics and weather modification since the early fifties, I would like to express my personal views on these subjects.

AMERICAN METEOROLOGICAL SOCIETY

Since its founding in 1919, the American Meteorological Society has played an important role in the advancement of meteorology in the United States and, indeed, has exerted a constructive influence on meteorology around the world. The objectives of the society as stated in its constitution are, "the development and dissemination of knowledge of meteorology in all its phases and applications and the advancement of its professional ideals."

The society has a membership of about 8,000, roughly half of whom are professional members. Among this group are scientists engaged in research on the atmospheric sciences as well as professional meteorologists engaged in weather forecasting or the providing of other meteorological services. For the most part, the members are associated with government agencies, universities, profit and nonprofit corporations, or as private weather consultants. All of the Federal agencies involved in geophysical activities are represented on the society's membership roles.

The society, as an organization, has been concerned primarily with what needs to be done in the atmospheric sciences, rather than who should do the job. Within this framework it has focused attention on particular scientific and technical problems requiring attention. Among the most pressing problems are the following: improved weather observations over oceans and sparsely populated areas; improved weather forecasting; increased activity in air pollution research; enlarged efforts in the study of the upper atmosphere; a better under-

standing of radiation processes in the atmosphere; greater efforts in the study of severe weather events such as violent thunderstorms, hail, tornadoes and hurricanes; and the development of means for detecting and forecasting clear-air turbulence.

The subject of weather modification has had the special attention of the society. Its executive director, Mr. Kenneth C. Spengler, was a member of the President's Advisory Committee on Weather Control during its existence 1953–57. In May 1957 the society, after a survey of the state of knowledge in weather modification, issued a statement giving the society's opinions on the subject. A new committee is now engaged in the preparation of a new society position.

Over the past 15 years the society has been a major force in dissemination of information concerned with research and other activities in weather modification. It has done this through the medium of conferences on regional, national and international scales. A significant number of these conferences have been cosponsored with such organizations as the American Geophysical Union, American Society of Civil Engineers, and the American Association for the Advancement of Science.

Probably the major function performed by the American Meteorological Society in fulfilling the objectives of its charter is the publication of periodicals containing the results of basic and applied research in the atmospheric sciences. The society issues the following journals: Bulletin of the American Meteorological Society, Journal of Applied Meteorology, Journal of Atmospheric Sciences, Meteorological Monographs, Weatherwise, Meteorological and Geoastrophysical Abstracts.

All of these outstanding publications contain articles or information directly or indirectly bearing on the subject of weather modification. The Journal of Applied Meteorology, started in 1962, has become a favored vehicle for the publication of articles on this subject. The last periodical listed, briefly called the abstracts, represents an invaluable source of information for researchers, particularly for students and others newly interested in weather modification and related subjects.

In its publication activities, the aims of the society are to stimulate more and better research and services by all its members—Government, university, and private. It has become increasingly clear in recent years that the national effort in the field of weather and climate modification falls far short of the level the problems deserve. The American Meteorological Society stands ready to take its rightful place in an enlarged effort.

INDIVIDUAL VIEWS

For the last 15 years, the author of this document has been directly involved with cloud physics and weather modification research. As a consequence, I have certain opinions on the subject and would like to express them. It is emphasized that these views are strictly my own and are not to be construed as representing those of the American Meteorological Society.

In certain respects the report by the Panel on Weather and Climate Modification of the National Academy of Science is in agreement with the final report issued in 1957 by the President's Advisory Committee on Weather Control. The Academy report notes that the evidence on hand supports the conclusions that in certain circumstances precipitation may be increased by 10 to 20 percent. However, the careful wording of the conclusions should not be overlooked. They do not say it has been proved that precipitation can be increased. They suggest optimism and hold out the hope for precipitation increases, but do not promise them.

Both the Academy report and the one issued by the Special Commission on Weather Modification of the National Science Foundation caution that in certain instances, cloud seeding might lead to precipitation decreases.

In my view, the evidence points to three possible effects on rainfall by cloud seeding with ice nuclei: (1) increase, (2) decrease, or (3) no effect. On the basis of number of project studies, the first category is dominant, but it is not clear that one can confidently predict beforehand which result will occur and give an adequtae explanation therefore.

For these reasons, rainfall augmentation cannot be regarded as entirely in the category of an engineering project. To be sure once a cloud-seeding project has been adequately designed, its conduct is largely one of engineering. The design

and selection of precipitation measuring gages, their installation and maintenance, the design, testing, and operation of the seeding generators are all engineering tasks. Also, if the project has been properly designed, even the analysis of the data can be largely routine, insofar as answering the question: Did the cloud seeding increase precipitation? However, the interpretation of the data collected in terms of the physical mechanisms involved is by no means routine. It requires meteorological knowledge and insight.

In the design phase of a cloud-seeding project, it is essential that combined talents of meteorologist, statistician, and in some cases engineer, be employed. It is essential that every program be planned and carried out in such a fashion that at the conclusion, valid statistical and physical evaluations can be made to determine if the seeding had any effect. A large measure of the uncertainties existing today in the evaluation of weather modification exist because relatively few of the many projects conducted during the past 15 years have involved the type of controls needed to draw convincing inferences about the results.

It is reasonable to ask why this is regarded as an appropriate time for enlarged research effort. In my opinion, there are several reasons: (1) Although conclusive proof of the efficacy of cloud seeding for rainfall augmentation is still not in hand, the evidence strongly suggests that in certain circumstances, increases of 10 to 20 percent can be produced; (2) the growing need for new supplies of fresh water makes it imperative that all possible sources be investigated; (3) we now have a better understanding of the properties of cloud systems and their microphysics than we had 10 to 15 years ago; (4) new instruments are now avilable for cloud and precipitation observations (doppler radar, aircraft instrumentation and satellites); (5) new theoretical models of atmospheric phenomena coupled with high-speed computers allow investigations which would have been virtually impossible a decade ago; (6) the number of scientists with an interest in weather modification research has increased and continued to increase; (7) there is an increasing desire within the Federal Government to tackle the difficult job of weather modification and a greater determination within the Congress that progress be accelerated.

Most of the emphasis in weather modification research has been centered on rainfall stimulation. Other areas of study also need to be given increased attention. The accumulation of engineering data for use in dissipating supercooled clouds and fogs over airports has been unnecessarily slow. Progress in developing techniques for opening holes through "warm" fogs has been disappointing.

Research in the physics of hail and hail suppression has been grossly inadequate. Efforts abroad particularly from Russia, Switzerland, and Argentina are conflicting. The Russians report amazing success in hail suppression by means of ice nuclei seeding, other groups suggest that seeding in particular instances might cause more damaging hail. In light of the tremendous destruction of agricultural products in the United States, it is esential that we learn more about hailstorms and how to influence them.

The research programs on such problems as lightning suppression, hurricane modification, tornado modification, range from very modest to virtually negligible in size.

The need for investigation of the causes for climatic change and the feasibility of exerting influences on the climate are of great importance. In this regard, the requirement for further international cooperation becomes increasingly obvious. The climate on one part of the globe cannot be changed without causing a change on other areas. The problem is, of course, quite complicated. At the present it is impossible to predict satisfactorily what the consequences would be if any large part of the earth were to be artificially warmed or cooled. As has been noted by others, it is essential that a better understanding of climate be obtained before attempting any experiments of this nature.

How much larger should the program of weather modification be than it is today? How fast should it grow? How many qualified people are working in this area today and how many can be attracted as more funds become available? How crucial are weather modification problems when compared with other Government programs?

These questions are not easy to answer. Clearly the present funding is inadequate when measured against the number of people eager to work on the problems and the importance of weather modification in relation to other Government programs. The Academy Committee and the NSF Commission project require-

ments of $20 to $50 million by 1970. Considering that the fiscal 1966 budget for Federal programs is $7.2 million, these projections do not strike me as exorbitant.

In my view, decisions on which agencies should play a major role in carrying out weather modification research should certainly take into account performances in the past as well as the existing scientific and professional staff with meteorological competence. At this stage the major problems are still meteorological ones.

On this basis, the National Science Foundation's program in weather modification research should not only be continued, but should be enlarged. With limited resources at its command, the Foundation has supported an active and productive program at universities, private companies, and has assisted various Government research efforts through transfer of funds. In supporting university research on the basis of merit, the Foundation has made it possible to carry out meaningful research. Some of this research has built the foundations for work now being financed by other agencies. A very important consideration which must be taken into account is that university support from NSF has provided for the training of graduate students and increased the number of available scientists.

The Environmental Science Services Administration (ESSA) has the greatest concentration of atmospheric scientists of all the Government agencies. Over the years it has shown that it can efficiently manage large observational programs involving up-to-date equipment. In the past the Weather Bureau for various reasons, one of them being a shortage of funds, has not had a large weather modification program. Since progress in this field will depend largely on the scientific talent employed, it makes sense to me that ESSA be encouraged to greatly enlarge its research efforts. It also seems reasonable that ESSA be charged with the responsibility for monitoring weather modification activities to prevent undesirable interference between projects, to protect federally supported programs from liability, and to compensate the public for damages which might arise as a result of Government-supported work. ESSA also is a logical agency to assume the responsibility for collecting and evaluating data produced by weather modification projects and for publishing the results at reasonable intervals.

Other Federal agencies having specific mission requirements should also be supported in larger measure. In the last few years the Bureau of Reclamation has initiated an ambitious program aimed at precipitation augmentation over watersheds in the West. These new programs promise to yield answers to important questions relating to increased precipitation and deserve to be funded at a higher level than at present.

Agencies such as the Federal Aviation Agency, Forest Service, Air Force, Army, and Navy have specific programs concerned with their assigned missions. In the past some of these agencies have had to seek funds from the National Science Foundation to conduct research. The programs should be supported directly at the levels which can be reasonably justified.

At the present time, Federal efforts in weather modification research is partitioned among the Departments of Defense, Commerce, Interior, Agriculture, and the National Science Foundation. Certain close coordination is needed and a mission-oriented agency needs to be assigned certain regulatory responsibilities. But at the present time there does not appear to be sufficient information on hand to justify the centralization of all authority in one agency. In my opinion, the absence of such centralized authority has not been the major reason for the inadequacy of our research efforts in weather modification. The low level of support and the shortage of qualified scientists must be regarded as important reasons for slow progress. Note that although Federal expenditure in weather modification research in fiscal 1965 and 1966 are listed as about $5 and $7.2 million, for the preceding 6 years they averaged just slightly over $3 million per year for the entire national effort.

The realization that a much greater research effort is overdue and the trend of increased funding over the last 2 years has injected new life into weather modification research. Continued increases in funding are in order if the problems are to be solved in reasonable times. At the same time, greater coordination is needed within the Government to assure that the available funds are being used wisely.

I thank you for the opportunity to express these views.

STATEMENT OF BERNARD A. POWER, PRESIDENT, WEATHER ENGINEERING CORP. OF AMERICA

INTRODUCTION

This statement summarizes eleven years of operational cloud seeding for water production in the northeast. One project in particular on the Gatineau River watershed, north of Ottawa, Canada, is the longest and largest contractual seeding project in the world to our knowledge. The mass of data from this one project alone powerfully reinforces the recent conclusions of the National Academy of Sciences as to the positive effects of seeding, and it amplifies the findings as to the average level of seeding increases attainable in the east.

OPERATIONAL INFORMATION

The Weather Engineering group consists of Weather Engineering of America, Weather Engineering of Canada, and Cosphere Corporation, a non-profit organization devoted to basic research in the atmospheric sciences.

In 1955, long term seeding operations were begun in wilderness areas of the northeast (New Brunswick, Maine, Ontario, Quebec, Nova Scotia and Newfoundland) to obtain definitive proof of seeding results. It was realized that other settled areas in the east and northeast offered little hope for the continuous, uninterrupted, long term operations which were necessary to establish positive findings beyond doubt.

The target areas have varied from approximately three hundred square miles to about eighteen thousand square miles in area. Applications have been principally for hydroelectric power utilities and for forestry interests for fire suppression. Operations have also been conducted for agricultural interests and for increased snow production for skiing. Clients have been principally private and public power utilities, forestry associations, governmental agencies.

The project on the Gatineau River watershed, north of Ottawa covers an area of approximately nine thousand square miles. It has been operated continuously 1955 to 1965, and has yielded a very large mass of data for analysis (75 project months in the season April through November).

These data have been evaluated independently by the Hydro-Electric Power Commission of Ontario (Ontario-Hydro) as well as exhaustively by our own statisticians. The summary of results from the Ontario Hydro report is shown as follows in Table 1.

Table 1

	Estimated increase (percent)		*Estimated increase (percent)*
April	27.2	September	24.7
May	23.2	October	4.6
June	35.4	November	25.7
July	43.9		
August	77.9	Total	33.3

The Ontario Hydro report released in 1964 covered the seeded period 1955–1962. A recent report by our own statisticians covering the period 1955–1964 shows an average increase of 29.5%.

The statistical methods have been those employed by the National Academy of Sciences committee in its report #1350 released in January 1966, namely regression analysis of the cube root values of target and control precipitation. The statistical significance of the results is 0.001 (99.9% level).

Other projects in Maine and New Brunswick, Nova Scotia, Quebec, and Ontario give results similar to those of the Gatineau project, namely indicated increases from 20% to 35%. A combined significance has not been calculated for all projects as it would be superfluous in view of the Gatineau 99.9% level. These projects add another some 70 project months to the data available.

It is obvious that these new data powerfully substantiate the NAS committee findings, since they provide in the case of the Gatineau project alone some three times the basic data used by the committee and consequently yield a higher level of statistical significance.

It should also be mentioned that not only can overall conclusions be drawn from the Gatineau data as to average seeding increases (29.5–33.3%) but

that statistically significant results are also found for *individual seasons and months.* Thus the data form an invaluable base on which to build the engineering phase of weather modification. Policy formulation with regard to water production potential in the east generally and especially over the vastly important Great Lakes basin can now draw upon a decade of actual experience.

It should be mentioned that possible bias such as "optional stopping time" or "drought" bias discussed in the NAS report in regard to short-duration projects do not apply to the above results because the project was continuous and because all precipitation occurrences are included in the evaluation.

It is hoped that this statement will assist the committee by bringing to its attention this body of additional evidence to further substantiate the NAS conclusions and to amplify its findings as to the levels of increase and levels of significance attainable.

From our experience we would like to offer two recommendations for research which appear to us to be particularly promising.

First, detailed statistical studies should be made of operational seeding data such as that on the Gatineau, by stratifying the data according to meteorological parameters such as synoptic situation, air mass stability, air mass temperature etc. Such studies could throw additional light on the seasonal variations already evident in Table 1, as well as on the variation of seeding effectiveness with meteorological conditions.

Second, our basic research into natural nucleators has led to the discovery of several classes of naturally occurring organic ice nucleators which could be of basic importance in natural precipitation processes. Among these are the amino acids, the terpin hydrates, vanillin, and potential nucleators such as methyl salicylate and eucalyptol or cineole. These substances are released to the atmosphere by vegetation and the rate of release varys with the season. It appears to us that increased research into interactions between such substances of vegetative origin and the atmosphere could lead to far reaching insights into both the balance and the imbalance of natural weather systems.

WEST LOS ANGELES, CALIF., *March 15, 1966.*

Senator CLINTON P. ANDERSON,
Senate Office Building,
Washington, D.C.

DEAR SENATOR: In August 1963 I conducted a rainmaking operation at Raton, N. Mex. This project was made possible by Nat Norman who solicited more than $500 from local folks to bring me there.

The situation was critical. New Mexico was in the throes of the most severe drought on record. The countryside was brown and tinder dry. Wide cracks crisscrossed the land like an intricate crossword puzzle. There were no clouds in the sky and no hope for any.

My log indicates that I arrived at Raton at 11:30 p.m. on Wednesday, July 31, 1963. The following morning I met with city officials and Nat; Nat took me on a short tour of the area and I decided to set up operations at the foot of Lake Maloya, source of Raton's water supply. The Bill Neish family agreed to board me for the 30-day period of operation.

On Thursday, August 1, I set up operation on the roof of the old chemical plant at the foot of the dam, and exposed 60 boxes of chemicals. I had promised an inch of rain by August 4, and the records for the previous year were available. It is interesting to note that during the entire month of August 1962 only 1.40 inches of rain fell there.

My log for August 3, Saturday, follows:

"August 3, Saturday., got up at 1:30 a.m. and began processing. Clouds that were present moved west, then clear sky, then new clouds began forming over area. These new clouds were alto-cu's but soft and nimbus type. Jerry Brown from Channel 7 of Albuquerque came out in the morning and got pictures of the dam and operation. The city manager, Al Pearce, called and wanted me to come for Raton for signing of agreement. Weather threatening. Drove to Raton and took car to McQueery's Chevron Station where John Farrell fixed power steering and tire was repaired (total $18.49). Started to rain while I was in Raton. Returned to Lake Moloya to find 0.36 inch had ruined chemicals. Rain with lightning continued. Precipitation at Lake Maloya before 5 p.m. 1.36 inches; 0.10 inch fell after 5 p.m. Storm began with lightning, ended with drizzle."

Senator Anderson, you will note from the log that this is no silver-iodide operation. Neither is it dry ice. Both those methods of inducing rain need a cloud to begin with and when I went to Raton there were no clouds—the ideal way to begin a real rainmaking operation. Begin with no clouds and making rain in 3 days: that is the real proof of rainmaking: making an inch of measurable rain at the site.

Now some people believe only God can make rain. And others believe man was given dominion over the earth and all that is in it. Still others believe only in the U.S. Weather Bureau; and Eric McCrosson of the Raton Daily Range was one of these. He got the impression that I was having a "ball" at Raton's Lake Maloya at the cost of the citizens—and Lake Maloya had no electricity; I was not permitted to ride the horses, and even the preachers took "potshots" at the rainmaker when I attended their services to worship God.

Mr. Senator, I would like to say I have mastered the art of rainmaking but I have to admit that I have not. While at Raton I did make a device based on an electronic principle which I hoped would increase the rainfall at the site. Unfortunately, I almost sabotaged my local operation before I realized I had discovered a control—a way of stopping rain. And while it takes 3 days to make rain—it only takes 30 minutes to stop it.

I do make this claim: that I have found a way of reacting hydrogen to oxygen in the earth's atmosphere to make measurable quantities of rain—usually over an inch within 3 days over hundreds of square miles.

By the end of August it was raining so hard at Raton that they couldn't get the horses out on the track for scheduled races at the local track. Ranches in the area had reported rainfalls of 2 inches in a single storm. Clayton, a ranch community to the southeast reported 4.4 inches on a single Saturday afternoon.

Mr. Senator, the Lake Maloya rain gage recorded 4.11 inches by the end of August—and the creeks had just begun to run in the area. But women shopkeepers in town told me they had never seen clouds like those since I had set up operations at Raton.

The whole point is this: the drought was broken by the end of August and the land was green for hundreds of miles in every direction. Des Moines reported more rains than in 20 years. Colorado reported mud slides where rains did not usually fall at that time of year. And all this was no accident, believe me.

Mr. Senator, the weather of the United States comes from two primary sources: volcanoes in the Aleutian Islands and in Hawaii. Anchorage, Alaska, gets the same average rainfall as Los Angeles and the reason is that neither is in the weather track of the volcanoes producing their weather (except under unusual circumstances).

What I do to make rain is the very same thing as the volcanoes do—only I do it in a much purer form and thereby attain results from my pills for Mother Nature. In a way, I prime nature into doing what comes naturally—I supply the missing ingredients.

The National Science Foundation isn't going to pay me for showing them how to make rain. They feel I should reveal the process in a scientific media—and open it up for discussion. That's like Douglas giving their missile know-how to Boeing or North American. Since when have these big operators been donating their missiles to Uncle Sam just for the sake of defense?

Let's be practical. Water through a pipe is worth money. Water on the land is worth money. Water is worth money. But rain is water and it is supposed to be free?

Rain is cheap—mighty cheap—and one man can make it any place on earth. But it can also be a weapon. And it is so simple a high school kid could do it—and a hundred high school kids could wash out Los Angeles.

So one can't tell the world how to make rain—for to do so would be to bring destruction. It should be regulated by the governments of the world—indeed, it has to be regulated.

Mr. Senator, we already know how to control the weather. We can make rain in 3 days and stop it in 30 minutes. We can make 45 inches in 26 days and have as a matter of record. We can destroy nations or make deserts bloom.

Henry Ford was not a Ph. D. but he made transportation available for the millions. Thomas Edison was no Ph. D. but he gave us lights and sound for the millions. Jesus Christ was no Ph. D. but he gave us something to believe in for the millions. I am no Ph. D. but I can give you rain when you need it and sunshine when you want it—and that ought to be worth something.

Very sincerely,

EDMOND C. JEFFERY.

NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY,
DEPARTMENT OF GROUND-WATER HYDROLOGY,
Socorro, N. Mex., March 17, 1966.

Senator CLINTON P. ANDERSON,
Senate Office Building,
Washington, D.C.

(Attention Mr. Claude Wood).

MY DEAR SENATOR ANDERSON: With reference to your bill S. 2875 to authorize a comprehensive program of scientific and engineering research for increasing the yield of water from atmospheric sources, with your permission we wish to submit the following brief statement for inclusion in the record. Later, if acceptable, we should like to appear to testify at an appropriate time during the hearings.

As you are well aware, New Mexico Institute of Mining & Technology has long been engaged in scientific research in the field of atmospheric physics. We feel that we are qualified and outfitted to undertake research also in the technology of atmospheric water sources.

Specifically, with regard to the proposed legislation and its implementation, we feel that in order to appraise the results of future operations designed to increase the yield of water in the atmosphere we must have a better understanding of the present undisturbed regimen of atmospheric water circulation and its involvement with surface waters and subsurface waters. Accordingly, we strongly recommend close coordination with inventories of surface and subsurface waters presently under the direction of the Secretary of the Interior.

We should like to emphasize also that combined atmospheric and land water balances must be regional in scope.

As an outgrowth of previous research at the institute, we feel the need to stress the importance of obtaining, in addition to a closed water balance, a geochemical balance. That is, associated with the movement of water from and into the atmosphere across the surface of the ground is the movement of chemical substances, mostly in minute concentrations, in gaseous as well as liquid states. This institute is very much interested in this phase of the program which, it would seem, is contemplated under the heading of quality of water and its adequacy (sec. 1), and which should be correlated with air pollution studies.

May we also go on record as indicating our interest in providing facilities and housing for one of the regional research and operations centers.

Thank you for the privilege of entering this statement.

Very truly yours,

C. E. JACOB,
Professor of Hydrology and Coordinator of Organized Research.

Senator MOSS. There are going to be some field hearings, too. We will be in Rapid City, S. Dak., on the 11th of April, and Aubuquerque, N. Mex., on the 14th of April. Should there be any one who has not had a chance to appear here and wants to get something in the record there, that will be his opportunity to do so.

Let me thank you very much here, this large group which has attended these hearings all the way through.

We can see that there is great interest in the subject and we certainly are approaching a problem that has grown more critical as the days and weeks have gone by. It is already late to attack it. All the members of this committee believe that we must press forward now without any further delay in the most practical and efficient way that we can devise to utilize the great resources of the atmosphere, to tame their destructive characteristics, but also to turn them to benign purposes when we can learn to do that.

The hearing is now adjourned.

(Whereupon, at 2:55 p.m., the subcommittee recessed, to reconvene in Rapid City, S. Dak., on Monday, April 11, 1966.)

WEATHER MODIFICATION

MONDAY, APRIL 11, 1966

U.S. SENATE,
WATER AND POWER RESOURCES SUBCOMMITTEE,
OF THE COMMITTEE ON INTERIOR AND INSULAR AFFAIRS
Rapid City, S. Dak.

The subcommittee met, pursuant to call, at 10 a.m. at the Surbeck Center, South Dakota School of Mines, Rapid City, S. Dak., Senator McGovern presiding.

Present: Senators McGovern, Moss, Metcalf, and Burdick.

Also present: Roy Whitacre, professional staff member.

Senator MCGOVERN. Gentlemen, we are happy to open these hearings this morning in Rapid City on the subject of "Weather Modification." I am very pleased that we have with us three members of the Senate Committee on Interior and Insular Affairs: Senator Metcalf, of Montana, Senator Burdick, of North Dakota, and Senator Frank Moss, of Utah, who has just flown into Rapid City. From the April snowstorm outside it is clear that these weather-modification experts have been playing some pranks on us during the night.

These hearings this morning represent a continuation of hearings on Senate bill 2875. The bill was developed by Senator Anderson, of New Mexico and I. All of the Senators around this table together with some 20 other Members of the Senate, are cosponsors. It is legislation to authorize and direct the U.S. Department of the Interior to conduct an accelerated and expanded program of weather modification research and experimentation, development and operations aimed at increasing precipitation—rain and snowfall—in areas where water is in short supply.

Three days of hearings were held in Washington, D.C., on March 21, 22, and 23. The Interior Committee heard 25 Government officials and scientists on those days. At least one additional day of hearings will be held in Albuquerque, N. Mex., on Thursday, April 14, and then the entire record, including a verbatim account of today's proceedings, will be published by the Interior Committee.

We have as witnesses here today scientists of high rank in the atmospheric sciences field from six Upper Great Plains States. They will tell us of work they have done and advise on further policy.

Senator Anderson, in opening the Washington hearings, described them as a continuation of hearings he conducted 15 years earlier, in 1951, on the same subject. The 1951 hearings were on 3 bills which had been introduced in the Senate that year proposing research on desalinization of brackish water and salt water, and on weather modification to increase water supplies. The first of these bills was

authored by Senator Francis Case of South Dakota, my distinguished predecessor in the Senate. He was one of the very earliest proponents of attempting to tap the streams of moisture that exist in the atmosphere.

The hearings in 1951 finally resulted in 1953 in the establishment of a Federal Commission, known as the Orville Commission, to study the feasibility of weather modification. The U.S. Weather Bureau was skeptical and critical of expending funds on the effort. The Bureau's scientists contended that there was no valid proof that cloud seeding or other techniques would increase precipitation. They described themselves as "agnostics" on the subject.

The Orville Commission reported in 1957 that there was, indeed, scientific evidence to support the claim that weather might be modified. It recommended that a program of research be undertaken by the National Science Foundation.

Because of scientific skepticism about the effectiveness of controlling atmospheric behavior, the National Science Foundation did not undertake a direct research program. It made grants to universities and colleges and some private groups in support of their research. Outstanding among these projects is the National Center for Atmospheric Research at Boulder, Colo.—a joint operation of a group of colleges and universities which early became aware of the Nation's impending water shortages and problems.

Another such effort which the National Science Foundation is supporting is the work of our own Institute of Atmospheric Sciences here at the South Dakota School of Mines.

During the past decade, because of the reluctance of the scientific agencies to get at atmospheric problems, agencies of Government with specific atmospheric problems have moved into the field.

The Air Force is concerned about dissipating fogs at airports, and it has successfully done the job where super-cooled cloud cover is involved.

The Navy involved itself in efforts to see if hurricanes and great storms could be ameliorated or suppressed, and it enticed the Weather Bureau into cooperating in their projects in this area.

The Forest Service in the Department of Agriculture started tests to determine if lightning, which starts many destructive forest fires, could be suppressed. It has had encouraging results. The Department of Agriculture is also interested in hail suppression, to end crop losses from that cause.

The Department of the Interior has, in the judgment of some, the major mission in the field—increasing precipitation not only in the arid and semiarid Western States, but now in the Eastern States where population and industries have outgrown drought-year water supplies. Because of the urgency of water supply problems, the Bureau of Reclamation has for the past few years been conducting "rainmaking" tests in about five locations. It is a substantial supporter of Dr. Richard Schleusener's work here at the School of Mines.

Growing evidence that weather modification gets results, and our demonstrated willingness in Congress to fund the work being done by the agencies which have missions concerned with atmospheric behavior, caused both the National Science Foundation, which is a Federal institution, and the National Academy of Sciences, a private

group, to appoint panels of scientists about a year ago to reappraise the possibility of weather and climate control.

These two panels reported in January. Both of them reported that weather modification efforts have resulted in increases in precipitation of 10 percent to 20 percent over areas as large as 1,000 square miles. Both of them recommended that there be large increases in Federal research because of the urgency of water and other problems and the promise which weather modification research holds. They were in substantial agreement that our Federal effort should be increased from a level of about $5 million annually to $30 million by 1970 on weather modification work alone. At the same time, they recommended an increase in study of the behavior of the atmosphere —basic research essential to back up the weather modification work— of about the same dimensions.

Because of my concern with water problems, and my sponsorship of several measures in the field, I was aware of what the two scientific panels would recommend somewhat in advance of formal release of their reports. Consequently, on my own behalf and on behalf of Senator Clinton Anderson of New Mexico, who has a great concern about water resources, I requested assistance from the Department of the Interior early in January in formulating a program and a bill to speed weather modification work in line with the recommendations of the two scientific panels.

Nine nationally outstanding scientists in the field assembled and spent 3 full days outlining a 10-year program of research which became the basis of the Anderson-McGovern bill.

The program they laid out proposes the establishment of six or eight regional laboratories and research centers for atmospheric and weather modification research. I make it no secret at all that I want the Institute for Atmospheric Sciences here at the School of Mines to be the nucleus for a regional center. The program outlines the facilities—regional laboratories, networks of atmospheric observation stations and testing centers—which may be needed. It estimates the equipment in terms of special radar, specially instrumented airplanes, computers much larger than any that now exist, and the more conventional items down to office equipment, which will be required. Also, it estimates the personnel involved, some of which will have to be trained at colleges and universities like School of Mines.

In the case of weather modification, however, the effort will be widely spread geographically—it cannot be centered in one or two huge installations but must be taken out across the land where varying climates, varying atmospheric complexes, and needs exist.

It is a "natural" for the have-not States, which were largely bypassed when atomic and space industries were being located, because we do have the water, hail, and climatic problems on which the work must be done.

I have gone into this background so those participating today and those attending may have a better understanding of the nature and purpose of the hearing. A pamphlet going further into purpose and background is available from the committee staff.

I would like before we go any further to introduce each one of the Senators who is with us this morning and perhaps they would like to extend a word of greeting. I will begin at my left here with Senator Metcalf of Montana.

Senator METCALF. Mr. Chairman, I appreciate the opportunity to sit on this panel of the Senate Interior Committee considering S. 2875, introduced by Senator Anderson and Senator McGovern, myself, and 19 other Senators to launch a nationwide atmospheric water resources program.

In the preceding hearings in Washington the fact that the late Senator Francis Case, of South Dakota, and Senator Clinton Anderson, of New Mexico, were involved in senatorial efforts 15 years ago to speed weather modification studies was brought out. So also was my predecessor in the Senate, James E. Murray, of Montana. A great many citizens of Montana have been interested and pressing for research and development in this area for at least two decades, including Harold Sheldon and Mr. Miles Burd of Galata, who was to be one of the witnesses today but I understand cannot get here at this time.

I am also pleased to see that Don Fuquay of the U.S. Forest Service Forest Fire Laboratory at Missoula, Mont., is to appear here today. The Forest Service Project Skyfire to study methods of lightning suppresion, is an example of mission-oriented work by various agencies which should be accelerated. Now that the scientists agree that such research can be fruitful, one of the key issues that we are going to have to resolve in connection with an accelerated weather and climate modification program is how the Government will approach the work, whether it is to be supervised by a lead agency as the Department of Commerce wants it to be, whether it will be put under a special commission, or whether it will be left to the agencies which have atmospheric problems or missions, such as the Department of Agriculture has in its Project Skyfire and in the problem of hail suppression. Similarly, the Department of the Interior has the tremendously important mission of determining if the great streams of water in the sky can be tapped to meet all or part of our water needs.

At this point in this hearing, I am convinced that each of the agencies with missions—Agriculture, Interior, and the Navy with its storm suppression work—should be encouraged to speed the projects they have undertaken and that a multiagency approach should be followed. Certainly the Department of the Interior with its concern about adequacy of water supplies not only in the arid Western States, but all across the Nation, should be supported in an expansion of the work that has been started here in Rapid City, among other places, by the Bureau of Reclamation.

The Upper Missouri River Basin will be using all of its available water supplies by 1980, the experts say. Unless we can find more, our economic growth will be at an end before it is even well started. Tapping the abundant water resources in the skies above us is now regarded as a scientific possibility, so I strongly support giving the Interior Department the comparatively small sums it needs to explore the possibility and find out how it can be done.

Senator MCGOVERN. Thank you very much, Senator Metcalf. On my immediate right is Senator Quentin Burdick of North Dakota. We will have Senator Burdick give us a word.

Senator BURDICK. Senator McGovern, what I have to say at this time will be an echo of what you two gentlemen have said. I want to say that the fact that there are four Senators here, all of them

members of the Senate Interior Committee, bespeaks the interest in this project, like the crowd we have today also bespeaks the interest in this project, in this phase of scientific involvement and discussion. This is particularly so on a day like this when there are minimum ceilings and some of us just scraped the bottom of the skies to get in.

To the average layman I suppose that weather modification is a sort of mystery. It is still a lot of uncertainty, fraught with unbelief or disbelief, but I was particularly impressed by the background material which you now have or will have before you which is the report of the Special Committee on Weather Modification of the National Science Foundation.

Just to quote you a sentence: "The scientific exploration of weather and its final modification is passing from that speculative phase to that rational phase."

That is a tremendous gain. And so I am going to be interested today to hear the witnesses and to hear this testimony so that we can form a basis for planning for Federal programs along these lines. It is indeed a pleasure to be in the State of South Dakota today.

Senator McGovern. Thank you, Senator Burdick. Now, Senator Frank Moss, who has been a member of this committee for a number of years. We will hear from you, Senator Moss.

Senator Moss. Thank you, Mr. Chairman. I am very pleased to be here with you today and with my colleagues at this fine institution which is already doing some useful work in the field of environmental sciences, including weather modification. I came to listen and to help make the record. I have followed with great interest the testimony that we have had from many expert witnesses in Washington earlier in these hearings and, indeed, in preceding years when we have had some hearings on weather modification.

As do all my colleagues on this panel, I come from an area which suffers from water deficiencies and we are anxious to find any way that is feasible and possible to augment our supply. We recognize that the possibility of weather modification would be one way of augmenting the supply of water available, but it has many other ramifications; goes into fields of lightning suppression and storm dissipation, and so on, so I am looking forward to the testimony today.

As Senator Burdick indicated, we have had a period of years when experiments have been fragmented and hit and miss, and now seems to be the time to pull the program together in scientific, directed efforts to find some solutions in this field. One of the witnesses we had in Washington, who talked about the work that we have done with rivers that were flowing on the surface, said, "we need to find out also about the rivers we have in the sky." I like that phrase. We have rivers running in the sky if we just know how to handle them.

I appreciate the opportunity of coming and being here today, and I look forward to the hearing, Mr. Chairman.

Senator McGovern. Thank you, Senator Moss. Our first witness today is Dr. Richard Schleusener, the director of the Institute of Atmospheric Sciences at the South Dakota School of Mines. I think it is well known to most of the people in this auditorium that Dr. Schleusener is nationally and internationally recognized in this field. I was interested in reading a report of the National Science Foundation to find he served on a number of the panels that went into the

preparation of that report; served in a very important and distinguished manner. I think the South Dakota Board of Regents and this institution where we are meeting today are to be congratulated for securing the services of a man of his caliber and the high-quality staff that he has working with him. They are to be congratulated, too, for approving recently the conferring of a master's degree in meteorology, and for their support of this whole program in the atmospheric sciences field. The so-called Project Hailswath, which Dr. Schleusener has been working with, will help to unite our entire upper Great Plains area in a cooperative effort. It is the kind of thing we need to be doing more and more in the interests of this part of the country.

I am very pleased to ask Dr. Schleusener to come to the witness table and we will be glad to hear his statement. If the witnesses have extra copies of their statement, it would be helpful if they would give them to Mr. Whitacre here of the committee staff.

STATEMENT OF DR. RICHARD SCHLEUSENER, DIRECTOR, INSTITUTE OF ATMOSPHERIC SCIENCES, SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY

Dr. SCHLEUSENER. Mr. Chairman, before I begin my statement, on behalf of President Partlo and also for the school, I would like to welcome you and your committee and all of our visitors to the campus of the South Dakota School of Mines and Technology. Very few students are on the campus today because this is the last day of our Easter vacation. If we can be of any assistance to your committee in any way, please let me know and we will do our best to try to help you.

I am very pleased to be here this morning to present my views on desirable policies for legislation in the field of weather modification. My name is Richard A. Schleusener. I am director of the Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, S. Dak. I have been involved in research in weather modification since 1958. I became interested in the subject as a result of contacts with farmers and ranchers who were involved in weather-modification projects for increasing precipitation and decreasing hail. As a result of my contacts with these people and subsequent research, I have developed a conviction that cloud modification offers promise for solution of some of the weather problems in this geographic region.

The Institute of Atmospheric Sciences is a department within the School of Mines and Technology, and was established by the regents of South Dakota in 1959 for the purpose of conducting research in meteorology, with particular emphasis on weather modification. At the present time the staff of the Institute of Atmospheric Sciences includes six scientists and seven supporting technicians. Two more scientists will join our staff within the next 6 weeks. We have a number of engineering students working with us part time. In addition, we draw upon the resources of private meteorological firms through subcontracts to provide support for our research program.

Last December we received approval from the regents of South Dakota to initiate a graduate training program in meteorology. This

program will begin next fall, and we are looking forward to the opportunity of training additional scientific manpower.

My remarks today should be placed in the context of two current factors:

(1) Substantial economic benefit could result in this region with only slight success in increasing precipitation or decreasing hail. As a result of having lived in this geographic region most of my life, I am convinced that substantial economic benefits would result if it would be possible to accomplish either of two major objectives in the field of cloud modification: increasing precipitation or decreasing hail. I believe that other testimony to be given before this committee today will further amplify this fact. Therefore, I will not elaborate on it further at this time.

(2) At the present time there is a consensus on the possibility of beneficial weather modification. This is a change from attitudes that prevailed only a short time ago. The committee print, "Expansion of the Atmospheric Water Resources Program of the Department of the Interior," summarizes correctly the changed attitudes toward weather and climate modification in the quotations given (p. 4 of the committee print). I am pleased to see this scientific consensus develop. It is overdue. I am also happy to be able to say that I am on record with optimistic statements concerning cloud modification substantially in advance of the current wave of optimism. I might add that my associate director, Dr. Arnett S. Dennis, can make a similar statement.

I have been responsible for the direction of the research program of the Institute of Atmospheric Sciences since my arrival in Rapid City on January 1, 1965. A statement of the program and description of the staff of the Institute of Atmospheric Sciences was presented to the hearings of the Subcommittee of the Committee on Appropriations of the U.S. Senate (p. 446, "Public Works Appropriations, 1966") by Senator Mundt in the hearings of the Appropriations Committee on the budget of the Bureau of Reclamation. In the same hearings (p. 446) Mr. Walter Garstka, who was then Chief of the Atmospheric Water Resources Branch of the Bureau of Reclamation, testified the institute was considered to be a regional center of weather modification research.

The objectives in our research program in atmospheric water resources with the Bureau of Reclamation include developing beneficial weather modification procedures and techniques for the northern Great Plains. Our work requires the preparation of long-range plans for research in atmospheric sciences and for the coordination of research with engineering practices and the art of weather modification with special emphasis on increasing water supplies.

I would like to report to you today some of our thinking as it has evolved in making plans for the development of operational weather modification systems in the northern Great Plains region. Most of my attention will be directed to the problem of obtaining increased precipitation from operational systems of weather modification, but I shall also point out how the same general approach also applies to other objectives, of which the reduction of hail is a very important one for this region.

I would call your attention to the fact that this program of development of operational weather modification systems is aimed primarily at cloud modification, as opposed to "climate" modication. While research related to climate modification is of vital importance, and should be pursued with vigor, we believe that development of cloud modification should be given top priority, for the following reasons:

Field experiments and operations in cloud modification do not constitute any risk of catastrophic weather changes. This is not necessarily true with climate modification.

Presently available knowledge offers greater promise for success in cloud modification.

Results and the resulting "payoff" are more likely to be obtained at a relatively early date.

We are in complete agreement with the committee statement (p. 6, committee print, "Expansion of Atmospheric Water Resources Program of the Department of the Interior") that the end objective of the program must be the development of operational weather modification systems. The general approach which is outlined in figure 1 is directed toward that end.

(With the help of an assistant, a number of slides were shown.)

Figure 1 shows a functional diagram for the development of operational weather modification systems. In the lower right-hand corner of that sheet we have the stated objectives, operational systems of weather modification to reduce hail or to increase precipitation. We consider that is the objective, that is what we are shooting for, that is what we want to accomplish. How do we get there? We show it in steps as we go on to the next slide. Each case I have outlined in red of the new information that's added as we go then to the left. On the left we say that additional data may be available so that operational systems for weather modification can come into being without elaborate research programs. I think Mr. Fisher is going to tell us about one of these programs that came into being without a lot of research. People have a problem. They believe they can solve the particular problem with operational systems, so they go about their business and this is one way that these operational systems of weather modification can come into being, simply by people going out and tackling a job and trying to do a job.

The next slide shows an input into this from research activity and shows one channel by which additional information can be fed into this system. As we go down from the top to the bottom we start out with an unmodified atmosphere, Mother Nature as she is. We take our equipment of radar and airplanes and other probes, get observations and process the data. We end up then with data in hand and then in the middle we have a block that says "Interpretation." We have to understand what these data mean. We then go down a notch farther and we end up with a model. What is a model? The model is simply a description of what the atmosphere is. As we go on farther down from the model we subject the data to an operational analysis. The operation analysis incorporates economic data. What is a given inch of rain worth? What is a half an inch of rain worth? What is it worth to reduce hail damage? And if we were smart enough following this chain, we could proceed to the bottom to the recommendations that would give an input into these operational systems

and help us to operate better. We find, however, that we are not that smart so we need some additional help and the way we try to solve our problem is to look at various kinds of experiments that are shown on the next slide.

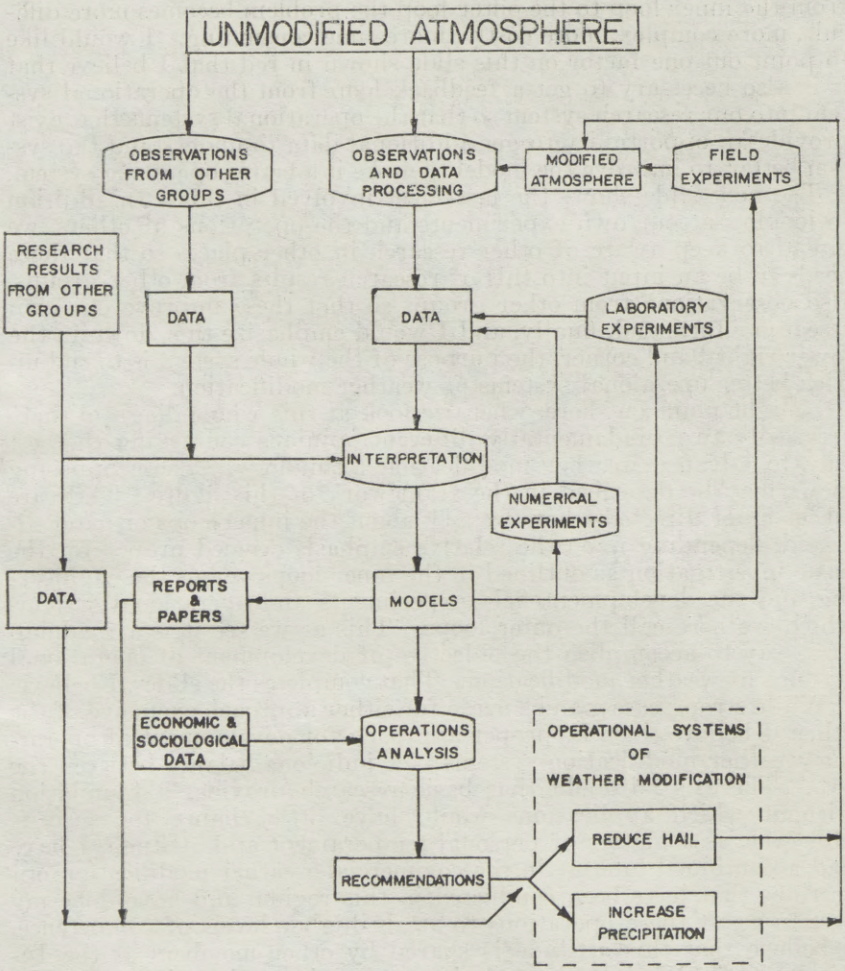


FIGURE 1: FUNCTIONAL DIAGRAM FOR DEVELOPMENT OF OPERATIONAL WEATHER MODIFICATION SYSTEM.

Here we are adding to the system various kinds of experiments. We talk about three. Numerical experiments. Here we notice we can go through a numerical experiment to test our model. We get additional data, we interpret the data and we improve the model. We will probably have to go to laboratory experiments and again we obtain additional data which must be interpreted to improve the model. Finally, we go to more complex field experiments where we would try to modify the atmosphere. We then end up in parts of a modified atmosphere that we can observe and again feed data into our inter-

pretation loop to get a better model which would give us a basis for recommendations.

There is more to this system that we see on the next slide. I might comment while he is putting the slide on that as we go from the inner loops—numerical experiments and laboratory experiments—as we go from the inner loop to the outer loop the problem becomes more difficult, more complex, more costly, more time consuming. I would like to point out one factor on this slide shown in red that I believe that it is also necessary to get a feedback loop from the operational system into our research system so that the operational systems that exist provide an opportunity to get additional data to understand the system better, to improve the model to make it a better operating system.

The next slide shows the last facet involved in this. In addition to looking at our own experiments and the operations of others, we intend to keep aware of other research in other places so that there needs to be an input into this of research results from other groups, also observations from other groups so that these improve our own research efforts and, finally, and I would emphasize this, down in the lower right-hand corner, the purpose of the whole system is to end up with better operaional systems of weather modification.

I might point out here, when we look at this whole diagram there are really two fundamentally different opinions concerning the best way to advance weather modification technology. These opposing views may be described in the framework of this figure. They are either inner directed where we talk about the inner loops or outer directed, depending upon the relative emphasis deemed proper for the basic investigation as outlined in the inner loops versus the engineering and the development field experiments and operational systems which we here call the outer loops. This as we see it is a roadmap of a way to accomplish the objective of development of operational systems of weather modification. That completes the slides, I believe.

While strong cases can be made for either approach exclusive of the other, I believe that the proper approach for development of operating weather modification systems is a judicious balance between the two. There is no doubt that basic research provides a foundation without which applications would have little chance for success. However, as a matter of personal temperament and attitude, I have had a continued interest in the commercial weather modification operations that have been conducted in this region, and have done my best to assist these operations to attain higher levels of competence. I believe that this attitude is shared by other members of the Institute staff. We intend to continue to render such assistance to the limit of our capability. I believe that it is in the best interests of development of the technology to do so, even though only a short time ago anyone who was associated with commercial weather modification seemed to be automatically "suspect" by other members of the scientific community. I hope that the current favorable attitude toward weather modification constitutes a permanent change in attitude toward these activities.

Development of operating systems for weather modification in parallel with field experiments provides an opportunity for research organizations such as ours to gain new insight into atmospheric processes. Observations of commercial weather modification projects can

provide additional data for improvements of physical models, and in turn provide a basis for better recommendations for future use.

In summary, I believe that the ultimate objective of developing operational weather modification systems can be best attained by a program which gives a continuous feedback of new information from experiments of various kinds and which works closely with existing operational projects.

In addition, the foregoing considerations suggest certain desirable principles of organization for development of operational weather modification systems, as follows:

Recognition must be given to the development of such systems as the primary objective.

"Inner loops" of basic research must continue, in order to provide a foundation for better attainment of this primary objective.

Existing cloud modification projects provide an opportunity for further study, and efforts should be made to utilize such projects for this purpose.

A proper balance must be maintained between the "inner loops" of basic research, and the "outer loops" of engineering development toward applications.

Organization for development of operational weather modification systems should be consistent with the geographic variation of the problems to be attacked. Because of the economic, social, and political complexities of development of weather modification systems, maximum utilization should be made of local knowledge and experience on these problems. Regional research centers for weather modification appear to offer a mechanism for mobilizing such knowledge and experience.

We have identified five major programs for our efforts in our current contract with the Bureau of Reclamation, as follows:

Field experiments: In our field experiments we have established two separate projects in which we are attempting to assess the effects on precipitation of cloud seeding with silver iodide. These are not operational weather modification projects, but are field experiments. One is located near Rapid City and another is located near the Shadehill Reservoir in northern South Dakota. Both are "randomized" experiments. They constitute a major part of our research effort. These experiments provide an opportunity for testing the validity of our concepts, and permit an interchange of information between theory, laboratory, and practice.

Cloud physics: Our cloud physics involves measurements in the unmodified atmosphere to determine the physical characteristics of clouds within this region. This involves a large number of observations, using instrumented aircraft and special radar, yielding data which we can interpret to get a better understanding of the physical mechanisms of precipitation.

Numerical experiments: Dr. Orville of our staff has been conducting numerical experiements that utilize computer simulation of cumulus convection. We consider this work to be a vital link in improving our understanding of convective clouds and precipitation from them.

Climatology: We make use of observations from other groups and attempt to keep current on research results from other groups. Specifically, we have utilized U.S. Weather Bureau data to analyze temperature, pressure, wind, and precipitation patterns in this region.

This has provided background information to assist in the planning, conduct, and evaluation of our field experiments.

Weather modification research as a regional problem: As a part of our responsibility, we have been asked to look at weather problems on a regional basis. In fulfilling this function, we have actively sought the cooperation of other research groups within this area. We have worked with Colorado State University, North Dakota State University, the University of Wyoming, and Chadron State College in Nebraska. As a result, new research interests in weather modification have been developed at North Dakota State University and Chadron State College. We have cooperated with staff members of North Dakota State University by providing radar data for their studies of a commercial weather modification project in the southwestern part of that State. Dr. Butchbaker will probably elaborate further on this point. We also are initiating studies of the characteristics of hail-forming clouds under National Science Foundation sponsorship in cooperatiton with staff members of Chadron State College in Nebraska. Professor Smith will probably give further information on this project.

I am pleased to note that Senate bill S. 2875 calls for participation of all Federal agencies in problems related to atmospheric water resources. We will have underway in the Institute of Atmospheric Sciences this summer a unique experiment in organization that will involve the close coordination of projects involving the objectives of increased precipitation and reduced hail, and also will include attempts at coordination of work being sponsored by several agencies. This project was conceived at the national symposium on hail suppression in Dillon, Colo., in October 1965. I have been asked to serve as coordinator for the project, which is named "Project Hailswath." The purpose of the project is to attempt to develop better techniques for evaluation of hail-suppression efforts.

Project Hailswath is sponsored by the National Science Foundation. It will be conducted in parallel with our research program for the Bureau of Reclamation. Project Hailswath calls for observations of hailstorms by various procedures and techniques by about 17 independent groups—government, university, and private—in conjunction with our Rapid project for the Bureau of Reclamation.

In addition to involvement by the Bureau of Reclamation and the National Science Foundation, we have extended invitations to other Federal agencies to participate in the research program.

I am pleased at the opportunity of undertaking this project, since I believe that it will demonstrate that it is possible for several programs to accomplish their several objectives, if operated in close coordination with each other. Moreover, each will benefit from the participation of the other. I believe that this demonstrates a pattern that might be followed profitably in the future.

The views and potential contributions of the persons and organizations who have been active in the field of weather modification in the past should be utilized in the future development of weather modification technology.

Regulation of weather modification should be separated from the operating agencies.

For an agency to be responsible for conducting large-scale weather modification research and also control the operations of other groups,

and to accomplish this dual task without prejudice, would require singularly fairminded administrators. Consequently, regulatory functions must be separated from operating functions in the field of weather modification.

A broad base of activity must be maintained.

An increase of support by various Federal agencies for weather modification research and operations is desirable, particularly in support of the missions of individual agencies. Rather than constituting undesirable duplication, such a broad base of activity provides insurance that the various missions of the various agencies will be conducted effectively, and avoids the risks of development of a "party line" which can be a deterrent to progress.

I believe it is desirable for the Department of the Interior to carry out a comprehensive program on atmospheric water resources, and I also believe that other agencies should be encouraged to carry out expanded programs on other problems of interest to the particular agencies. For example, I believe that progress in all fields of weather modification research would be accelerated by expanded activities by the various agencies in their respective missions, such as fog dispersion by the Federal Aviation Agency, hurricane modification by the Environmental Science Services Administration, reduction of lightning damage by the Forest Service, or reduction of hail damage to crops by the Department of Agriculture.

I believe that the National Science Foundation should retain a mission of supporting research in weather modification. Research support by the National Science Foundation is a desirable adjunct to the development of operational weather modification systems by mission-oriented agencies, and complements such mission-oriented agencies, rather than constituting an undesirable duplication of effort.

Following are my specific recommendations on various sections of S. 2875.

Authority of the Secretary of the Interior to conduct a comprehensive program for increasing yield of water from atmospheric sources.

I endorse the provision of S. 2875 for the Secretary of the Interior to conduct a comprehensive program of scientific and engineering research, experiments, tests, and operations for increasing the yield of water from atmospheric sources. This activity should not be limited to the Western States only, but should include all of the United States.

I would prefer to see regulation of weather modification activity carried out by effective State licensing agencies, such as I believe exists in our State of South Dakota, where the State licensing board has taken a very forward-looking view of protecting research projects from encroachment by commercial projects. If, however, Federal licensing and regulation are determined to be in the best national interest, I believe that it is essential that the regulatory function be completely separated from any operating function. Within this framework, I am in general agreement with the testimony given to the committee previously by Mr. Robert Elliott, which calls for the creation of an independent weather modification regulatory board.

With reference to section 201 of S. 2875, I am in agreement with the principle that liability for damages should be assumed by the Federal Government on federally sponsored weather modification projects.

I endorse the provisions of S. 2875 that call for the comprehensive program to take full advantage of all of the Nation's scientific and

technical capability, public and private, governmental, academic, and industrial. I believe that greatest progress in development of this technology can occur if the program is conducted by utilizing all of these various talents, rather than to concentrate the program of research and development within any "in-house" governmental agency.

I endorse the provisions of S. 2875 which call for the establishment of regional research centers as one method of implementation of the purposes of the bill. I believe that the progress which we have been able to make at the Institute of Atmospheric Sciences during the recent past demonstrates the feasibility of this approach.

I believe that the funding levels called for in S. 2875 are not unreasonable when viewed in the light of the magnitude of the problems to be attacked.

In my concluding remarks I would like to share with the committee some thoughts concerning what I hope will be the contrasts between our past and future research activity in weather modification.

During the past decade, most of our weather modification research has been carried out on a part-time basis, by university professors, for example. I do not mean to be critical of such efforts. However, our typical researcher has seen as his goal the solution of the immediate problem in hand—that is, What is the composition of the chemical, the composition of the cloud, or the wind velocity? If the goal of weather modification for a practical end has been recognized at all, it has been comfortably deferred to some time in the distant future.

Now, with the issuance of the recent reports from the National Academy of Sciences and the National Science Foundation, we have a consensus that cloud and weather modification are very important fields of inquiry and that substantial efforts must be made to speed the development of operational systems of weather modification for the public good. What kind of research effort have we mounted in the past? Frankly, they have been of a horse-and-buggy nature. For example:

> Aircraft being used for thunderstorm modification research studies are largely of World War II vintage—newer models are either unavailable, or too expensive.
>
> I have spent time as an observer in the back seat of a T–6 aircraft, scanning a dozen dials, and attempting to record data with a pencil on a kneepad, holding a stopwatch in the other hand, and in the meantime turning slightly green from motion sickness caused by the turbulent ride.

The resources provided to tackle the job of cloud modification to date are nowhere near the present level of technology in other fields. We have seen what modern data acquisition and processing can do in the space program; recently, a defective rocket was automatically shut down seconds after firing because the monitoring system indicated a defect.

When we consider the job to be done in acquisition, processing, and interpretation of meteorological data to provide for operational systems of weather modification, we recognize a task of substantial dimensions. This task need not—indeed cannot—be handled by kneepad, stopwatch, and pencil-and-paper procedures. Sophisticated techniques and procedures must be applied to our problems if we are to make real progress in the future.

Permit me to speculate a bit with you on what the future could hold —if we simply were to utilize existing technology. While I support our efforts to get men into space and to the moon, I would be gratified to see the space technology—already developed at considerable expense—applied to problems such as the following for immediate benefit to our society:

Multiple aircraft probes under positive ground control.

Systematic probing of storm systems by unmanned aircraft, radar, and other devices.

Automatic data transmission from probes to a ground data center.

Immediate display of pertinent data at a central station.

Immediate analysis of data by computer to yield recommendations for treatment of clouds to produce predictable beneficial results.

All of the above are attainable within the framework of existing technology. Indeed, I expect that a few decades from now we shall see most of these concepts in use, and that this country will be deploying personnel and equipment against weather hazards just as it now deploys resources against disease, floods, and other natural calamities.

These speculations are conditioned on the requirement for programs to be conducted in the future having a scope comparable to that outlined in S. 2875. With such programs, I believe that it is possible to accomplish the goals set forth.

But there should be no illusions that this task can be accomplished easily. Substantial effort, time, money, and equipment will be required. Indeed, if the first 20 years of effort (on the relatively simple problems of weather modification) provide any index, it is to be expected that the more difficult tasks at hand will require substantially larger effort and resources to be successful.

I believe that S. 2875 provides a framework within which substantial progress can be made toward the goal of development of operational systems for weather modification. I am pleased to be involved with this challenging problem, and look forward to the future with anticipation.

Mr. Chairman, thank you very much for the opportunity of appearing before you.

Senator McGovern. Dr. Schleusener, as I said, we are delighted that you are pushing ahead on such an aggressive and well-organized program here at the School of Mines. Your statement today will be a helpful and an important part of the committee records. I am very grateful for it.

I notice in our list of witnesses who will be heard from today, Mr. Louis Bober, who has been a very energetic advocate of soil and water research programs in the Great Plains area. As you know, there are various ways that we can increase, stretch our water supply. One would be through the method you are suggesting, artificial modification. The other is largely in the area of Mr. Bober's proposal, making better use and conservation of the water that we have. There actually is a very close relationship in the area which you are working and the general area which Mr. Bober and many people like him have been advocating.

Dr. Schleusener. Yes, sir; there certainly is. As we see the problem, our efforts first have been directed at the problem: what goes on

in the clouds and what comes out of the clouds, as we pointed out on the diagram here. When we look at the question, what is this increment of water worth, we then certainly have a close relationship between the work that we are doing and that in which Mr. Bober is interested. There is a very close relationship between these. I would like very much to see the work that Mr. Bober has proposed to be carried out be continued and expanded.

Senator McGovern. You mentioned in your statement the important role that a regional center could play, the kind of a regional center that I hope will grow and develop here at the School of Mines. Recognizing all of the commonplace, political and economic factors that will be involved in trying to coordinate the work over a six or seven State area, how do you see that kind of a regional center functioning?

Dr. Schleusener. I believe that the principle here is that the people who know their local problems best should be the people who work on the problems. So as I see the development of this kind of a center it would have to involve very close coordination with the State universities in the respective States with their knowledge brought to bear on the problems as they exist in their particular State. Because of these complexities it seems to me absolutely essential that the problems be dealt with by people in the respective States through the State university.

Senator McGovern. In your prepared statement you say you think it is important to retain the role of the National Science Foundation as the agency involved in weather modification. I wonder if you could elaborate on that just a little.

Dr. Schleusener. Yes. I have a strong feeling on this point. I believe that the kind of support that the National Science Foundation has given to the individual university professor as he works in his laboratory is very important, and also I have a strong personal feeling in this regard because I consider myself primarily a product of this system. As a relatively young researcher when I started in this business it was the National Science Foundation that provided support for the projects I wanted to conduct, provided the basis for the things we have been able to do. For this reason I think it is highly desirable for the National Foundation to remain active in this field.

Senator McGovern. I was interested in your comments on the Project Hailswath which you are coordinating and directing. What agencies have you invited to participate with you in that project?

Dr. Schleusener. We have invited the representatives of the Weather Bureau, Department of Agriculture, FAA, and have involvements from the Air Force and the Navy.

Senator McGovern. Senator Moss, do you have any questions that you would like to direct to Dr. Schleusener?

Senator Moss. I do not think I have any questions, Mr. Chairman. I am very interested in the testimony that was given and again I congratulate this fine institution and you, Dr. Schleusener, for the impetus already given and the research already undertaken. I am glad to have your report of the provisions in general of this bill to provide for the supervision and support.

Senator McGovern. Senator Burdick?

Senator Burdick. I was interested in your comment on page 13 of your prepared text. You say the regulation of weather modifica-

tion should be separated from the operating agencies. I wonder if you would elaborate a little more on that.

Dr. SCHLEUSENER. My feeling is this: using the State of South Dakota as an example and Mr. Bruce is chairman of the State's weather control commission, he is responsible with his commission for regulating the activities of people involved in this business. I believe that it is desirable to keep the regulatory agencies separated from the agency that conducts the operation. I would be afraid that if an agency were both operating and regulating that if anybody else wanted to get in the business, for example, that they might suffer a prejudice for their operation for this reason.

Senator MCGOVERN. Senator Metcalf?

Senator METCALF. I enjoyed the very informative statement and I have no questions.

Senator MCGOVERN. Thank you very much, Dr. Schleusener.

Dr. SCHLEUSENER. Thank you.

Senator MCGOVERN. Our next witness is Mr. Don Fuquay from Montana so I have asked Senator Metcalf if he would present the second witness.

Senator METCALF. Mr. Chairman, I am very pleased to present Don Fuquay, who is director of the Forest Fire Laboratory in Missoula, Mont., in region 1. He is from Montana and his program was started in the 1950's for lightning suppression. It is known as Project Skyfire. It is exactly the kind of mission-oriented work which should be accelerated and would be accelerated by enactment of this legislation. Don Fuquay is more than a meteorologist. He has done a great deal of the engineering involved in developing the procedures used in Project Skyfire. Many of them were very difficult modifications of war surplus material and he is probably the world's leading authority on lightning and the suppression of lightning as the cause of forest fires. I think this is an example of what we were talking about concerning regional research centers. The interchange of information from Montana Research Laboratory and the information that they have there to the Institute of Atmospheric Physics here, are all a part of our environmental research. I was glad that the preceding witness pointed out the necessity for the regional interchange of information and I think that Mr. Fuquay will give us the benefits of his experiences. I am pleased and proud to present this outstanding citizen of Montana.

Mr. FUQUAY. Thank you, Senator.

Senator MCGOVERN. Mr. Fuquay, you may proceed.

STATEMENT OF DONALD M. FUQUAY, DIRECTOR, FOREST FIRE LABORATORY, MISSOULA, MONT.

Mr. FUQUAY. I am Donald M. Fuquay, research meteorologist in charge of Project Skyfire, Northern Forest Fire Laboratory, U.S. Forest Service, Missoula, Mont. We appreciate this opportunity to summarize for the committee the research program of Project Skyfire.

Project Skyfire is mission oriented research of the U.S. Forest Service aimed at the lightning fire problem in American forests. The research program has two major objectives: (1) to gain basic knowledge of the fire-igniting mechanisms of lightning and (2) to develop

the knowledge and technology for the possible prevention of lightning fires through weather modification.

Lightning causes 10,000 to 15,000 forest fires annually in the United States. These fires cause severe damages to forest resources, germinate air and water pollution, take human lives and injure natural resource based industries. The annual cost of lightning-caused forest fires is estimated to $40 million. Damages amount to a much larger sum. A critical feature of lightning fires is the tendency for very large numbers of fires to occur in a short period of time.

This places a great overload on fire control forces and makes fire-fighting very difficult and costly. Any method which may reduce great concentrations of fires or will prevent fires at critical times and places would be of great economic importance to the Nation. Weather modification offers the best hope for reducing the severity of lightning fires.

The Skyfire research program was initiated in 1953. The first efforts were devoted to surveys of lightning storm systems and lightning fire occurrence in the northern Rocky Mountains. In 1956 in cooperation with the President's Advisory Committee on Weather Control we started pioneering efforts in the development of cloud seeding technolgy for application to mountain thunderstorm situations. From 1956 to 1959 these pioneering efforts were performed at Flagstaff, Ariz., and at forest sites in northern Idaho and western Montana near Missoula. These studies have led to the design of a definite experiment in lightning suppression which is being performed under joint sponsorship of the Forest Service and the National Science Foundation.

Several other agencies and research groups have assisted in the research program. These include the U.S. Weather Bureau, U.S. National Park Service, California State Division of Forestry, the Minitalp Foundation, University of Montana, University of Washington, University of Arizona, and Colorado State University. Project Skyfire lightning storm survey stations are located at fire lookouts in the national forests of Oregon, Washington, Idaho, and Montana, and in Yellowstone National Park.

The major Skyfire research results, to date, include the following:

1. Development of a physical model of mountain thunderstorms. This model describes typical storm characteristics including height of cloud base, visual and radar indicated levels of cloud tops, temperature structure, negative charge center, and time sequences in storm development and action.

2. Development of instrument systems and technology for the measurement and analyses of lightning discharges. This system, installed in our lightning experimental area adjacent to the forest fire laboratory at Missoula, includes a network of electrostatic field change sensors, photocell devices for sensing luminosity, thunder transit time recording units, automatic camera stations and multi channel magnetic tape recorders. Two modified military radar units are used to record storm position and cloud height. In addition, the U.S. Weather Bureau radar station on Point 6 Mountain near Missoula transmits information on large scale storm systems directly into relay scopes in the forest fire laboratory. This overall instrument system permits us to record each lightning discharge in the experimental area, to identify whether the discharge is cloud to cloud or cloud to

ground, to fix its location, to measure its intensity and time duration, and to record general details of the storm system which generated it.

3. Identification of the type of lightning discharges most likely to ignite fires. Our research shows that the probable fire igniter is a cloud-to-ground discharge with a long continuing current portion. This hybrid discharge starts out as a typical cloud-to-ground discharge with one or more return strokes. However, after the initial return stroke, it goes into continuing current discharges which lasts for 200 or more milliseconds. Identification of this type of discharge is especially important to weather modification. We need to determine the specific effect of cloud seeding on such discharges because their modification could have great significance in the prevention of forest fires.

4. Development of special equipment and technology for the seeding of lightning storms. Our approach to the possible prevention of lightning requires that very great quantities of ice forming nuclei be delivered to the cloud systems. We have developed a high output, ram-jet type silver iodide generator for the purpose. Technology has been developed for supplemental seeding from ground stations utilizing the Skyfire silver iodide generators.

5. Performance of laboratory experiments on methods of modifying the electrical structure of clouds. These experiments are investigating the effect of water drops and ice crystals on the sparking potential of air within a simulated cloud environment. We have found that irregular ice crystals lower the sparking potential across a gap by a factor of 35 to 40 percent at a barometric pressure of 675 millimeters hectogram. The breakdown field with ice crystals is virtually independent of the size of the crystal. The sparking potential in the presence of ice spheres is changed by both the size of the spheres and the pressure of the surrounding air. Wet ice spheres lower the sparking potential to that found for water drops of the same size. These experiments indicate that heavy seeding of supercooled clouds with ice-forming nuclei is an appropriate experimental method for lightning suppression.

6. Development of special analytical methods for evaluation of cloud-seeding results. We have developed statistical procedures for analysis of the results of randanized treatment of storms with silver iodide nuclei. The basic input of data for these tests is the number of cloud-to-cloud and cloud-to-ground lightning discharges occurring from both seeded and not seeded storms. Our statistical tests are designed to find out whether or not a significant change is achieved by cloud seeding. We are also performing analyses of the physical features of lightning discharges and storms.

7. Performance of cloud-seeding experiments on lightning storms. We have performed experimental seeding operations in an instrumented test area during three lightning storm seasons. The results to date show more than 30-percent reduction in cloud-to-ground lightning from seeded storms. This is still a small sample for evaluation of the complex features of lightning suppression through cloud seeding. We estimate that 2 or more years will be required to gain a large enough sample for significant evaluation of lightning suppression.

The Project Skyfire research results provide essential background for more intensive investigations of lightning suppression. Moreover, they indicate significant new opportunities for progress. We hope to

perform intensive investigations of the special type of lightning discharge which seems to be the fire igniter and of the specific effects of cloud seeding on it. We hope to further increase the efficiency of generators in producing a high output of ice forming nuclei. With the background of knowledge and technology that has been developed, we are ready to perform larger scale experiments. Such experiments are essential for development of the knowledge and technology for modification of lightning storms.

Senator McGovern. Mr. Fuquay, certainly you and your organization are to be commended for the encouraging field projects that are already underway. I am wondering, does not this data that you secured through your efforts that are aimed primarily at lightning suppression also assist agencies that are working in the general area of weather modification but with a different mission. Isn't there a benefit to all the other groups in what you are doing in your field?

Mr. Fuquay. I think that virtually all phases of weather modification are related. For instance, in our storms we found a rather close relationship between hail and lightning. Further, our work on determining the amount of nuclei to seed or glaciate a cloud system will have application to many other fields of weather modification.

Senator McGovern. I think all of us here are interested in doing what we can to speed up the work in atmospheric sciences. Do you think with sufficient funding there could be a material step-up, or acceleration of the work going on? We do not want to waste money or provide funds that are not needed, but do you see the possibility of practical acceleration of this program?

Mr. Fuquay. Yes, I think the level of technology is such that our present effort could be expanded threefold or fourfold without any waste of money. Also we are investigating the different methods by which we can trade, so to speak, space for time in this weather modification. I think that this effort can be increased greatly without wasting any money.

Senator McGovern. Senator Metcalf?

Senator Metcalf. Thank you, Mr. Chairman. We know from experience in Montana that an outstanding contribution was made to this business of fire suppression and, of course, it is so important in that whole Rocky Mountain area where we have so many of these lightning storms. You heard the preceding witness testify that much of our work is done in what he called the horse and buggy means. I know that when you first started with Skyfire you were using expedients and modified surplus equipment from World War II. To carry out the chairman's question, if you used some of the techniques that have been developed in space for example, the advance in computerization, would this accelerate your program?

Mr. Fuquay. Yes, sir. I think this would be of great benefit. A matter of just data processing; that is, the accumulation of data and putting it in a form for automatic processing is one place where we could make great strides, make up for lack of people which I think exists now in this field of weather modification. So I think there is some argument to modernize our efforts. Dr. Schleusener talked about radar in particular. We are still using World War II radar which we picked up on surplus. We are using aircraft which are decidedly inadequate for this problem of examining thunderstorms.

As a result from this we must approach it very cautiously and very slowly. The use of more modern equipment, I am sure, would speed up our efforts.

Senator McGovern. As Dr. Schleusener suggested, we could also use unmanned aircraft, and so forth.

Mr. Fuquay. Yes, sir. All of this new technology, in a sense, would speed up data processing.

Senator Metcalf. I notice that you said you have had a great deal of assistance from the University of Montana, the Universities of Washington, Arizona, and Colorado State University. Where did those institutions get the money to help in this research program?

Mr. Fuquay. I believe most of them have their funds from the National Science Foundation.

Senator Metcalf. Federal grants.

Mr. Fuquay. Yes, sir.

Senator McGovern. Thank you for a very helpful and informative statement. Senator Burdick, do you have any questions?

Senator Burdick. No, thanks.

Senator McGovern. Senator Moss?

Senator Moss. Is your work primarily so far the seeding with silver iodide nuclei?

Mr. Fuquay. Yes, sir; it is restricted to silver iodide.

Senator Moss. The way that you are proceeding on this suppression, then, it to try to cause the cloud to disappear because of precipitation?

Mr. Fuquay. Primarily it is the complete conversion of the liquid water to ice form in the cloud.

Senator Moss. Thank you.

Senator McGovern. Thank you very much, Mr. Fuquay. The third witness is Dr. Butchbaker of North Dakota. I am going to ask Senator Burdick to present our witness.

Senator Burdick. It is a real pleasure for me to introduce Dr. Butchbaker. He came to our State university at Fargo not so long ago and brought with him competence along with ability in his field of weather modification. It is a pleasure to be able to present to the committee Dr. A. F. Butchbaker, associate professor of agricultural engineering at the North Dakota State University at Fargo.

STATEMENT OF DR. A. F. BUTCHBAKER, ASSOCIATE PROFESSOR, AGRICULTURAL ENGINEERING, NORTH DAKOTA STATE UNIVERSITY

Dr. Butchbaker. Thank you, Senator Burdick. Distinguished Senators, my name is Alan F. Butchbaker and I am assistant professor in the agricultural engineering department at North Dakota State University, Fargo, N. Dak.

Annual losses due to hail in the United States have been estimated to exceed $100 million. North Dakota receives its undue share of these losses based upon the Federal Crop Insurance records and other insurance records on crop and property damage.

The losses in North Dakota may even approach the $5 million mark annually. The greatest portion of these losses occur in the southwestern corner of the State. Some farmers have reported being hailed-out in the last 7 out of 9 years. Suppression of hail in this area of the

State could substantially reduce crop risk and property damage resulting in increased standard of living for the farmers, and a boost in the area's economic well-being.

Hail is just one of the weather elements that concerns the people of North Dakota. Many other climatic factors affect economic activities in the State. The remainder of this testimony will be concerned with how weather influences some of the major economic activities in North Dakota, to indicate the type of research related to water resources and weather-related research, and to indicate the interest in the State regarding weather modification.

Agriculture is North Dakota's major industry. Approximately 85 percent of all State income is derived from agriculture. The gross annual farm income is approximately $700 million with about 60 percent from crops, 35 percent from livestock, and 5 percent from other sources. Agriculture occupies over 41 million acres or about 93 percent of the entire land area of the State. Total cropland is about 25 million acres which is exceeded only by Texas, Iowa, Kansas, and Illinois. Approximately two-thirds of the 632,000 people live in rural areas. According to the 1959 U.S. Census data there are 54,928 farms, averaging 755 acres each.

Other major industries adding to the economy of North Dakota are: transportation, petroleum, lignite mining, small manufacturing—mainly for agricultural machinery—and food processing plants. Recently, several electric powerplants have been added near the lignite fields and Garrison Reservoir.

As a result of the major role of agriculture in the State, North Dakotans are very much concerned with the weather. The weather records show that the average annual temperature is approximately 40° F. for the State. Mean maximum daily temperatures in July are in the low 80's over most of the State, with minimum night temperatures generally below 70° F. The mean annual precipitation averages about 19 inches in the eastern third of the State, about 16 inches in the middle third, and about 14 inches in the western third. On an average, about 77 percent of the annual precipitation occurs during the crop-growing, freeze-free season, April to September, and almost 50 percent falls during May, June, and July. Because the soil is quite well supplied with all the necessary plant nutrients, it is of prime importance that the rains come principally during the crop season. Much of the North Dakota soil is capable of yielding surprisingly well on little moisture, provided moisture is present when it is most needed. However, some years have been recorded where the average precipitation for the State has been 12 inches (1933–36 principally).

North Dakota must generally be considered a marginal State for precipitation adequate enough for agricultural production. In many years, an increase of small proportions at the right time (5 to 10 percent of annual mean rainfall) would be all that is needed to prevent crop failures.

With just a little added precipitation, the climate of the State is such that water losses would be at a minimum compared to many areas of the United States because of the low nighttime temperatures, low mean maximum daily temperatures in the summer, and shorter growing season. Thornwaite and Mather illustrate this point very vividly

in the Yearbook of Agriculture, 1955, in an article entitled, "The Water Budget and Its Use in Irrigation," and in a map published in Geographic Review, January 1948, showing the potential evapotranspiration for various areas of the United States. North Dakota has an average annual potential evapotranspiration between 21 and 24 inches compared to some areas in the Southwest with near 60 inches. It is easy to see that the annual precipitation nearly matches the average annual potential evapotranspiration in North Dakota with an average deficit of about 7 inches. If weather modification for precipitation could increase rainfall a few percent over normal, this deficit could be cut even less. Also, the increase in precipitaton should come in the summer when the crop needs are the greatest, and evapotranspiration rates are the highest with an average loss of about 5 inches per month during July and August.

Although precipitation may be considered to be the most important weather variable, other weather factors cause serious consequences and amount to several million dollars loss annually. Hail is a major problem which may wipe out mature crops and cause complete crop losses for individual farmers. Rainfall at inopportune times, such as seeding and harvest, causes major losses in crop yields. For example, in September 1965 many farmers in northeastern North Dakota could not harvest a record crop of Durum and Hard Spring wheat due to the continuous rainfall from August 23 through September 30. Windstorms may produce extensive damage to farm buildings, houses, utility lines, and growing and mature crops. Tornadoes, of course, possess some of the most awesome forces in nature for the destruction of property and life. North Dakota gets a good number of these every year. One cannot mention weather elements in North Dakota without mentioning blizzards. The recent blizzard of March 1966 has caused millions of dollars in losses to North Dakota farmers, ranchers, transportation industry, and governmental units because of snow removal operations plus many other inconveniences to the area residents. A recent estimate by the North Dakota State University Extension Service places the total livestock losses from the blizzard at approximately 27,000. Floods cause other severe property damages and many inconveniences which, of course, are the direct result of precipitation in the form of snow or rain.

North Dakota State University is conducting research in the area of water resources. A Water Resources Institute has recently been established which works in cooperation with the University of North Dakota at Grand Forks. Some of the major projects of research in the Water Resources Institute deal with irrigation, infiltration, water reuse, economic studies, and soil survey studies. A list of the current projects is appended to this report, appendix A.

Other research projects related to weather are being carried on by North Dakota State University Agricultural Experiment Station at their Fargo station and at the Carrington Irrigation Branch Station, by the University of North Dakota, and by the Denver Wildlife Research Center substation at Jamestown. These projects are listed under appendix B.

In the agricultural engineering department at North Dakota State University, some projects were recently initiated to study structural failures of pole buildings due to windstorms, and to evaluate commer-

cial weather modification projects in North Dakota. The latter project receives cooperation from the Institute of Atmospheric Sciences, South Dakota School of Mines & Technology, Rapid City, S. Dak. A radar station, located at Lemmon, S. Dak., and operated by the Institute, supplies radar data on hailstorms in southwestern North Dakota. In addition, Dr. Schleusener, director of the Institute of Atmospheric Sciences, is a special consultant for many phases of the project.

At the present time there is considerable interest in North Dakota in hail suppression. In 1961, the Bowman-Slope Hail Suppression Association began seeding thunderstorms in the southwestern tip of the State in hopes of suppressing hail to reduce crop damage. This activity has continued and has increased in scope. In 1965 North Dakota State University began a study of this project in hopes of determining the effects of seeding the clouds and whether hail was being suppressed and precipitation increased from these activities. The only other weather modification project in North Dakota is based at Minot, where a commercial operator seeds clouds in the north-central portion of the State to obtain precipitation increases. The operator claims moderate success from his activities.

There is definitely a need, and the climate is certainly favorable for the study of various means of modifying weather in North Dakota, ranging from hail suppression and precipitation increase, to reducing the hazards and effects of blizzards and tornadoes. Therefore, North Dakota State University endorses the broad objectives of Senate bill 2875 (see app. C).

I would like to conclude my remarks by reading the following letter from Arlon G. Hazen, director, Agricultural Experiment Station, NDSU, to Senator Clinton P. Anderson. This is appendix C to my report. [Reading:]

FEBRUARY 18, 1966.

Senator CLINTON P. ANDERSON,
U.S. Senate,
Washington, D.C.

DEAR SENATOR ANDERSON: The Congressional Record of February 4, 1966, carries your statement and introduction of Senate Bill 2875, a bill to authorize and direct the Secretary of the Interior to conduct a comprehensive program of scientific and engineering research, experiments, tests and operations for increasing the yield of water from atmospheric sources. I note this bill also includes both Senators Young and Burdick from North Dakota.

This letter is to support the kind of legislation you have introduced because of the great need for additional scientific information regarding weather modification. I have not examined a copy of your bill, but I would hope it will also permit such studies as suppression for hail or other devastating kinds of weather as well as the object of increasing the yield of water from atmospheric sources. Should this provision not now be contained in the language of the bill, perhaps you would consider added language as the bill proceeds through the legislative process.

The North Dakota Agricultural Experiment Station, North Dakota State University, has participated to a small extent in the area investigations being conducted under the direction of Dr. Richard Schleusener, South Dakota School of Mines. We have participated to the extent that we are enouraged to continue our cooperative effort, and also to expand it. Your bill would undoubtedly help in this effort should it become law. Needless to say, this type of research is quite expensive and is also the kind of research about which the several units of

State and Federal government should maintain full interchange of knowledge and techniques. Again it appears to me your bill is intended to accomplish this objective in a sound and methodical manner.

I am also impressed with the fact your bill is based upon the advice and counsel of scientists who have been working with weather modification. Certainly there is much to be learned from their experiences as you contemplate sound legislation for the future.

Sincerely,

ARLON G. HAZEN, *Director.*

Senator MCGOVERN. Dr. Butchbaker, in order to complete your statement, we will print appendixes A and B at this point. You have read appendix C.

(The data referred to follows:)

APPENDIX A

List of current projects, water resources institute

NORTH DAKOTA STATE UNIVERSITY

Project No.	*Project title*
W–1–100–1	Institute administration, development and planning.
W–1–100–2	A feasibility study of a livestock waste disposal system involving reuse of water.
W–1–100–3	Water quality in relation to productivity of Lake Ashtabula reservoir in southeastern North Dakota.
W–1–100–4	Effect of water quality and management on chemical and physical properties of soil under irrigation.
W–1–101–1	Economic impacts of water resource development.
W–1–101–2	A limnological study of the water quality of Spiritwood Lake, N. Dak.

UNIVERSITY OF NORTH DAKOTA

W–2–100–1	The biogeochemistry of Devils Lake, N. Dak.
W–2–100–2	Microbiology of sewage lagoons.
W–2–100–3	Water pollution abatement by improved coagulation of effluents from lye-peel potato processing plants.
W–2–100–4	Mussels and pollution in the Red River drainage, North Dakota and Minnesota.
W–2–100–5	The determination of suitable average values of meteorological data for use in estimation of evapotranspiration from free water surfaces and soil surfaces.

PROPOSED PROJECTS TO BE FUNDED IN 1967

W–2–100–6	Water balance in sewage stabilization lagoons.
W–1–101–3	Impacts of irrigation on economic development.
W–1–101–4	The efficiency of water use under varying conditions of plant stress.
W–1–101–5	Design of vertical sand drains for the recharge of glacial aquifers.
W–2–101–1	Effects of ground water seepage on stream regimen.

APPENDIX B

List of other research projects related to water resources and weather

NORTH DAKOTA STATE UNIVERSITY

Project No.	*Project title*
S–3–11	Economic impacts of water resource development.
S–3–13	Recreation development in North Dakota.
H–4–12	Water intake rates and physiochemical properties of irrigable soils.
H–4–13R	Automatic livestock waste disposal systems.
H–4–17	Structural failures in pole buildings due to windstorms.
S–4–4	Prefabricated linings for irrigation ditches.
H–6–7	Low-temperature endurance in corn.
H–6–19R	Drought injury and resistance in plants.
H–7–19	Saline waters and livestock production.
H–9–2	Botanical composition and forage production of native grass grazing lands in western North Dakota.
H–12–2	The influence of hardy stocks on cold resistance in apples.
McS 12–1	Establishment, maintenance, and effects of shelter belts in North Dakota.
H–15–11	Temperature effect on the equilibrium energy status of water held by soils and soil materials.
H–15–12R	The relationship of meteorological variables to evapotranspiration.
H–15–13R	Water infiltration into soils.
S–4–7	Concrete ditch lining and pipe for irrigation systems.
S–4–6	Effect of ground temperature on underground water pressure tanks.
	Soil surveys of areas proposed for irrigation.
	Irrigation and water conservation.
	Human adaptation to the Great Plains.
	Effect of commercial fertilizers on field and soil moisture use by corn.
	Legal and economic factors of water use in North Dakota.
NSF grant GP–5485	Hail suppression—weather modification.

UNIVERSITY OF NORTH DAKOTA

	Water balance in sewage stabilization lagoons.
	A study of the bacterial and viral flora of sewage lagoons (oxidation ponds).
	Effect of leonardite or oxidized lignite on properties of colloidal suspensions.

DENVER WILDLIFE RESEARCH CENTER SUBSTATION, JAMESTOWN, N. DAK.

	Intensive cooperative investigations (U.S. Geological Survey and U.S. Bureau of Sport Fisheries and Wildlife) of selected pothole on the Missouri Coteau in Dickey and Ward Counties, N. Dak.
	Long-term investigations of pothole complexes on the Missouri Coteau in Stutsman County, N. Dak.

Senator McGovern. Dr. Butchbaker, we appreciate your statement. I am sure there are going to be fruitful results with the work you are doing in North Dakota, not only for your State but for other States in the area. I was impressed by the precipitation figures that you cited. With the low precipitation that we have, I think it is another tribute to the genius of our Great Plains farmers and producers, that they can do as much as they do with as little precipitation as there is. I referred earlier to the findings of the two scientific panels that made the recommendations on which this bill is based. They concluded that weather modification now shows promise of increasing precipitation by 10 to 20 percent. If that were possible, wouldn't that have much greater proportionate impact on the economic results in areas such as North Dakota and the other States in this part of the country?

Dr. Butchbaker. Yes; it certainly will.

Senator McGovern. Or is the economic increase much greater than the 10 or 20 percent increase in precipitation?

Dr. Butchbaker. I think that is quite true because if we get precipitation at the right times, of course, the crop yields will be that much greater increased. It might be double.

Senator McGovern. Senator Burdick, do you have any questions?

Senator Burdick. I was wondering, Doctor, how much time do you spend or how much time the State University at Fargo spends on this phase of weather modification?

Dr. Butchbaker. Personally, I am half time teaching and half time research, and I am spending about half of my research time practically on this project; about a quarter of my time. There are very few projects along this line being conducted at North Dakota State University on weather modification. So we are primarily concerned with the hail suppression activities of the State. I might add that there are some nitroclimatology studies going on in the soils department and in the botany department and in the agricultural engineering department related to the heat value and moisture value from plants primarily.

Senator Burdick. With a little more money you could step this investigation up; couldn't you?

Dr. Butchbaker. Yes; we could.

Senator Burdick. And I am sure that Mr. Hazen is also interested in this?

Dr. Butchbaker. He is very much interested in this as indicated in his letter.

Senator Burdick. We will see what we can do about that.

Senator McGovern. Senator Moss?

Senator Moss. I enjoyed your testimony very much, Dr. Butchbaker. You underlined the economic factors that make weather modification so important in North Dakota. I was intrigued by your reference to the fact you might suffer damage from getting too much precipitation at certain times. Is there any phase of your research that goes to this factor of how to avoid precipitation at certain times?

Dr. Butchbaker. We have none.

Senator Moss. You have none underway at all. I have often wondered about that. This crops up usually as a possibility for damage liability if we should become too successful in the positive thrust and I just wondered if any of the examination was going to ways to prohibit precipitation in inopportune times and places.

Dr. BUTCHBAKER. Not to my knowledge.

Senator Moss. Thank you.

Senator MCGOVERN. Senator Metcalf?

Senator METCALF. I, too, want to thank Dr. Butchbaker for a fine statement. As I heard this testimony develop this morning, all three witnesses have said that a great deal more could be done with more modern, more up-to-date scientific equipment. I am wondering if we have in this country the personnel, however, to multiply three or fourfold or tenfold the amount of money that we are putting into this weather modification and get maximum results.

Dr. BUTCHBAKER. I cannot answer that specifically. All I can say is that through Dr. Schleusener and some of his work there have been other States interested in weather modification. North Dakota State is interested in it and being in the agricultural engineering department, we, of course, are vitally concerned with the irrigation aspects and the drainage aspects which involve a certain amount of study with the weather and besides, as far as increasing the number of participants in weather related research, it may come through increased appropriations and funds to increase the research capabilities in various agencies in the United States and increase the technical competence in that manner.

Senator METCALF. I should have probably asked this question earlier when Dr. Schleusener was here. It is suggested that we increase the support from the 1955 level from $5 million to at least $30 million by 1970, and are we trying to create the engineers, and so forth, so that we could manage a program that is going to be increased sixfold?

Dr. BUTCHBAKER. I still could not answer that specifically. Maybe some of the later ones can. Maybe Mr. Graham can. A further problem in research comes in instrumentation and, of course, converting all of the data collected. This is where a great amount of the money would be spent in research and thereby also reduce a certain amount of technical personnel.

Senator METCALF. If you had more instrumentation you would have better use of our present skill.

Dr. BUTCHBAKER. Yes.

Senator MCGOVERN. Thank you very much.

Senator BURDICK. Just one more question. I notice in your statement you testified about a private operator in cloud seeding in western North Dakota. Do you have any data on the before and after results on things like that? Do you keep any at the university?

Dr. BUTCHBAKER. We are still working at this. The only thing we can work with beforehand is the crop damage records. Last summer we obtained some information on the hail injury values and frequency of occurrences in the area so we cannot go back to before the time that they started seeding operations.

Senator BURDICK. Thank you.

Senator McGovern. Is it not true, Dr. Butchbaker, that the provision of adequate funds would in itself provide part of the basis for attracting more personnel and financing their training and result in more education and research so that we are actually not only making provision in this bill for more equipment but facilities also, laying the basis on which more trained personnel can be brought into the field?

Dr. Butchbaker. That is true.

Senator McGovern. Thank you very much for your testimony. I might say that Senator Burdick and Senator Metcalf, because of the unfavorable flying weather, are going to have to go out on a commercial plane instead of a charter flight. They have a 12:50 plane to catch so I am going to call the witnesses from North Dakota before Senator Burdick has to leave. I think we will call Bill Fisher from Bowman, N. Dak., to come to the witness stand. Senator Burdick, do you want to say a word about Mr. Fisher?

Senator Burdick. I have heard about Mr. Fisher for some time, and I enjoyed my conversation with him before the hearing. He is going to give you some real down-to-earth experiences. He is ready to go. This is actual and practical. I know you will enjoy his testimony.

Senator McGovern. Mr. Fisher.

STATEMENT OF BILL FISHER, BOWMAN, N. DAK.

Mr. Fisher. Mr. Chairman and distinguished Senators, it is indeed a pleasure for me to be here today. I would like to say that we have made many trips to Rapid City to talk to Dr. Schleusener since he has come to this State. We began this operation of ours in 1961 and it was born purely out of necessity. The hail losses in the area in which we live were so tremendously high that something had to be done.

Now, from my statement I will read a little bit of it and then, of course, I will comment at times on other things. The hail-insurance rates for small grains were in the 20-percent bracket at that time. This made insuring crops against hail loss extremely expensive and it was a question of trying to outguess the weather or put hail-insurance protection on one's crops. The incidence of hail occurrence in Bowman and Slope Counties was such that this did not make very much sense. You were forced to take out hail insurance on part of your crop. In the growing season of 1960, our area had a real good crop. On the evening of July 1, 1960, at about 9 o'clock we had a devastating hailstorm move through our area. It started in Montana and throughout the night, after it passed this area, carried all the way to Ortonville, Minn., tearing down barns and inflicting almost complete damage to small grain and hay crops and things of this nature. This particular storm is not significant to you, probably, but it is to us in this respect, that it marked a turning point in Bowman and Slope Counties of not merely accepting what Mother Nature had to hand out to the farmer and switching to a program of setting out to do something about it.

Mr. Brewer and myself are both small-grain growers. We are also livestock growers. We have lived in this area all our lives. Our

fathers and grandfathers came to that county and helped to open it up and settle it. So our roots are pretty deep. We would like to stay there and, of course, we feel that everyone should sometime during his life do something to make things a little bit better for people who remain here after you are gone. So this is what we are trying to do. Now, of course, with the high hail incidence ratio that we have in this area, we feel it is a perfect place to start the program. Of course, at this time we did not know anything about this at all, and purely by coincidence, a few days after this storm some relatives of Mr. Brewer's passed through Bowman and stopped in to see him. And they were on their return from a trip to Alberta, Canada, and, of course, the main topic of conversation for a week or two after this storm passed through was this storm. They could see the damage and they asked what had happened and were told. "Well," they said, "we were recently in Alberta, Canada, and we found they have a hail-suppression program up there where they seed clouds with silver iodide to decrease the incidence of hail."

This started us thinking a little bit and sometime later by casual conversation we learned there were people in the Montana area doing just this thing and we learned that the gentleman's name, who was on this program, was Ora Lohse. Mr. Lohse operates a small airport and a spraying operation over there and his background was that he had had the opportunity to fly an aircraft and do some work along with the Project Skyfire with Mr. Fuquay from Missoula. After seeing some unnatural occurrences from seeded thunderstorms at Missoula, this started to turn an idea in Mr. Lohse's head and he thought that maybe something could be done in his own area, which had quite a hail-loss ratio. He set about building some silver iodide generators purely on his own. He built these generators with money out of his pocket in his hangar at his airport and he funded the entire project. And he is, in my eyes and Mr. Brewer's eyes, a pioneer in this field. Although he is not a scientist he has, I am sure, contributed a great deal to the advancement of this science.

Upon visiting with Mr. Lohse, he was quite helpful and got us off the ground with this hail-suppression program. He really did. And we leased four generators and one aircraft that he had surplus to his needs, and we bought another one. In 1961 we started our project. In 1961, in southwestern North Dakota and western North Dakota in general, we had a drought so, as you might guess, we had problems because it was quite difficult to start a program in that area because in years past there had been a weather-modification program utilizing only ground generators and, of course, they were spaced many, many miles apart and they were of extremely low output and weather modification was regarded as something of a poor bet. Let us face it. It was difficult for us to get started, and 1961 being a drought year, we had our problems. Nevertheless, we were back in 1962 and, of course, this is when our wet cycle, as it was referred to, started. We had a lot of work to do in 1962 and it puts a burden on Mr. Brewer and myself in this respect, that we are both farmers and we don't have funding nor are we able to spend all of our time and effort toward this program. We have to do it part time but this does not means that we only seed clouds at our convenience. We seed clouds

when they enter our area and look as if they would threaten us and we do some real bad gambling on them.

We use North American AT–6 aircraft. They are 20 and 21 years old. The generators are hand built but everything works. We have our problems, of course, keeping a parts supply and keeping these aircraft in flyable condition, so we are looking to possibilities of using more modern aircraft.

In 1963, in addition to our aircraft generators, we secured blueprints for the Skyfire generator from Dr. Schleusener and we had 20 built and we had them spaced within our target area. Now, we can't space them exactly the way we would like to because people don't live where we would like to have generators and the farmers operate the generators for us. So they are placed in a farmer's yard and they light them for us when a storm approaches.

The way we seed clouds in Bowman and Slope Counties is: When a storm approaches from the southwest early in the season and the area toward the northwest later in the season, we fly out to meet this cloud. And we learned in our initial season that you don't try to outguess these towering cumuli. We tried this and got into trouble. Damaging hail grew out of this cloud that we didn't think was going to produce hail. So now we seed them all. And we fly quite close to these thunderstorms. I would say, at times we get as close as half a mile. We fly in the updraft of these thunderstorms. We get a good ride going in. Sometimes we find that we can maintain altitude and sometimes actually gain altitude with the engine idling, with the landing gear down, and the flaps in the down position. Normally an AT–6 will lose altitude at 2,400 feet per minute. In this configuration we find ourselves at times exceeding 1,000 feet per minute of climb. So there is a lot of violence actually going on in these thunderstorms.

Our initial target area first was only 18 by 30 miles. We kept it down at first because we just didn't know what we could do or how to go about it. We felt that if we spread ourselves too thin the project would probably fall away in the first year. At the present time it is 30 by 70 miles. In our first 4 years of operation we relied mainly upon visual reports from ranchers in the western area of our county and also on what our own eyes could tell us, and from what weather reports would give us on a continuous weather broadcast put out by the Weather Bureau. In 1965 it was our extreme good fortune to have the assistance of the radar station that was located at Lemmon, S. Dak., under contract to the School of Mines by Atmospherics, Inc. This proved to be a great help to us in that it gave us storm warning. At first they were not too sure of the range that they would have because of the geographical location. But it proved they could see towering thunderstorms as far away as Glendive, Mont., which was about 200 miles. This gives us ample opportunity for seeding. Now we saw that this was such a wonderful thing to us that we have leased a radar for our own operation this year. It will be placed in a good geographical location and will give us good surveillance. We will have our own personnel operating it but also one of Dr. Butchbaker's staff, Lawrence Hagan, will spend some time operating it. He will be one of the research people from North Dakota State University. He will be spending the summer in Bowman and Slope Counties researching what we are trying to do.

Since our beginning in this venture we have invited people of the scientific community to look over our shoulder, in effect, and see what, if any, good we are doing.

We feel that we are doing a lot of good and the hail incidence has dropped in Bowman County. I can't give you the figures that will indicate this because the State hail insurance department figures are no longer available. Their last report was in 1963. And if you go to old-line companies for their figures you don't get too much information, but I can report to you that the cost of hail insurance has dropped somewhat in our area and I no longer carry hail insurance on my own crops. And this is quite a risk for us because we plant something in the neighborhood of 1,700 acres of crop every year. Mr. Brewer plants approximately that amount. And maybe it wouldn't be good public relations if we were conducting a cloud-seeding project to suppress hail and still buy hail insurance. But, nevertheless, the first 3 years of operation we did continue to buy hail insurance in limited amount but since that time we have stopped. We just feel that anything that you can do to advance this weather modification research is certainly time well spent because it is hard to imagine the potential of the income increase that could be developed in a rural community.

Recently I took a clipping from the Bismarck Tribune concerning a report by the Department of Agriculture indicating that in Montana, our good neighbors to the west, the farmers lost $6.5 million in crop loss in 1965 due to hail. Now, this is a staggering figure. It meant that a lot of people just probably couldn't pay their bills when the season was over. Let's face it.

Of course, we know that Montana still harvested a lot of wheat but a hailstorm or a drought for rural people is a pretty personal thing. I have seen, in areas where I live, where people have had to leave the farm and seek employment elsewhere so they could come back the following spring and start operations again. The bill, S. 2875, surely should step up this operation considerably. We have operated on a budget that is extremely ridiculous. We have operated this project on amounts varying from $6,000 per year to $14,000 per year. This bought our equipment, it bought our seeding material, but it didn't pay us any salary. But we get compensation in this respect, that we are keeping the hail off of our crops. While we haven't tried too much in the way of rain increase, we have, in a limited amount, tried this and we explain to you that we don't know much about it. But we have tried on various occasions and we have seen some things that were quite unnatural and I am sure the field is wide open.

We have received a lot of good information and help from Dr. Schleusener and we are extremely indebted to him for the help that he has given us. We first saw him in 1962, in February, after a conference held on this campus where many people in the weather modification field throughout the United States and Canada—one fellow was even from England—were invited to present their views and I might say we went home from this meeting quite discouraged, not because some of your people in research didn't provide much encouragement. There was one fellow who was a statistician and, of course, he didn't add much to it. Nevertheless, we went back and I think maybe in a limited amount now we are in a position to tell him, "Well,

we told you so." Now, gentlemen, I thank you very much for your time. It is almost a crime for me to be here because we have worked at this for quite some time and we are real pleased to be a part of it.

Senator McGOVERN. Thank you very much, Mr. Fisher. Your statement is not only informative but it is inspirational, very helpful to the committee. I must say after listening to what you have done, you are not only a man of foresight, you and your partner, Mr. Brewer, but one of considerable bravery to do what you have done in recent years. I wonder if you could tell us a little bit about your early experiences in trying to get scientific support, some backing for your efforts?

Mr. FISHER. The first man we talked to with a scientific background was Jim Wells, of Missoula. We were favorably received and he was quite helpful. He gave us a lot of encouragement. Now, I don't know what became of Mr. Wells, but I would like to meet him again. I would say generally, on the scientific matter, they have been kind of skeptical. I think they have sat back looking at us to see if we were really sincere.

Senator McGOVERN. Has that cooperation improved over the years?

Mr. FISHER. Yes.

Senator McGOVERN. What impact does that have on your own operations?

Mr. FISHER. They are giving us more inspiration and I think the people at home that support our program through voluntary contributions are greatly impressed by it.

Senator McGOVERN. Do you think the kind of regional research center as called for in the bill for which these hearings were called would be substantially helpful to you and others?

Mr. FISHER. Yes, I think it would because we could draw heavily on it, at least in an advisory capacity.

Senator McGOVERN. Senator Burdick, question?

Senator BURDICK. I know that the southwest corner of the State has a very high incidence of hail through the years. One of the highest in the country, is it not?

Mr. FISHER. Yes, it is as high as 22 percent.

Senator BURDICK. Am I right in saying some companies just would not write insurance down here?

Mr. FISHER. It became that bad.

Senator BURDICK. It became that bad. Now that you have had almost 5 years of experience, has it changed the attitude of the insurance companies?

Mr. FISHER. Well, there is one insurance company which had previously not written hail insurance in our area, but it came in in a limited amount about 2 or 3 years ago and wrote some. It wrote more last year and now this year it has been writing hail insurance for 2 months. This is unprecedented in our area.

Senator BURDICK. You made it a better risk.

Mr. FISHER. Well, we tend to think this. To give you an idea of the rates of these insurance companies, most of the old line insurance companies on the average charged 18 percent with a 10 percent deductible off the top. Now this company writes at 14, no deductible. Whether there is something afoot here, I don't know. We suspect.

Senator BURDICK. I just have one other question. This is pretty hard for you to answer, but are you able to project the economics of this? Does it pay?

Mr. FISHER. It certainly does.

Senator BURDICK. Is it a better investment than investing in hail insurance that gives you only partial coverage?

Mr. FISHER. I think it is a better deal. As our techniques and our equipment improve I think that it will be a better bet. If we could get their rates down to 3 or 4 percent like they have in eastern North Dakota, even if people went back and bought hail insurance this would be a tremendous savings. This would more than pay for the cost of the program. Our costs, if you are interested, are really quite low. They are 15 cents per seeded acre on small grains. Pastures and hay land, corn, all are accepted, so the average farmer would probably pay from $50 to $100. The highest contributor we have is $300. When a farmer starts out in the spring and goes for this crop, he just pushes it all out and says, "I've got this much." And he is at Mother Nature's mercy.

Senator BURDICK. I will say this, Mr. Fisher, that you have been a very persuasive witness.

Senator MCGOVERN. Senator Moss?

Senator Moss. How about the farmers? Do you still have doubting Thomases among them?

Mr. FISHER. We have fewer and fewer every year.

Senator Moss. Is it becoming more universal?

Mr. FISHER. That is true. In our first season of operation it was kind of humorous. I received a call one morning after we seeded a thunderstorm and didn't produce very much rain. About 6 o'clock in the morning this fellow said, "I'll shoot you down the next time I see you." These are some of the things we have to put up with. But now we are received very favorably.

Senator BURDICK. Of course, since 1961 we have not had a moisture problem.

Mr. FISHER. No.

Senator BURDICK. The next big frontier challenge will be tackling a dry cycle.

Mr. FISHER. This is true. At the present time I am wondering what are we going to do when we have the long dry weather such as Northeastern United States had this last summer. I am convinced that you can increase the precipitation from clouds if you have the right kind of clouds. But what do you do when there are clear skies?

Senator Moss. Well, I want to add my word. It is quite inspiring to hear Mr. Fisher's testimony. The necessity of protecting your crops caused you to go out and take this action. You had to fly by the seat of your pants and get help wherever you could get it. You just had to press forward and try to do something about it and you have had some impressive results. You are certainly to be congratulated.

Senator METCALF. I, too, want to concur. You told us this morning an exciting story. It is what people can do with modern information that we have at hand. You cited some stories from my own State. They were using every expedient that you used in developing these things in the early days and if anything has convinced me of the fact

that we need more research and more information and better witnesses, it is the kind of story you have told here today. Thank you very much.

Mr. FISHER. Thank you.

Senator MCGOVERN. I will ask that a prepared statement by Mr. Brewer, a partner of Mr. Fisher, be printed at this point in the hearing where it will be following Mr. Fisher's statement.

(The statement follows:)

STATEMENT BY WILBUR BREWER, BOWMAN COUNTY, N. DAK.

I am a grain farmer in Bowman County, North Dakota. I was born in Bowman 41 years ago and have lived here my entire life with the exception of two years in Air Force Pilot Training in World War Two and two years in Business Administration School at Long Beach City College, Long Beach, California. I am married and have three children. I have been actively engaged in grain farming since 1946 and before this was dependent upon my parents who were farmers in the Bowman area since 1910 or shortly after the Milwaukee Railroad reached the area. I operate a farm of slightly more than 3000 acres with 1000 acres of wheat allotment and 200 to 300 acres of oats. We also run a small herd of sheep on the untillable land. I operated an Aerial Spraying Service for seven years by myself and six more years with Bill Fisher as my partner before quitting the Aerial Spraying Business last fall (1965).

Bowman County is one of the highest hail loss areas in the United States as far as we can determine and in a series of years, 1954 to 1960, inclusive, I was hailed either severely or totally in six out of the seven years. The Fisher farm lies in the same general area as my farm does and their losses would be comparable to mine. Bill and I discussed this situation and decided that we should look into the possibility of doing something about it.

We corresponded with as many people as we could to find out the costs involved and the possibility of reducing hail losses. We were able to contact several people with some knowledge of this business and one commercial firm indicated they would be interested in suppressing our hail if we had a million acre target and $200,000.00 to spend on it. This, of course, was far beyond the means of our community so no further contact was made with these people. We also came in contact with a Mr. Ora Lohse of Valier, Montana, who had an active project and went to Valier to discuss his project. The outcome of this meeting was the basis for our operation and we leased one airplane and four Silver Iodide Generators from him. The second airplane was purchased from a private party in Great Falls, Montana. We went to our neighbors and asked them if they would help support this program as we really don't know if it would be successful but thought it should be worth a try. They started an association known as the Bowman Slope Hail Suppression Association and collected money on a voluntary basis at the rate of 15 cents per seeded acre on small grains. Our original area was 18 miles wide and 30 miles long. We used two AT–6 type aircraft and held our area small because we didn't know how effective we would be as neither of us had any formal training in Meteorology and were not familiar with this type flying. The first two years we seeded clouds on a daylight only basis but then had heavy losses at night. We decided that we would also have to seed nights to be effective. We have done so the last three seasons.

We have had requests at different times to expand our area and have expanded to what we feel is as large as we can handle with the equipment we have. Our present area is 30 miles wide by 70 miles long or over 1,300,000 acres. We have plans to lease a portable radar this season and we feel this will be a great help. We are also buying two light aircraft in the Piper Comanche or Beechcraft Bonanza class to seed with this year. We are going to lighter airplanes because of the cost of maintenance and fuel on the AT–6 type is getting prohibitive for our budget and parts are almost impossible to get as they are World War Two Trainers.

The money collected and turned over to us has varied from $6000.00 to $14,000.00 per year which has covered the bare necessities of the project. We have kept our planes ready to go on a moment's notice for three months (June 1 to September 1) each of the last five years. We also have 20 ground generators placed throughout the area.

We don't know how effective we have been statistically but we do know it has helped in many specific cases and we feel that if we can keep the hail losses down and possibly get a slight increase in rainfall in this semi-arid area we can repay the cost of the project many times over. We are sure we have done this.

We are using the Lohse type generators and have leased four of them from Mr. Lohse each year for the past five years. We have also had much helpful advice from Dr. Richard Schleusener of the South Dakota School of Mines which has been very beneficial to us over the last four years and has helped to make our project more successful.

I sincerely believe any money spent in Weather Modification or Weather Modification Research will return dividends inconceivable in any other business.

Senator McGovern. The next witness is Dr. John Bellamy, director of the Natural Resources Research Institute at the University of Wyoming at Laramie. We are happy to have you with us this morning, Dr. Bellamy.

STATEMENT OF DR. JOHN BELLAMY, DIRECTOR, NATURAL RESOURCES INSTITUTE, UNIVERSITY OF WYOMING

Dr. Bellamy. Mr. Chairman and members of the committee, it is indeed a pleasure to have this opportunity to discuss with you the subject of weather modification and climate control. For your information, I am the director of the Natural Resources Research Institute of the University of Wyoming, a registered professional engineer and land surveyor (Wyoming License No. 280) and a certified consulting meteorologist (American Meteorological Society No. 23). My professional interests are primarily those of civil engineering, in which I obtained a bachelor of science degree from the University of Wyoming in 1936. I have specialized in the development of operational procedures which better uilize our knowledge of meteorology, in which I obtained a doctor of philosophy degree from the University of Chicago in 1947.

Our active participation in the general field of weather and climate modification at the University of Wyoming began and has been closely associated with the Bureau of Reclamation's program in this field since its inception in 1962. Our approach from the outset has been that of engineering development. That is, the primary goal of our particular research program has been more to learn how to utilize existing knowledge concerning precipitation phenomena than to try to extend such scientific knowledge ourselves. We feel fortunate to have discovered one particular kind of cloud which is especially amenable to the controlled production of significant amounts of additional snow on the ground with well known techniques of seeding with silver iodide. This is the cap cloud which frequently enshrouds Wyoming's higher mountain peaks in the wintertime, about which I understand you have already been briefed.

STATEMENT OF PROBLEMS

As I understand it, the subject of this hearing is that encompassed by Senate bill S. 2875 including its relationship to Senate bills S. 23 and S. 2916. I thus assume that we are interested today in considering the entire field of weather modification with special emphasis on what legislation the Congress should enact to help provide for fuller

utilization of our atmospheric water resources. As I see it, this involves considerations of what levels of funding, operational responsibilities, and regulatory authority various Federal agencies should have in this field with respect to each other and with respect to State and private agencies.

Finding answers to these difficult questions seems to me to depend, first of all, on a clear recognition of the extremely broad implications of the term "weather modification and climate control." This term, without additional qualification, encompasses the control of three of the four elements—earth, water, air, and fire—which the Greeks recognized long ago as being essential to all life. That is, it encompasses the control of the state of the atmosphere, of our water supplies which nearly all fall originally from the atmosphere, and of the radiations from the fires of the sun which in turn control the circulation and precipitation processes of the atmosphere.

In view of the vital importance of the air, water, and fire to all aspects of human life and endeavor, the problem at hand resolves itself largely into recognizing the relationships, first, between the control of atmospheric water resources and other kinds of weather modification and climate control and, second, between the many different kinds and characteristics of atmospheric water resources in different parts of the country. A clear recognition of such relationships should provide the guidelines required to reach conclusions concerning the most desirable kinds of legislative action.

SCALES OF WEATHER MODIFICATION ACTIVITIES

It is noteworthy in this regard that the general field of weather modification and climate control is hardly new. It has long been practiced in a very real sense by building houses and setting thermostats to control the weather and climate of the atmosphere in which most of us spend most of our lives. The extension of such weather and climate control to the use of protective covers for plants—in the form of cloth or plastic sheets, greenhouses, or protective layers of smoke over orchards—differ more in scale than in kind or intent. A slightly larger scale of control is now starting to be exercised by artificially dispersing fog over airport runways; the seeding of cap clouds is representative of a somewhat larger scale but very similar kind of control.

The point here is that considerations of the different scales of weather modification and control provide a useful perspective concerning the kinds of problems which confront us today. Evidently the road of progress in this field (and of civilization itself) is marked by the scale of control of weather and climate that mankind has learned to exercise. From this point of view, we are currently at that stage that control is starting to be exercised on the scale of airport runways; we are rapidly learning how to control some precipitation processes on the scale of cap clouds or individual storm cells; and long-term research is now underway which will undoubtedly lead to knowledgeable control of larger storm systems and even—at some time in the remote future—large-scale circulations of the atmosphere.

REGULATION OF WEATHER MODIFICATION ACTIVITIES

Such considerations of the scale and present status of weather modification activities provide some very useful guidelines concerning their regulation. They clearly point out a continuing growth of a need for some regulations since the lives of more and more people are affected more and more significantly as the scale of such operations grows. Conversely, however, they also clearly indicate that the large-scale effects are not likely to become operational (or even tried experimentally) for some time yet, and hence that no urgent need now exists to impose restrictive regulations on them at this time.

As a general principle, it seems to me to be most desirable to vest whatever regulation might be needed in those governmental agencies which correspond in size to the scale of the effects of the kind of modification involved. For example, the regulation of extremely small-scale modification is now well accomplished by cities with building codes and zoning. Similarly, whatever governmental regulation of airport fog-clearing operations might be found to be necessary could well be vested in the cities or counties involved. At the next larger scale of modification, the effects of seeding cap clouds are limited to fairly small regions at fixed geographical positions, and hence could best be regulated by those relatively few States in which cap clouds occur and can be advantageously seeded. In accordance with this principle, whatever Federal regulation of weather modification activities might be found to be necessary in the future could well be limited to those kinds of activities which are definitely known to affect areas as large as several States.

In this regard, the regulation of cap-cloud seeding operations by the States involved seems especially appropriate. The intent of such cap-cloud seeding operations will be to increase the high-mountain snowpack in—and only in—those Western States in which the resultant increase of surface water supplies will be useful for, especially, power generation and irrigation. Consequently, the mechanisms for regulating such operations are already at hand in much the same way that those States now regulate the diversion and use of their surface waters; the seeding of cap clouds can well be considered to be little more than a diversion of an atmospheric stream of water at a particular fixed geographical position. Whatever interstate problems might be encountered in such operations are likely to involve changes of the flow of surface streams more than of atmospheric streams of water, and hence can well be solved within the framework of existing interstate compacts and commissions.

The regulation of the seeding of other than cap clouds potentially presents more problems, largely because the areal extent of the effects of such seeding are usually somewhat larger and are as yet less well known. Impending operations of this kind, however, are not likely to be effective in regions much larger than a single State for a long time yet. Consequently, the regulatory control of such operations could probably best be vested in the States in which they are to be conducted or, if and when necessary, to compacts between those few States in which a particular kind of operation is likely to be effective.

LICENSING

Much of my opinion concerning such regulatory policies stems from the closely related problem of licensing those who are to obtain permits for specific weather modification operations. Regardless of the degree of regulation, such operations can be no more effective than provided for by the technological capabilities and motivations of those who design and establish them.

Again the guidelines for the solution to this licensing problem is provided largely by considerations of the scale of phenomena involved, and by the example of impending cap-cloud seeding operations. The directly applicable precedent in this case is that only licensed professional engineers can submit applications for permits to divert surface waters in those Western States in which cap-cloud "diversions" of atmospheric streams of water are likely to be effective. I can see no advantage, and several serious potential disadvantages, of Federal rather than State licensing of comparable "atmospheric water-resource engineers," at least until such time as much larger scale diversions of atmospheric waters than are now impending become practicable.

As most of you are probably aware, this basic kind of regulation and licensing procedure has already been established for the utilization of atmospheric water resources within the State of Wyoming. It is appropriate that such action be pioneered by Wyoming since it was in Wyoming that Elwood Mead first established such procedures for regulating the utilization of western water supplies, and since Wyoming was the first State to institute the licensing of professional engineers in order to implement those procedures.

It is also noteworthy that the essential reason for requiring application for permits by a registered professional engineer is to insure the same kind of protection of the public interest and welfare that underlies most stated desires for the regulation of weather modification activities. This is clearly reflected in the following quotations from the creed of the pledge of the National Society of Professional Engineers, for which the primary prerequisite for membership is registration as a licensed professional engineer in one of the States.

> As a Professional Engineer, I dedicate my professional knowledge and skill to the advancement and betterment of human welfare.
>
> I pledge * * * to place service before profit, the honor and standing of the profession before personal advantage, and the public welfare above all other considerations.

LEVELS OF SUPPORT

With regard to the levels with which various kinds of weather and climate control should be supported and/or conducted by various Federal agencies, it is only necessary here to indicate virtually complete agreement with the general philosophy and most of the details—with the exception of regulation and licensing details—expressed in Senate bills S. 23 and S. 2875 and Senator Anderson's statement of the purpose of hearings on S. 2875. The vital importance of this general field to all kinds of human activity clearly demonstrates to me the need for increased activities by each of several mission-oriented agencies such as the Bureau of Reclamation, NSF, ESSA, DOD, and

the Department of Agriculture. I especially endorse the concept that effective lines of communication are required among such agencies, but that each of them must be empowered to direct its own activities in accordance with the particular needs of its own mission. I also heartily agree that the Bureau of Reclamation is the most appropriate Federal agency for the major engineering responsibility to develop operational methods of fully utilizing our atmospheric water resources.

CONCLUSIONS

In conclusion, I wish to thank you for the opportunity to express my views concerning this subject of such vital importance to us all. I sincerely hope that they will help to establish that course of legislative action which will best serve the needs of each of the several Federal agencies which can and must be involved in quite different aspects of weather modification and climate control. I especially hope that they will help establish those kinds of regulations and licensing procedures with which the widely differing kinds of atmospheric water resources in different parts of the country can ultimately be utilized most efficiently and effectively for the greatest public good.

Senator McGovern. Thank you very much, Dr. Bellamy, for your statement on control, since you are the senior scientist-engineer with us today.

Dr. Bellamy. I am not sure of that. There are other people who have a lot more experience.

Senator McGovern. We appreciate your testimony as a longtime veteran in this field, particularly knowing about some of the criticism and opposition you encountered in the early days. Dr. Vonnegut has told the committee that your cap-cloud seeding method works every time. That being the case, do you know of any practical reason why that isn't made operational to be used wherever possible, where more precipitation is needed?

Dr. Bellamy. I will say this: One of the big problems we have now is the economic aspects. We are working as hard and as fast as we can to get the detailed information, operational procedures whereby we can get good gaging. For example, if we started right now—whoof—I don't know what would happen to our interstate compacts we have with regard to water. We are proceeding as rapidly as we can to get operational utilization for the plan, which is called experimental operation, meaning the intent is to get more water. The Wind River Mountains, especially the headwaters of that project of the Bureau of Reclamation, is under study. We are proceeding full speed ahead on a reasonable basis to try to get it.

Senator McGovern. One man told me today that when you seed a cap cloud the effect is quickly visible. He said that when you drive the truck around with the seeder going, you see the snowfall follow the truck. Is that true, or was I getting my leg pulled a little?

Dr. Bellamy. It isn't quite that easy but in principle this is right, yes.

Senator McGovern. Senator Moss, do you have any questions?

Senator Moss. Well, I was very interested in the testimony of Dr. Bellamy and, of course, this cap-cloud seeding intrigues me. We

have a lot of those and we have been seeding them because we are always short of water. It is your feeling, I gathered from your testimony, that we really do not need any National or Federal regulation at this point. That can be left to the States.

Dr. BELLAMY. Yes.

Senator MOSS. To what extent would we run into conflicts between States when we are close to the border areas?

Dr. BELLAMY. Once in a while you get into this. Again we have this in our surface waters. I think it could be worked out. The way to handle this is between the States. Sure, there are always the problems but I don't think these kind of problems would get solved with Federal regulation. I think that our history, when we are talking of water resources, the history of the interstate compact is that the States have worked out their problems. It is a good question. It is the only way they can be worked out.

Senator MOSS. Thank you.

Senator MCGOVERN. Thank you very much, Dr. Bellamy. We are going to have time for one more witness before we break for lunch. To avoid getting all of our professors grouped together here we might change the order a little bit. I am wondering, Mr. Brown, if you would be willing to give your statement now, or would you prefer to wait?

All right. We will call Mr. Willis Brown, who is the publisher of the Rapid City Journal, to give his testimony before we break for lunch. He has been very much interested for some time in this field and also in encouraging the development of the resources of the Great Plains area as a whole. I think we all know that the press plays an extremely important role in the public understanding and support for a program of this kind, so we are very happy to have you with us this morning, Mr. Brown. You can proceed in any way you see fit.

STATEMENT OF WILLIS BROWN, PUBLISHER, RAPID CITY JOURNAL

Mr. BROWN. Mr. Chairman, and members of the committee, it is a real pleasure to be invited to appear as a witness at the hearing on Senate bill 2875. It is my hope that I can offer some testimony that will be helpful in the determination that a stepped-up research program in the field of weather modification under the Department of the Interior will lead to greater economic stability in the United States.

I am not an expert in the field, therefore, my remarks are based on reading, studying, discussions, and general information assimilated on the subject of weather modification and the problems that we humans have with certain unusual and sometimes devastating actions of the weather.

Our newspaper has published numerous news stories and editorials which I have brought with me and will give to the committee secretary. The dates are: March 10, May 11, May 23, July 12 and 13, and August 11 in 1965, and January 2, February 6 and 20, and April 10 in 1966. Our managing editor, Jim Kuehn, has written editorials and directed the news material used, which included Associated Press dispatches and one from our exclusive New York Times news service.

Dick Rebbeck, our agriculture and conservation editor, has a feature story and also included is a reprint from the Minneapolis Tribune by Victor Cohn. I hope they will be helpful.

In this area of the United States, as in many other regions, proper rainfall is of basic importance in the harvesting of a successful and useful crop. On the other hand a single hailstorm can wipe out a ready-to-harvest crop and spell failure for not only the farmer or rancher who owns it but the hundreds and hundreds of others who are dependent on it.

Crop production in South Dakota, for example, ranks in the top 10 States in a number of the most important crops in the Nation. (The source of the facts I am quoting from include: The Rapid City Journal's Market Guide; the information book of the Western South Dakota Development Co.; Crop Reporting Service Bulletin; South Dakota Agriculture, 1964; Agricultural Statistics, 1964–65.) South Dakota is 2d in production of rye, flaxseed and sweet clover seed, 3d in wild hay and other spring wheat, 4th in Durum wheat and smooth bromegrass seed, 5th in oats and crested wheat grass seed, 8th in all hay production, 9th sorghum grain and alfalfa seed, and 10th in alfalfa hay.

As of January 1, 1965, there were more than 4,250,000 cattle and calves in South Dakota, which was an increase of 5 percent over the previous year and placed the State in ninth position. The more than 1,750,000 beef cows on the same day placed the State fourth in the Nation. Many other States in our region have as high or higher rankings in livestock and poultry in South Dakota which volume is $585 million.

These two—crop production and livestock raising—go hand in hand. Each depends on the other. And both depend largely on the weather. A poor year for one often means a poor year for the other. In 1964, for example, South Dakota cash farm income was $706 million compared with $718 million the previous year of 1963. Much of the drop, according to the Market Guide, "depends on the weather." That is where I have to do some curbstone quarterback second-guessing. But if weather modification research had progressed far enough so that they could do just 5 percent more than now, it would be possible that the manipulation of our "weather" could have produced a 5-percent increase in farm income instead of the loss. That would have meant instead of a $12 million loss a $36 million gain and you can see what that would do to the economy. After an increase like that the other things follow like lower prices in grocery and meat stores, a healthier and more nutritiously fed American populace, and the other theoretical aspects that could be tied to it.

Reducing a devastating hailstorm to a helpful and nourishing rainfall can mean millions in the crop producing States of our country.

The Institute of Atmospheric Sciences has come quite a distance in the study of weather. The expansion of its work should be of more help for the entire multistate Great Plains region. Other regional institutes would benefit and grow in importance to the country's economy. There was a great deal of speculation and disbelief at one time in whether or not humans could reach the moon. Research has dispelled this doubt. What Dick Tracy is writing for our amusement and relaxation can become fact.

What Athelstan Spilhaus, dean, University of Minnesota Institute of Technology, portrayed in yesterday's Minneapolis Tribune comic section in using lightning to control rainfall can't be brushed aside either. The city of Minneapolis, for example, predicts that if the water pollution problem isn't solved that their fresh water supply will be depleted, or polluted, by 1980—just a few years away. Now, if the work of Dr. Schleusener and his staff at the Institute of Atmospheric Sciences can continue their present progress with the greatly increased help from Senate bill 2875, the accelerated program has a fine chance of producing near-miracles.

The Nation would be high in their praise of the Bureau of Reclamation—and it would make the Bureau happy, too—if a nice, heavy rain cloud could be guided onto another "flight path" and guided over a reservoir and then stopped so that it could unload enough water from the atmosphere to bring the reservoir to its desired level. Two satellites now are sending pictures back to the ground on the position of clouds. Perhaps one day soon it will be standard procedure for certain commercial scheduled airline flights to have as one of their jobs the reporting of various types of cloud formations and their position so that they can be directed to localities that need the help.

Scientists can do almost anything with the proper encouragement and this bill does just that, it seems to me. The National Academy of Sciences, the National Science Foundation, and many other fine groups and organizations see a future in research on weather modification. Regional institutes strategically set would be in a position to do a lot for the economy.

The current issue of the Saturday Review carries an article by John Lear, their science editor, titled "Shepherding the Wind" in which he states that "the emphasis is on the technology—the doing of it—rather than an scientific explication of the natural laws involved in the process." Dr. Schleusener's institute is doing just that. Others, I am sure, are close behind in several other parts of the country.

Certainly, a substantial increase in appropriations for weather modification research can hasten and enrich the benefits from the research. The Institute of Atmospheric Sciences, located here near the heart of the United States at the school of mines and technology, is moving forward markedly. From June 10 to July 10 some 50 scientists representing 17 different groups will be making news as they work together on study of hail suppression techniques in a program called "Operation Hailswath." This can be a real stepping stone.

A Journal editorial said on May 11, 1965:

> Work on weather modification started more than a decade ago. * * * No miracle is anticipated, but everyone should be interested in the program for weather research. * * * Funds for the research allotted here so far perhaps merely equal the damage in the immediate area. * * * It's time that more people pay attention to the potential of preventing—at least reducing—the storm havoc. If we can gain rain at the right time, that will be good. Weather modification research has been urged by South Dakota's congressmen for years. Storm-stricken citizens in other areas might be advised that help could be forthcoming in the future if their congressmen planned for the future.

Your committee members are interested. That is proven. South Dakota's active interest began with Senator Francis Case along with South Dakota-born Senator Clinton Anderson, now from New Mexico, and I am glad to see it continue with the very active interest of you,

Senator McGovern, and your colleague, Senator Karl Mundt. We hope that the committee report will be most favorable and that it will aid in passage of 2875 soon. Regional centers are necessary for complete study of weather modification, but with the seeming headstart here it just might be good to have the institute here designated as at least the "training capitol" for all other regional institutes.

Thank you for permitting me the opportunity to bring some of these points to your attention from a layman who is intensely interested in the future betterment of our country.

Senator McGovern. Thank you very much, Mr. Brown. That was an excellent statement. Beyond that I think we are all indebteded to you and the Rapid City Journal for your editorial coverage and the news coverage of developments in this field. I don't have to tell you that the best project in the world can be blocked or can be hampered, slowed down, by ignorance on the part of the general public, so I think the press has an enormously important role to play in moving these projects along. I am wondering what you, yourself, believe as a layman, one who watches these things closely, what you believe the public attitude is in this region toward the general objectives of the Senate bill that we are now considering.

Mr. Brown. Discussions have had quite a bit of impetus from the chamber of commerce and with the combination and you gentlemen coming and with the institute here at the school, a great many people have learned a great deal more about the subject recently. And as a result, not only the coffee talk but a lot of business discussions and dinnertime chatter has become serious on the matter of weather modification and upon this Senate bill. People are extremely interested and hopeful that it will pass. That is the general feeling, the general tempo that I pick up.

Senator McGovern. You may recall that when Senator Symington was here last November he made the statement that the School of Mines, the work that they are doing in a number of fields, and the potential of this institute probably constitutes the most valuable resource that we have in the Rapid City area. What is your feeling about the public attitude toward the school and specifically toward the Institute of Atmospheric Sciences?

Mr. Brown. The attitude toward the school is one of extreme interest, one of extreme importance to the State of South Dakota in particular. Of course, it can do much for the entire country, and, from the number of students who are learning technology here, it can do much for the rest of the world because there are quite a number of students enrolled here who will be going back to their countries in Asia and Europe and take back the knowledge that they have learned here. The people of the State are extremely interested in the well-being and future growth of the School of Mines and technology. The attitude of the townspeople is excellent toward it, they hope that it will grow. Everybody is happy that their children will be able to take an enriched course in liberal arts and sciences here, and have the opportunity of going on after 2 years, to get their bachelor's degrees in other State colleges. Generally the feeling that I have heard in the past year has been extremely good on President Partlo's school.

And as far as the Institute of Atmospheric Sciences is concerned, it is a thrilling note to a lot of people here in town and this area— the

Black Hills area, the West River area, including part of Wyoming, too—to know that all of this information is being gathered and pushed forward and made so important in our scheme of life and the economy of our particular region.

Senator McGovern. Thank you very much. Senator Moss, do you have any questions?

Senator Moss. Well, I, too, congratulate Mr. Brown for his testimony and I echo what the chairman said about the importance of having public understanding and public awareness of a program such as this. I am glad to have you know that people are less likely now to shrug it off as some impossible thing by your reference to Dick Tracy and Buck Rogers before him. So many of their exploits are now almost commonplace with us that it is recognized now there are tremendous areas of possibility and nobody dares say now we can't do it. We can direct enough of our energy and resources and materials to get the job done. I think what we are saying, too, in part, is that we have to devote enough of our resources to support our scientific effort to make a meaningful advance here. In a position such as Senator McGovern and I have, we are constantly being told that we must stop all nonessential spending. The point is, is this nonessential or is it essential? And that is the part I think you have told us about.

Mr. Brown. I have "letters to the editor" from people, and places almost unknown, so that they are reading and understanding and interested in the entire program.

Senator McGovern. Thank you very much, Mr. Brown. I want, before we break for noon lunch, to take this opportunity to thank President Partlo and the members of the staff of the School of Mines and Technology on hosting this conclave, for providing the comfortable and excellent facilities that we have available to us. Our hosts have a registration book just outside the door which they would like everyone to sign and I am personally hopeful that you will do that, because we would like to send everyone here a copy of these hearings, not only the testimony taken here today but the testimony taken previously in Washington and the testimony that will be taken at Albuquerque on Thursday of this week. So we will now break. We will come back and resume our hearing after lunch in this same room at 1:45. Thank you very much.

(Whereupon the hearing was recessed to reconvene at 1:45 p.m.)

AFTERNOON SESSION

Senator McGovern. Gentlemen: Senator Metcalf and Senator Burdick, who left a while ago, were grounded and unable to reach their destination. Senator Burdick will be back with us in a few minutes. Senator Metcalf has taken off by car to Montana, but if there is anyone here in the room who knows of anyone who is driving by car to the eastern part of the State this afternoon, Senator Burdick is very anxious to be on his way. He has to try to be in Fargo sometime tonight, if possible, so anyone who has any knowledge of a car that is going over that way please let us know. We will see that Senator Burdick gets the information.

The first witness this afternoon is Mr. Lewis Grant of the Department of Meteorolgy of Colorado State University, Fort Collins. Is

Mr. Grant here? We would be glad to hear you at this time, Mr. Grant.

Although Senator Mundt is not a member of the Interior and Insular Affairs Committee, I extended him an invitation to be with us for these hearings. He was unable to accept because of a longstanding commitment that he had elsewhere, but he did want me to bring his greetings to those present.

Mr. Grant?

STATEMENT OF LEWIS GRANT, DEPARTMENT OF METEOROLOGY, COLORADO STATE UNIVERSITY

Mr. GRANT. Thank you, Mr. Chairman. My research at Colorado State University is directly concerned with physical and statistical studies of Rocky Mountain orographic clouds and their modification. My field studies have been carried out in the central Colorado Rockies and have been in progress since 1960. I have been continuously concerned with weather modification since 1948, first as a graduate student at California Technical, subsequently with a commercial seeding concern, and with Colorado State University since 1959. My comments are concerned with the complexity of weather modification and with approaches for obtaining engineering know-how for the rapid development of operational programs.

Background.—The demonstration in 1946 by the General Electric group that clouds could be modified was followed in rapid succession by a number of advances in the general understanding of cloud processes and the technology of their modification. It appeared by the late 1940's that this start would be rapidly exploited and that the physical demonstration that clouds can be modified would develop into practical weather modification. Interest did not lag and weather modification activities were continued by basic researchers and Government agencies and to a larger extent by private commercial groups. The rapid technological advances of the late 1940's, however, did not continue. The General Electric group had taken a preliminary look into many, if not most, of the interesting avenues of approach. Further development, however, was found to be extremely involved and complex.

Private seeding operators were primarily concerned with development work that would lead to practical uses and all groups, both research and private interests, were confronted with the evaluation problem to determine actual results of seeding. If precipitation increases from seeding were of the order of 100 percent, 50 percent, or even 25 percent, they could be readily determined. It is apparent that they are generally smaller than this and extremely hard to distinguish from natural variations in precipitation. The private seeding operator has found that while his interest is great, his resources are insufficient to look into the complex physical problems involved.

Steady scientific advances in cloud physics have come from the scientific community but during the 1950's, these investigations were not, in general, directed principally to the basic and immediate problems associated with weather modification. The slow progress in weather modification was apparent by the mid-1950's and on the recommendation of a number of groups and committees, the National

Science Foundation was assigned the task of encouraging research directly related to weather modification. Progress was slow at first as a number of researchers began diverting their attention to specific weather modification problems. These problems, in many cases, were pertinent but were of necessity primarily representing the interests of the investigators and were not necessarily directed to the most vital or practical problems. The direction of emphasis, however, became well oriented by the early 1960's and signficant results are now becoming available.

Problem evaluation.—Every aspect of the weather modification process is complex and leads to other problems. Of greatest complexity is the understanding of the relationship of various variables of the cloud systems affected by weather modifications to each other. An understanding of the complex relationships taking place in cloud systems, both natural and seeded, is a primary goal for investigations of Rocky Mountain orographic clouds and Great Plains hailstorms currently in progress at Colorado State University. These studies are concerned with each phase of the seeding process starting with the characteristics of the seeding materials and continuing to their transport in the atmosphere, action in the cloud, and the resultant precipitation.

All phases of the process are vital to our understanding of and utilization of seeding effects. These various aspects must be investigated simultaneously to understand the importance of each phase of the process and must be studied for a variety of different type cloud systems in different regions. This requires a large effort by a number of researchers and will require substantial financial support. A summary of the current status of the Colorado State University orographic cloud studies is attached.

While beneficial increases in precipitation are probably being obtained from some seeding projects, I do not believe that knowledge is sufficient for large scale operational programs for the explicit purpose of increasing water supplies or suppressing hail by weather modification. It certainly appears that vastly different effects (positive, negative, and none) take place under different circumstances and we, as yet, do not have a sufficient understanding of these circumstances to be able to consistently obtain a desired result. It does appear that we are at the threshold of obtaining sufficient understanding within a relatively short period of time if sufficient effort is expended.

Future programs.—Research that can resolve the basic understanding of cloud, precipitation, and weather modification processes should be continued and expanded. The program of the National Science Foundation is sound. This program is directly or indirectly responsible for many of the advances now being made.

A concentration of research effort must be directed toward understanding the many aspects of weather modification attempts made to the cloud systems which one hopes to modify. There are a number of different scale cloud systems that can be considered. These include those producing orographic precipitation in different regions and those producing hail, flatland precipitation, hurricanes, et cetera. The obtaining of an understanding of the relationship of all of the basic cloud processes involved is necessary since variations in any one process can change the general characteristics and precipitating efficiency in the entire cloud system.

I would like to briefly refer to specific studies that I think are important in developing the weather modification potential of Rocky Mountain orographic clouds. While these comments are directed at a specific cloud system in a specific region, they apply just as directly to a number of other weather systems that should be investigated in the same detailed manner. Similar investigations should be directly concerned with flatland, precipitation, hail, lightning, hurricanes, orograph precipitation in other regions, et cetera. Getting back to the modification of Rocky Mountain orographic clouds, studies should be undertaken to understand the characteristics of various seeding materials and their specific effects in the temperature and storm regimes that occur in this region. Knowledge of many aspects of the transport of these materials under the airflow and stability conditions existing in the Rocky Mountains is also vital.

Knowledge of the concentrations and the characteristics of already present natural ice nuclei is vital to an understanding of the potential from and techniques for undertaking operations to change these concentrations artificially. Of equal importance is the understanding of the generation and growth rates of snow particles under different temperature and humidity regimes. This last item is vitally important in knowing where the precipitation will fall or even whether it will be enhanced or hindered. This enumeration of important aspects of the seeding process could be extensively continued. These items are mentioned, however, only as possible examples. They are not just basic questions of pertinence to the scientist. They are vital questions that must be understood before we can know when we can help and when we would hurt ourselves by weather modification. They are vital in engineering procedures for obtaining not only optimum effects but probably even for consistently obtaining any results. The conflicting results of many past weather modification operations probably don't result as much from the overall lack of potential as from the lack of knowledge of the constantly changing potential and how to use it.

In my opinion it is important that sufficiently large and competent groups be organized to look at the various aspects of modification of specific weather systems in a coordinated and systematic manner. I realize that competent people are presently not available to undertake such extensive programs. People are available, however, for forming the nucleus for such groups and I believe that good supporting researchers and engineers can be drawn from other disciplines during the next 3 to 5 years.

It appears reasonable that the groups or agencies affected most by the respective cloud and precipitation systems should concentrate their efforts in the development of weather modification effort that can benefit that group. It does not appear feasible for one group to attack all problems of weather modification that affect all cloud systems. Clouds look much the same but vary to critical degrees between and within given regions. Special groups have a direct interest in many of these cloud systems and should develop the technology to use existing potential.

Coordination of all weather modification activities is needed at the Federal level. Weather systems and the modification efforts themselves are much broader than State boundaries.

If responsibility for coordination is centralized in a single governmental agency, other agencies, interests, and groups should be represented in weather modification matters at a policymaking level. It is important that considerable freedom be maintained for many interests and researchers in this developing field. The importance of this freedom of action is emphasized by progress in weather modification over the past 15 years which has come largely from dedicated groups and individuals who have operated out of the mainstream of established programs. The complexity of weather modification and its potential effect on all aspects of our environment, justifies consideration of the ultimate formation of a specific agency or group for handling weather modification matters. This agency could deal with and coordinate all aspects of weather modification, research and operations, and all areas of interest—economic, biological, legal, social, political, et cetera.

And then I might add here that the abstract that I have briefly covers the program we have underway. It is an abstract of a paper that will be published.

A weather modification project being conducted by Colorado State University in the central Colorado Rockies near Climax is described. This is a randomized project in which approximately half of the experimental days are seeded from upwind ground sites and the remaining half retained unseeded to be used in determining what precipitation would have been during this interval without seeding. Two hundred and eighty-three experimental cases have been collected since February 1960.

This paper deals primarily with the experimental design and statistical analyses used for the detection of actual changes in precipitation. These analyses extend, however, to each stage of the seeding and precipitation process as well as to actual precipitation. The following briefly summarizes the current status of these studies.

1. Laboratory cloud chamber analyses verify that the seeding generators being used are very efficient in producing large numbers of particles effective in seeding subcooled water clouds in the temperature range experienced in the atmospheric experiment.

2. Large concentrations of this seeding material are arriving in the target area on "seeded" days. These concentrations are greater than on the "nonseeded" days by a statistically significant amount (1-percent level).

3. Cloud probing in the precipitation formation region of the mountain clouds with instrumented kites and balloons is just getting underway.

4. Differences in snow crystals reaching the ground on "seeded" and "nonseeded" days are being observed but these differences have not been established as being significant. These analyses are continuing.

5. The analyses of the precipitation data is still in progress. The seeded cases have received substantially greater precipitation on days with warmer cloud temperatures (500 millibars temperature $-12°$ to $-20°$ C.). An increase is not indicated for colder clouds. Determinations of significance levels involve data transformations and have not been completed. I want to thank your committee for giving me the opportunity of expressing my ideas on this important matter.

Senator McGovern. Thank you very much, Mr. Grant, for your thoughts and statement. Your testimony on the projects which you have undertaken both in the laboratory and field I am sure will be very helpful to this committee. If we are to make greater progress toward the development of operational systems there are professions other than meteorology that need to be heavily involved.

Mr. Grant. Certainly there are. We are dealing here with physical matters that involve the physicist, the chemist, engineers, and so forth.

I might add that I feel one of the real strong points of our program at Colorado State University is that we have a small group of people working in the atmospheric sciences that, shall we say, have aimed the program, but we have been able to draw in extremely good people from the math department. We have a very good statistician. I believe he is consulting with the Rapid City group here. We have a real good and highly educated engineer from our mechanical engineering department. We are working closely with one of our professors from physics and also one from chemistry, and all in all, these people, I feel, are the ones we need to draw into the program and they are people who can become interested in working on this problem.

Senator McGovern. Do you think it is most desirable, Mr. Grant, to have a number of different mission-oriented agencies carrying on work in weather modification research or would you prefer to see that centered in a single agency?

Mr. Grant. As I tried to point out in my statement, I feel that it is very important that the mission-oriented groups develop their problems. After all, they are the ones that have the interest and are really going to get involved in the followthrough.

Senator McGovern. Do you think the weather modification responsibility with the National Science Foundation should be strengthened in the Foundation or possibly transferred into the Department of Commerce?

Mr. Grant. My personal feeling is that this is a developing science and I really feel that the place for the coordination and the reporting function for the next few years, while it is developing, should easily rest with the National Science Foundation. They are a noninvolved group. They do not have a direct personal interest where they are going to favor one program over another. I feel just as strongly that as this field develops in the next 3 to 5 or 10 years—I wouldn't want to put a time limit on it—that in all probability there should be a single agency, not a mission-oriented one. Perhaps a new agency formed that would deal with all aspects of weather modification, which, I believe, will become a very complex matter in our whole society.

Senator McGovern. Thank you.

Senator Moss.

Senator Moss. Thank you. Professor Grant, this is a very interesting paper and I am happy to have this abstract appended to it. It gives some idea of how you are proceeding. I rather gathered from what you said, however, that you thought that the state of the art had not developed far enough to warrant taking any positive action steps now. On page 3 you say, "I do not believe that knowledge is sufficient for large-scale operational programs for the explicit purpose of increasing water supplies or suppressing hail by weather modi-

fication." I suppose you heard Mr. Fisher testifying earlier and in discussing this with some other people I gathered, not from Mr. Fisher but from them, that this was about a 90 percent successful operation, being able to suppress the hail when they go out and seed the updraft of air. Is that inconsistent with what you said in your statement?

Mr. GRANT. No, sir. I do not believe so. I am familiar with the work by Mr. Fisher and many of the other operators and this may sound inconsistent. And I agree with their program wholeheartedly. I think it is a matter of terminology here. The point that I am really emphasizing here are large scale and operational and for the explicit purpose of increasing water as against learning how to do it. Now, first, starting with the large scale, I do not believe that we are at the point where, for example—and I will be specific in this—that we are ready to start an operational program for the entire Upper Colorado River that would have as its sole objective, or primary objective, making additional water. This is what I really mean to infer by it. I feel that in the Upper Colorado River we have to tie down the know-how a little bit before we have a chance of coming out.

Let me elaborate on this deal a little bit. We actually have strong indications of certain weather regimes where we are getting big increases in precipitation. On the other hand, there appear to be temperature regimes where we could easily be hurting the precipitation. If we cannot discriminate between these two, then we do not know when we are hurting ourselves and when we are helping ourselves, and our experiment has been going on for 283 experimental units and if we do not make this discrimination of the favorable and the unfavorable situations we come up with an indecisive answer with no indication that we have helped. On the other hand, I feel confident that there is a big class of situations that we have helped in a big way but that we have hurt ourselves in others.

Senator MCGOVERN. Can't those two be combined? Can't you be doing the research, the statistical work, and so on, at the same time you make it rain when you can make it rain?

Mr. GRANT. I doubt it very much. If we start a massive program in the Upper Colorado River, and I have never really considered what it would take to do this in a very serious way, but it would involve the operations, I am going to say, with numbers of generators that would run into hundreds and releases of silver iodide that would run into many, many pounds per operation so that the entire basin would now go from the situation where there is no seeding to one which everything is just damped out by the massive seeding. In addition, we do not know what the effect of such massive operations on the Colorado would have farther downstream. So that I feel that in the long run we would be delaying the day when we can carry out beneficial operations. Now, our program—and there are others, I use my own just as an example here—is so designed that we can tell which types of situations we can help ourselves with and which ones we are hurting ourselves with. Now, I feel that we have to find this out before we obliterate our chance of getting this information.

Senator MOSS. Thank you. I think I understand your point now. Certainly, you do have to complete the research part. Of course, the only way we are ever able to blast this loose at all and get some money to work with is because of the urgency felt for increasing precipitation, specifically in the Colorado River Basin, but elsewhere, too.

Mr. GRANT. Well, I would like to say that, being a westerner and having been in and out of South Dakota for many years, I am aware of the water problem in the West. As I pointed out here, I have actually worked with a commercial concern for many years and I felt, as I have tried to point out here, that there was a good chance of resolving these problems to start these programs just for increasing rainfall for many years. But it is obvious, as we have gone along, that the problems are just too complex and so I have actually personally backed off where I was at the point of operational seeding 5 to 10 years ago, and having actually done it for 5 to 10 years, I feel now that we have just got to get some of the basic answers. For example, one we have done at our Climax Observatory, which is at 11,300 feet, is to actually observe the ice nuclei in the atmosphere. In other words, the natural nuclei that cause precipitation to fall. And we have extended periods when this is below the level we would like to have. There are other periods when actually—from what cause I don't yet know—but the concentrations in the atmosphere are greater than we want to start with and we have just got to know these things before we know how to go about it properly. So it really gets back to engineering.

Senator MOSS. Thank you, Professor Grant.

Senator MCGOVERN. Thank you, Professor Grant.

Our next witness is Professor Merle Smith, who is the head of the Physics Department at Chadron State College, Chadron, Nebr.

STATEMENT OF PROF. MERLE D. SMITH, PHYSICS DEPARTMENT, CHADRON STATE COLLEGE

Mr. SMITH. Mr. Chairman, members of the committee, it is indeed a pleasure to have the opportunity to appear as a witness before this committee.

This report is prepared by Merle D. Smith, director of hail research at Chadron State College, Chadron, Nebr.

The opinions expressed in this testimony are those of the research group at Chadron State College and do not necessarily reflect the views of that institution or the Nebraska State Normal Board.

In considering the merits of S. 2875, one feels that the first question should be, "Is a program of this scope justifiable?" This question has been answered very well in the recent reports by the National Science Foundation Special Commission on Weather Modification. There is, however, one aspect of this question deserving expansion. A point has been reached where cloudseeding may well be paying its own bill with increased precipitation, and the resultant knowledge that evolves is free. Today a 10- to 20-percent increase in usable water seems likely. Hopefully, even greater increases will be possible as our understanding of the forces which control the precipitation process increases. If one extrapolates the curve of atmospheric knowledge relative to the past 50 years, he can hardly reach any other conclusion.

The development of weather modification has been slow in reaching its present state of respectability. There are several reasons for this: the lack of adequate financial support, the lack of scientific coordination, the shortage of personnel trained in atmospheric sciences, and the

prospect of liability for property damage resulting from experimentation.

There are few areas of research in which so many parameters are involved. The only complete laboratory at our disposal is the atmosphere itself. The number of atmospheric events which would lend themselves to the process of weather modification is indeed limited and is controlled by the temperaments of nature. Such events encompass recognition and understanding of the processes of meteorology, thermodynamics, climatology, and certain aspects of physics and chemistry.

To expand the present state of our ability to modify weather, moneys must be provided beyond the present level of availability if we wish to maintain our relative position of leadership in scientific technology.

To date, the National Science Foundation and the Bureau of Reclamation of the Department of the Interior have been virtually the sole supporting agencies for weather modification research. The National Science Foundation is due an expression of gratitude for pioneering this research. There are also cases of community-financed weather modification projects but, unfortunately, only limited evaluation of the results was financially possible. Even when research accompanied the seeding project, the exchange of information was difficult to achieve. A desirable outgrowth of expanded weather modification activities would be the creation of an abstracting service which makes available a periodic expression of all weather-modification publications and activities.

In most colleges and universities, atmospheric science beyond the study of basic meteorology is either not recognized or is only incidental to other curriculums. The establishment of a weather modification research and training center should be inherent in an expanded program of research. Such institutions could well provide for the training of personnel needed for expansion. Substantial support for research to universities, colleges, and private agencies should also be made available. The likely byproduct of such a financial effort will be the establishment of programs in atmospheric science at the graduate and undergraduate level. Two examples can be cited in this immediate area: The Department of Atmospheric Science at Colorado State University and the Institute of Atmospheric Sciences at the South Dakota School of Mines and Technology. Neither of these organizations was in existence prior to National Science Foundation funding for weather modification research at these institutions. The funds should be provided for research in the field, in the laboratory, and for theoretical studies—a three-pronged attack on the problem at hand.

Some provision should be made to minimize the prospects of damage suits, which are a constant threat to research groups and have no doubt had a somewhat impeding effect. It is not difficult to find those who are unfriendly to the efforts being made in weather modification and who will place the blame for severe weather damage on these efforts. Indeed, although it seems more likely that modification techniques decrease the chances for severe weather, it would be extremely difficult to prove otherwise. In the case of hail suppression, this is the very proof for which we have been striving for the past 10 years.

To assure maximum progress it is imperative that some agency of the Federal Government accept the responsibility for liability, and with this responsibility must go the authority to limit the program of weather modification to responsible and capable research individuals and institutions. The possibility of inadvertent modification by air pollution points up a need to clearly define the legitimate activities of any proposed research.

The bill before us today, S. 2875, provides very well for the needs that have been outlined. The author of this transcript, therefore, speaks favorably in behalf of this bill.

I would like permission to add a postscript. Listening to the testimony I have made a few notes that I think are pertinent. I would like to add at this time a postscript to my testimony. Because hail suppression is not a primary concern of Senate bill 2875, so much of it is being made in research being conducted at my institution. It appears, however, that there is at least one pertinent implication which points clearly to the need of the establishment of regional research centers. I am confident that the research at Chadron will result in a significant contribution. I know that a good measure of our success will be due to the guidance and the help we have received from Dr. Schleusener, Dr. Dennis, and their staff. We have also received valuable advice from Dr. Vincent Schafer. The point I am trying to make is that weather research centers with expert staff can, by working cooperatively with neighboring institutions, greatly increase the potential of those institutions. Thank you very much.

Senator McGovern. Thank you very much, Professor Smith. We appreciate your testimony and also the growing activity at Chadron State College in this field. I understand that through a grant from the National Science Foundation you are going to help the atmospheric sciences program at the School of Mines and the hail suppression project this year. I think it would be interesting to tell the committee how Chadron State College became involved in this whole area of weather modification work.

Mr. Smith. Yes, sir. This dates back to, I guess, 1959. The late Dr. Lyle B. Andrews initiated it. I believe his name was brought up favorably in reports in Washington, and Nebraskans are proud of his name, and Chadron College. At this time Dr. Andrews took part and directed research at Chadron; hail research, which continued for some 4 years.

I think he had some very fine ideas but in 1962 he passed away, leaving the staff at Chadron shorthanded and there was really no one to take up the reins. Since that time a number of the staff who were working with the project at that time have returned to school and have continued their interest in this area and through this last year have become interested, or even before that interested, and have been encouraged by Dr. Schleusener to again activate the program. Some now are in the process of initiating the project of hail research in western Nebraska.

Senator McGovern. Do you think there is a problem, Dr. Smith, of getting public acceptance, support, or a substantially increased program of weather modification research engineering?

Mr. Smith. I don't believe so. I think the majority of the people favor it. Perhaps my testimony indicates that there are a lot of people

who are not in favor of this. I know there are some, or I should say at the time when I was more active in the research there were. Perhaps this has changed. There were projects in progress in the Scottsbluff area and also in northeastern Colorado in which we had an active part in evaluating. At that time there was some unfriendliness, not as a whole but at least with some individuals. I don't believe, though, as a whole there should be any great disapproval.

Senator McGovern. Senator Moss, do you have any questions?

Senator Moss. I appreciate your testimony, Professor Smith. Do I understand that you feel that we now already know how to increase precipitation somewhere, 10 to 20 percent, possibly, and that we ought to be doing that where we can do it, as we have other areas where we can be carrying on this research about which we were having the discussion with the immediate preceding witness?

Mr. Smith. I think probably I should yield to Mr. Grant on that particular point. He is much better acquainted with recent results of weather modification than I am.

Senator Moss. In other words, now, you are not sure that we could do both at the same time. Perhaps we had better concentrate on the research feature.

Mr. Smith. Yes. I think perhaps this points up a need. As I came to Rapid City today I was of the opinion this was pretty cut and dried, 10 to 20 percent without any doubt, until I heard Mr. Grant's testimony. I believe this is one of the reasons we need such a research center at Rapid City so that we can advise and counsel with people. And I must say that Dr. Schleusener's help has been invaluable in our project.

Senator Moss. Thank you.

Senator McGovern. Thank you very much, Professor Smith. The weather does a good many things for us. It has also kept Senator Burdick with us. He will be with us for at least a while. I am sorry about the personal problem of his flight. If there are no other questions, we thank you.

Our next witness is Mr. Louis Bober, president of the Bober Seed Co. of Rapid City. He is the chairman of the Upper Great Plains Soil and Water Conservation Research Advisory Committee, and he has long been interested in the overall problem of soil and water conservation. We are happy to present him. Mr. Bober told me he did not have a written statement. He will be speaking extemporaneously.

STATEMENT OF LOUIS BOBER, CHAIRMAN, ADVISORY COMMITTEE, NEWELL FIELD STATION

Mr. Bober. Thank you, Mr. Chairman, members of the committee. First of all, I am honored to appear as a witness with many distinguished scientists in the room. I had presumed that by the time you got around to me anything I had to say might be superfluous and that is why I did not prepare a written statement. I do want to correct my title, at least. I am chairman of the advisory committee to the Newell Field Station which is concerned with, among other things, soil and water conservation and watershed research, and I am a member of the Public Advisory Committee of Soil and Water Conservation to the Secretary of Agriculture. In those two positions,

and having been in the seed business most of my life, I have been intimately connected with farmers and ranchers and their problems among which is the lack of moisture at the proper time, a point that has been mentioned on previous occasions during this session.

We, in this area, and in a large area throughout North Dakota, Montana, and Wyoming, are right on the border of whether we have a crop failure or a bumper crop, depending on whether we get sufficient precipitation at the proper time. As has been pointed out, we are in roughly the 12- to 14-inch rain belt. The difference between 8 inches in one year and 14 inches in another year makes a difference between prosperity and complete failure on the part of some ranchers and farmers. The advisory committee—I think I can speak freely for the Newell Field Station, for the advisory committee, which is extremely interested in research and weather modification. We are extremely interested in having the regional center as proposed in Senate bill 2875 located in Rapid City at the School of Mines. Our primary and basic reason for our position is that our watershed research is intimately connected with the work that the Institute of Atmospheric Science is doing here. And it is our belief that the work that they are doing is not necessarily meaningless but could be augmented and supplementary to the work that we are doing. My point is that, although weather modification could conceivably—and does, in my opinion—increase precipitation, that unless we know what the results of that precipitation are in terms of growth and economics, then the work is simply the work that Dr. Schleusener's group is doing, and Dr. Grant's and others. It is purely research without the practicality of knowing what the results will be. We have measuring stations at Newell, at Gillette, at Antelope, at Cottonwood, certain areas in Montana and 15 cooperating rancher watersheds where we do have measuring devices. We believe that the network of measuring devices that we have at the present time, showing the runoff under certain conditions, the absorption under certain conditions, the destruction under certain conditions, would be valuable complementary information for the Institute of Atmospheric Sciences.

I would like to include in the record the proposal which the entire committee has made to the Senate and to the House and which I will hand to you later.

Senator McGovern. We will see that that is printed as part of the record.

Mr. Bober. And I would like to read to you small portions from there which would substantiate the few brief remarks that I have made.

Much is being done to try to change the basic precipitation patterns. But it does not appear a means of significantly altering processes that produce soils. However, if we can gain knowledge of the existing situation, it then becomes possible to manipulate nature's two elements, water and soils.

In that connection I might state, since I'm quoting here, I see personally no objection to having the direction of research under the Department of the Interior with combined National Sciences Foundation since soil and water are natural resources and the Department of the Interior is concerned with natural resources. To continue:

A wealth of knowledge and understanding of the existing situation is prerequisite to the establishment of important methods that will assure best possible

use of soil and water research in the area, and herein lies the challenge of watershed research with which I am vitally concerned.

I am speaking of an area that covers 65 million acres in southeastern Montana, all of eastern Wyoming, the southwestern part of North Dakota, and the entire western part of South Dakota, and we dip down into Nebraska so far as the watershed research is concerned. There are, as has been pointed out, some several hundred million dollars of livestock and crops produced in each of these areas. I would disagree somewhat with a statement previously made by Mr. Brown, publisher of the journal, in which he said a 5-percent increase in precipitation might result in a 5-percent increase of gross product. A 5-percent increase in precipitation in any given year might result in a 100-percent or a 300-percent increase in the gross product. It might mean a difference in, as I said previously, failure and success.

Reading further from the proposal to establish a watershed research center here in Rapid City with substations:

Of special significance in establishing a center here at the School of Mines for a recently organized Institute of Atmospheric Sciences which is supported principally by U.S. Bureau of Reclamation contracts and National Science Foundation grants, conducting experiments on the possibility of increasing rain and suppressing hail and modifying weather. In accomplishing these goals, they must be accompanied by studies of effects that changes in the weather might have on productivity of the region, and the present proposal includes studies of these types.

Anything I might add at this point is somewhat repetitious to what has already been stated in scientific terminology, but I would say that there is someone out here called Mr. Fisher and I call him also a pioneer in weather modification. But I happen to have been president of the Western South Dakota Rain Increase Corp., we called it at that time in 1951, so I preceded Mr. Fisher by some 10 years, if my notes are correct. At that time our primary function as an organization was to increase precipitation. It was our hope—and we so stated to the public, and among the public are several ranchers in the audience here who at that time contributed of their own funds—to contract with a private organization to run studies out here principally for research. We hoped it would lead to research, the type of research you are talking about now in Senate bill 2875. At that time we were called Communists and we have since become somewhat more respectable. I will agree with Dr. Grant, it may well have been one of the members of that commercial firm that we contracted with, that there are complexities. I see no reason, personally, why we could not continue reasonably large-scale projects and at the same time do basic research of the type Dr. Schleusener has been doing. That concludes my statement on the Senate bill.

Senator McGovern. Thank you very much, Mr. Bober. As one who has been working in this field now for over 15 years, you recognize some of the complexities and problems involved. You feel, nevertheless, that major expansion of the programs as outlined in the Senate bill is desirable.

Mr. Bober. I very definitely do and I speak for a group that does.

Senator McGovern. You serve on the Secretary of Agriculture's Advisory Committee on Soil and Water Conservation. As you know, this legislation calls for agencies other than the Department of Interior to cooperate with the Department of the Interior in an expanded

program. Do you see the Department of Agriculture willing and able to work in a cooperative relationship as outlined in the bill?

Mr. BOBER. The bill as it is outlined has been brought to the attention of the Public Advisory Committee to the Secretary of Agriculture. There has been testimony on it by both the Department of Interior, Agriculture Research Service, and the Department of Commerce. The research by the Committee which is made up of 15 members as representatives of all geographic areas and discipline of the United States, is a good one. I see no reason why the Department of Agriculture would not be wholeheartedly in support of it. But I am speaking of what has been going on in 3 years. The testimony referred to 3 years on this subject. And I can't speak for the incoming Committee. But it is my opinion that they would be of the same mind today as they have been for 3 years.

Senator MCGOVERN. I would like to say that the Committee that Mr. Bober has been one of the most enthusiastic advocates, not only of weather modification but of various steps that can be taken to build up the economy of the Great Plains area, so we are very happy to have his statement as a part of the record.

Senator Burdick, did you wish to ask a question?

Senator BURDICK. I don't have anything. Thank you, sir.

Senator MCGOVERN. Senator Moss?

Senator Moss. I like your testimony, Mr. Bober, and the Secretary of Agriculture sent us a report on the bill after he examined it and he said, among other things: "We believe, however, that the legislation posed by S. 2875 is not needed or appropriate at this time to accomplish that purpose," talking about experimentation. You would take issue with that, then?

Mr. BOBER. I would. I do.

Senator Moss. Very good. I just wanted to have that in the record.

Mr. BOBER. There are great advantages of having an Advisory Committee to the Secretary of Agriculture.

Senator MCGOVERN. Thank you very much, Mr. Bober.

Mr. BOBER. Thank you very much for the opportunity of appearing here.

Senator MCGOVERN. As I previously stated, your proposal will be printed at this point.

(The proposal referred to follows:)

PROPOSAL TO ESTABLISH A WATERSHED RESEARCH CENTER FOR THE NORTHERN GREAT PLAINS

About this proposal:

Described and presented in this report is a watershed research program for western South Dakota and parts of adjacent States to solve vital and critically important water, soil, and related resource problems of a 65-million-acre region of which almost 80 percent is rangeland dependent entirely on direct precipitation to support grass and provide water for municipal, industrial, livestock and other uses.

The research proposal costing $500,000 annually would provide basic information on how the limited water and other resources of watersheds of the region might be more effectively and efficiently converted to grass and forage for livestock use.

This program would supplement, would not duplicate, and would be cooperative with other regional resource research projects underway on weather modification; management of forested lands; and livestock management, feeding, and grazing.

This report is an updating of a proposal for a Northern Great Plains watershed research program developed by the Newell Station Advisory Council in 1962. It represents a coordinated plan which was prepared and received preliminary endorsement by responsible representatives of the following groups at Rapid City, South Dakota, in December 1965:

Newell Station Advisory Council
Rapid City Chamber of Commerce
Black Hills Conservancy Sub-District
South Dakota Association of Soil and Water Conservation Districts
South Dakota State Soil and Water Conservation Committee
South Dakota State University College of Agriculture and Biological Sciences
Institute of Atmospheric Sciences, South Dakota School of Mines & Technology
Newell Valley Irrigator (Weekly Newspaper)
Rapid City Journal (Daily Newspaper)

ABSTRACT OF PROPOSED WATERSHED RESEARCH CENTER FOR THE NORTHERN GREAT PLAINS

The following proposal asks that the Agricultural Research Service immediately establish a watershed research center for the Northern Great Plains. The center would collect and analyze data on the relationship of precipitation, runoff, land use, streamflow, sedimentation, stream channel stabilization, reservoir losses, water quality and other related water factors. The center would be located at or in close association with the South Dakota School of Mines and Technology in Rapid City, South Dakota with four field stations in the effected area.

The proposal sets forth the need for such a center for the Northern Great Plains, which includes some 65,000,000 acres in South Dakota, Wyoming, Montana, North Dakota and Nebraska. Cited as evidence of need are Senate Document 59, 86th Congress, 1st Session; Soil Conservation Service Reports, and National Association of Soil and Water Conservation Districts resolutions. The proposal is supported by a large number of interested and related groups including the Newell Station Advisory Council; South Dakota Association of Soil and Water Conservation Districts; South Dakota State Soil and Water Conservation Committee; South Dakota State University College of Agriculture and Biological Sciences; Institute at Atmospheric Sciences, South Dakota School of Mines and Technology; Black Hills Conservancy Sub-District and others.

The Research Center would be established at or in close association with the South Dakota School of Mines and Technology in Rapid City, South Dakota with field stations at Newell, Brookings and Cottonwood, South Dakota, and Gillette, Wyoming. The center so located would provide facilities for data analysis and exchange of information with the Forest Service Research station, Institute of Atmospheric Sciences, and School of Mines staff. The field stations, already established, would provide data and research conditions not available in any other manner.

The fiscal requirements include a first year non-recurring investment of $500,000 for expansion of facilities and purchase of necessary instrumentation. The annual recurring cost would be $500,000 for salaries, equipment, supplies, travel and other operational needs. A total of 25 personnel would be employed.

The proposed Watershed Research Center will fill the serious gaps between existing programs seeking to harness all phases of the hydrologic cycle. The result would be that the vast area of the Northern Great Plains would be made a more valuable segment of our national economy.

I. Background information

A. The water problems of the Northern Great Plains

We all recognize that water, delivered to us by the precipitation phase of the oft-referenced hydrologic cycle, and soil, evolved through geologic time and associated climatic activity, are two of nature's primary sustaining elements. We also recognize that the distribution of precipitation and the quality of the soils vary radically from one physiographic or geographic region to another. As a result, in some regions there are excesses of water and deficiencies in soils whereas in others the reverse is true. In many areas a delicate balance between the two elements, water and soil, exists. Such is the situation in a large segment of the Northern Great Plains.

Much is being done to try to change the basic precipitation patterns, but there does not appear a means of significantly altering the processes that produce soils. However, if we can gain sufficient knowledge on the existing situation it then becomes possible to manipulate nature's two elements, water and soil, to assure their maximum usefulness within our ability to understand and direct the processes toward this maximum usefulness. Development of knowledge and understanding of the existing situation is prerequisite to the establishment of means and methods that will assure best use, now and in the future, of the soil and water resources of an area, and herein lies the challenge in watershed research.

Except for general concepts and fundamental studies of processes, the information acquired from research investigations in one physiographic region cannot logically be applied or used to explain happenings or solve problems in another physiographic region. For instance, the 50-inch precipitation, with 30 percent surface runoff conditions of the humid coastal plains areas of the Southeast have little meaning in relation to the 14-inch precipitation with less than 5 percent surface runoff in the semi-arid tributary drainages of the Northern Great Plains.

In this area a delicate balance exists between water received from precipitation and requirements for sustained agriculture. Too often the balance tips toward the insufficient side, and extreme fluctuations occur from year to year and season to season.

There are few places in the United States where the water balance, in terms of sustaining agriculture, is more critical than in this region.

B. Watershed concept of planning is basic

Wherever we live, we are in a watershed whether it be our own yard or an area drained by a small creek or a large river. Scientists and Engineers have long recognized the value to taking a whole drainage into consideration when planning a development anywhere within it.

The increasing use of soil and water conservation measures for watershed protection and flood prevention, such as provided for in Public Laws 566 and 46 is resulting in more and more emphasis on the "watershed" approach to problem solving. Senate Document 97, 87 Congress, 2nd session, which was prepared under the direction of the President's Water Resources Council states that drainage areas are to be used as the basic unit for planning. Therefore, whether we are planning for one particular small watershed or an entire river basin composed of many smaller watersheds, it is necessary that we have full information on the characteristics of watersheds.

C. Description of project area

The portion of the Northern Great Plains encompassing western South Dakota, northeastern Wyoming, southeastern Montana, and southwestern North Dakota (see map), includes about 65,000,000 acres of which almost 80 percent is rangeland dependent entirely on direct precipitation to support grass and provide stock water. Over 13,000,000 acres or 20 percent of the agricultural lands are cultivated and depend upon direct precipitation or irrigation water for production. The percentage of total land area in agricultural use is among the highest in the United States.

A great deal is known about the quantities of water contributed to the Missouri River by its various major tributaries, many of which originate in this rangeland area. Something is known about the quantities of water delivered to the tributaries by the minor tributaries. But very little is known about the hydrologic performance of the minor tributaries. In general terms, the average long-term annual precipitation in the Northern Great Plains, west of the Missouri River, is about 14 inches and the stream flow stations show that less than one inch of annual runoff occurs—perhaps averaging ½ inch or 3½ percent of the precipitation. Yet studies of small upland watersheds in the vicinity of Newell, South Dakota, indicate that the surface runoff ranges from less than 1/10 of an inch to over 3 inches, depending upon precipitation amount and intensity, soil, vegetation and topography, or from less than one percent to over 18 percent of the precipitation.

D. Need for Program Recognized

Senate Document 59, 86th Congress, 1st Session, titled "Facility Needs—Soil and Water Conservation Research," contains a nationwide assessment of watershed research. It recognizes the need for national type research investigations

on fundamental processes and broad generalized type studies and it also recognizes the need for national type research investigations on fundamental processes and broad generalized type studies and it also recognizes the concomitant need for regional investigations that would provide the knowledge and understanding needed to meet the soil and water problems peculiar to a particular physiographic area. As a result, the Document includes recommendations for national laboratories, and regional facilities. On page 171 it is stated that major experimental watershed centers are needed in all 15 major land resources regions. However, recommendation is made for only 4 to 6 of these centers as of that time (1959). During the past 5 years, four of these watershed centers have been fully or paritally funded. These centers are: (1) Reynolds Creek near Boise, Idaho; (2) Walnut Gulch near Tucson, Arizona; (3) Washita River near Chickasha, Oklahoma; and (4) Columbia, Missouri. In addition, watershed centers for the Southeastern and Northeastern sections of the United States received initial partial funding this year. It is evident that one of the most vital agricultural regions in the United States, where water balance is the key to the economy, was neglected in the initiating recommendations of Senate Document 59.

The Senate Document did recognize the watershed research needs of the Northern Great Plains as is evident from the following passages:

"The primary factor influencing the agriculture of the Northern Plains is the irregular and generally deficient rainfall." (page 70)

"Lack of precipitation in this region is perhaps the dominating characteristic and results in a general condition of inadequate moisture for maximum plant growth in most years." (page 70)

"On rangelands, conservation and efficient use of moisture is a major problem." (page 70)

"Research needs of greatest urgency in Watershed Research: precipitation-runoff relationships and moisture conservation." (page 74)

The urgent watershed type research needs have been stated often by the Soil Conservation Service in their reports of Soil and Water Conservation Research Needs which are submitted to th Agricultural Research Service.

The January 1963 report relative to the Soil and Water Conservation Needs of the Northern Plains Region pinpoints these watershed research needs.

Further emphasis of the needs is contained in "Soil and Water Conservation Research Needs," a Report from the Soil Conservation Service to the Agricultural Research Service, 1963 (A National Summary). From the above-mentioned reports and the knowledge and experience that have been gained by exploratory, but limited, studies at Newell, South Dakota, and elsewhere in the Northern Plains region, it seems clear that watershed research needs must receive some greatly expanded attention if a minimum response is to be accomplished.

Dr. C. H. Wadleigh, Agriculture Research Service, Beltsville, Maryland, in comments to a group of interested people in Rapid City said recently "the level of Great Plains productivity is going to play a vital role as the world faces monstrous starvation in 20 years." He stated further that there is much necessary work to be done on campuses but much work can be done only at relatively small and remote, but adequately supported field stations.

II Proposal

A. Watershed Problems Needing Study

Based on the above-mentioned reports and the observations and experience of farmers and ranchers of the region, it is proposed that an experimental watershed research program for the Northern Great Plains be immediately established to conduct research on:

1. *Precipitation—runoff relationships and the hydrologic balance.*—This must include a full water-accounting procedure with quantitative determination on a storm, seasonal, and annual basis of precipitation, surface water runoff, soil moisture, evaporatranspiration, contribution to groundwater, channel transmission losses, and interflow.

2. *Snowfall*—Snowfall with emphasis on new methods and techniques for measurement and water content determination, determination of the significance and proportion of total precipitation, entrance of snow moisture into the soil and soil holding capacity under frozen soil and freezing and thawing condition, and effect of artificial means of increasing snow deposits in selected agricultural areas.

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3. *Land use, vegetation, soil chemical and physical characteristics, and topography influences on watershed hydrologic performance.*—Surface soil moisture and vegetative root activity should receive special attention.

4. *Sediment yield and delivery from land areas in upland watersheds to downstreams or interbasin locations.*—These investigations must clearly establish the sediment yields for different soil type and vegetative cover and must provide information needed to determine stock pond and reservoir capacity loss to sediment deposition.

5. *Groundwater reserves, accretions, and deletions is important in water accounting and agricultural uses.*—This would involve a concentrated study of the underlying water mantle and its reaction to precipitation, channel transmission losses, and interflow.

6. *Flooding with some new approaches related specifically to the Northern Great Plains area.*—Included would be studies of flood routing under ice flow or ice cover conditions which would influence flow retardance, valley storage, and flood peaking. Of particular interest is the significance of the ice-gorging on small stream floods and the influence of reservoir and pond backwater on upstream flooding. This is of primary interest in PL. 566 type installations.

7. *Water spreading in swales and flood plain or valley areas.*—It has been demonstrated in a few locations that spreading of snowmelt and torm runoff in flat areas or valley lands can significantly increase hay production. In spreading water the sediment carried is also deposited. The studies here should include determination of the physical effects of spreading, probably influence on salinity balance and water table, and mechanical means and methods for the most efficient control of the water and accompanying sediments.

8. *Stream channel stability and stabilization with particular emphasis on the effects of freezing and thawing and ice action.*—Although channel stability studies are underway at several locations in the United States, none of these fully consider the colder climate conditions. Freezing and thawing may well be the primary factor in channel forming and bank scour in the Northern Great Plains major and minor tributaries, but there is little supporting research information.

9. *Evaporation and seepage in stock watering ponds and small reservoirs.*—Studies have shown that vast amounts of water are lost from stock watering storages by seepage and evaporation and in many cases the ponds or reservoirs fail to serve their purpose because of these losses. Research investigations must include studies of surface water sources in relation to pond location and ways to store runoff for minimum loss and long-time use. Water harvesting possibilities should be evaluated in connection with these investigations with consideration given to utilizing the poorer lands as a "roof" to shed water.

10. *Water quality and recreation aspects in soil and water source development.*—One can no longer ignore the importance of water quality and recreation in water shed research. Any investigation must be designed to give factual data on water quality and environmental factors associated with land and water quality. Similarly, the recreation factors associated with land and water alterations must receive consideration. These aspects of watershed research will require some new and original thinking since water quality and recreation have in many instances received minor attention in the past but are likely to be major items in the future.

B. Scientists and Facilities Required

To solve the research needs outlined above will require the following technicians, laboratories, instrumentations and field installations:

1. *Rapid City, South Dakota.*—(*a*) Establish a center for data analysis at or in close association with the South Dakota School of Mines where access to the computers and contact with Forest Service Research and School of Mines staff would enhance the analytical studies and permit exchange of scientific knowledge and development.

Of special significance in establishing the center at School of Mines is the recently organized Institute of Atmospheric Sciences which is supported principally by U.S. Bureau of Reclamation contracts and National Science Foundation grants, to conduct research on possibilities of increasing rain and suppressing hail. But modifying weather to accomplish these goals must be accompanied by studies of the effects that changes in weather might have on watersheds of the region. The present proposal includes studies of these types.

This location would serve as the central office and analytical center with data being funneled in from the various field studies.

(1) Facility requirements: office space, ownership, rental, or access to computer equipment or services, calculators, office equipment, vehicles.

(2) Personnel requirements: one Hydraulic Engineer (Supervisor), one Agricultural Engineer, one Geologist, one Statistician, two Statistical Clerks, two gradute students, and one Stenographer.

2. *Newell, South Dakota, Irrigated and Dryland Field Station.*—A. Personnel additions: one Range Specialist, one Soil Physicist, one Engineering Technician, one Agricultural Research Technician, and two Engineering Aids.

B. Continuance of the present field investigational program on water yield and sediment yield. Fully instrument selected watersheds, such as the one at Newell Lake, for detailed study or accounting of the precipitation-runoff-sediment yield relationships from source areas to complex areas. This would include studies of manipulation of vegetative cover, such as by reseeding or testing and establishing new or improved species.

C. Improve the existing laboratory space, including instrumentation and shop facilities so that Newell can serve as a central location for instrument and equipment repair and fabrication, and perform essential analytical work on soil, sediment, water, and plant samples.

D. Strengthen the current investigations on pond and reservoir seepage and evaporation studies and maintain the existing weather station.

3. *Brookings, South Dakota.*—Laboratory type studies in existing facilities at South Dakota University in support of the field program would be performed. These would include model studies, stream hydraulic experiments, special instrument and measuring device development, and scientific assistance on specific problems. Coordination with the graduate program would be an important aspect of this phase of the overall watershed research plan.

One Hydraulic Engineer, one Stenographer, and three Graduate Student Assistants would be required at Brookings to carry out this phase of the program.

4. *Cottonwood, South Dakota.*—A. The study initiated in 1962 on the South Dakota Agricultural Experiment Station's Cottonwood Field Station and concerned with the effects of grazing intensity on water yield should be continued and expanded. Precipitation and surface runoff are measured on twelve 2-acre watersheds representing light, medium, and heavy grazing intensities.

(1) Facility requirements: primarily additional instrumentation and measuring devices for collection of data on complex grazing areas within the Cottonwood Experiment Station.

(2) Personnel requirements: One Engineering Technician and one Engineering Aid.

5. *Gillette, Wyoming.*—A. No watershed research investigations are underway in the northern rolling High Plains area. Selection of one or two watersheds for detailed hydrologic study and determination of the influences on observed water yield would fill a gap and greatly enhance the coverage in the northern Great Plains region. In the vicinity of Gillette, Wyoming, there are minor or headwater tributary drainages to several of the major Missouri River tributaries.

(1) Facility requirements: office space, field instrumentation and measuring devices including rain gages, weirs, stage recorders, and related hydrologic, soils, and vegetation measuring equipment. Also vehicles.

(2) Personnel requirements: One Engineering Research Technician and two Engineering Aids.

C. Fiscal Requirements

A first year nonrecurring fund of $500,000 would be required for expansion of facilities and purchase of necessary instrumentation and equipment in support of the proposed program at Newell, Brookings, Rapid City, and Cottonwood, South Dakota, and near Gillette, Wyoming.

The annual recurring cost of the program would be $500,000 which would be used for salaries of personnel, purchase of equipment, supplies and materials, travel, and other necessary operational needs. Total projected personnel would include 6 professional, 1 statistician, 3 engineering technicians, 1 agricultural research technician, 5 engineering aids, 2 statistical clerks, 2 stenographers, and 5 graduate students.

III. Supportive arguments

In keeping with basic requirements for water and soil research and doing so in the most efficient and progressive manner, a Watershed Research Program for the Northern Great Plains is proposed for the following reasons:

1. The National interest would be served through an attack on problems confronting the entire United States Population including pollution abatement, agricultural efficiency and recreation. All indications of the future point toward increasing problems in these areas and the Northern Great Plains will contribute greatly to either the alleviation of these problems or their compounding.

2. Results of such a program would tend to reach a stated national objective of maintaining the family farm which would tend to further proper economic balance. In this 65,000,000 acre area, the difference between profit and loss, staying or leaving is often in delicate balance and the proposed program would bring a substantial contribution in knowledge this important segment of our economy.

3. Benefits of this program would extend to the entire nation through information contributed toward the control of sedimentation, seepage, and evaporation of all water storage, including municipal water supplies, industrial and livestock water and large multipurpose impoundments such as the Missouri River Dams.

4. Watershed Research Program would substantially increase the effectiveness of existing water conservation and development programs. This would include Institute of Atmospheric Research, Missouri River Basin Study, the new Seven Year pollution study of the region, the Water Resources Research Centers, Soil and Water Conservation Districts, the Projects under the Small Watersheds Act (PL 566) which are of vital interests to all of the states concerned. Other programs to which this would be a necessity include the Black Hills Conservancy Sub-District which has initiated efforts to secure a "Resource Conservation and Development Project" in the Black Hills area.

5. Discussion between the technical staff of the Agricultural Research Service, Forest Service, School of Mines, and Institute of Atmospheric Sciences indicate that location of the headquarters of the research center on the campus of the school of Mines at Rapid City would be advantageous for exchange of technical information on related problems. Common problems of data acquisition and reduction could be handled by computer facilities being developed at the School. Preliminary discussion with School officials indicates a desire to further such interchange of information and facilities by locating the research group on the Campus.

6. The rapidly growing Institute of Atmospheric Sciences doing research in the heart of the Northern Great Plains would be greatly benefited. The proposed program would allow a very close working relationship, a co-ordination of effort and an extension of effectiveness of the Atmospheric Research program.

In summary, the proposed Watershed Research program would fill a much needed gap between the existing programs that seek to harness all phases of the hydrologic cycle in the Northern Great Plains for the benefit of all the people of our Nation.

Resolution approved by the Council of National Association of Soil and Water Conservation Districts, 19th Annual Convention, Portland, Oreg, Feb. 7-11, 1965:

GREAT PLAINS RESEARCH

The NACD Northern Plains Research Committee, consisting of the chairman of the Research Committee in each of the six Northern Plains Area states, was established to evaluate the nature and seriousness of conservation problems and need for research over the six state area.

The following recommendations were submitted by the Research Committee and adopted at the Northern Plains Area meeting in 1964:

Item 1, Whereas, with reference to the program outline in the priority rating proposed projects in Senate Document 59, 86th Congress, 1st Session, there is an obvious void with respect to hydrology research within watershed development as applied to the *Missouri River Basin Area*, it is therefore recommended that corrective effort be made to expand the scope of Senate Document 59 with

the establishment of an Experimental Watershed within the Northern Section of the Central Great Plains for the following purposes:

1. To study the relationship between precipitation and water yield and floods, particularly under the frozen soil conditions that frequently exist in the Northern Plains Area.
2. Study the effect of kind and type of conservation practices; cropping systems, and cultivation practices on water intake into soils; water yields; and sediment production.
3. Study soil, land slope, and other factors affecting sediment production, and ways of reducing and controlling sediment production and stream channel instability on agricultural watersheds with the Missouri River Basin.
4. Evaluate factors involved in the recharge of water into underground basins within the area.

FIELD STATIONS

On December 31, 1964, it was directed that all research at 20 small field stations be closed down, and that designated lines of research be terminated at 34 other locations throughout the nation. A large number of these projects are located in rural areas and serve significant land resource regions; are directed toward such problems as watershed and range management, irrigation and drainage, and the preservation and wise use of the land resources of their respective regions.

The NACD believes that such field stations and projects are essential to the total resource research effort of this nation and urge the Secretary of Agriculture to reconsider these decisions to close out these stations and projects.

Senator McGovern. Our next witness is Mr. Art Svendby, who is the director of the National Reclamation Association at Lemmon, S. Dak., and he, too, has been working in this field for a good many years so we are happy to have his statement for the record.

STATEMENT OF ARTHUR SVENDBY, DIRECTOR, NATIONAL RECLAMATION ASSOCIATION, LEMMON, S. DAK.

Mr. Svendby. Hon. chairman and members of the committee, I want to beg your pardon for having caught a cold this morning. I hope you can hear all right. My name is Arthur Svendby. I am manager of the Lemmon Chamber of Commerce and a resident of that city. I, too, am the South Dakota director of the National Reclamation Association. I here represent that organization on a local as well as the national basis.

The purposes of the National Reclamation Association can best be expressed by this brief abstract of its constitution, section 3:

> The purposes of the Association shall be to promote the development, control, conservation, preservation and utilization of the water resources of the Reclamation States, to work for the continuation of the services and coordination of the activities of the presently existing Federal agencies dealing with these water resources—and to promote the adoption of legislation in furtherance of, and to oppose legislation detrimental to these purposes.

It is in the furtherance of the aforementioned that I appear in behalf of the National Reclamation Association and for our South Dakota Reclamation & Water Development Association in support of the general proposals of S. 2875.

The National Reclamation Association has had no fixed resolution as to a policy directed toward so-called weather modification or specifically S. 2875, but the association has been highly interested in this phase of the possibility of obtaining additional or supplemental water through the scientific research results of the atmospheric water resources program.

During the annual National Reclamation Association convention in October of 1963 at Sun Valley, Idaho, the membership listened with interest to Mr. Walter Garstka, of the Bureau of Reclamation, as he detailed problems and potentials of weather modification.

Many noted scientists, the world over, are predicting a doubling of our population by the year 2000 with starvation diets being the normal mode of life. This diet due to the lack of food, in turn due to lack of highly productive land which is being withdrawn from cultivation by expanding cities, airports, highways, and other public and private facilities. This leaves the less productive and more arid lands of our Nation to carry the burden of agricultural production on a necessarily increased yield scale. Additional water for increased irrigation, or other means must be found to place water on these more arid lands—that is, weather modification, increasing precipitation; to secure the necessary food production.

The National Reclamation Association is working toward the goal of utilizing all available water for beneficial use whether it be for domestic or irrigation utilization. This is depicted on pages 4(b) and 4(c) of the March issue of the National Reclamation News. Here is illustrated the whole gamut of the activities of water resource uses as we in the West understand them. From the precipitation of rain and snow in the mountains to the sewage drains into the ocean; conservation use of the soil-water combination. All of these for the most beneficial use to mankind.

All the so-called low-cost water reservoir structures have been built. Only higher cost multipurpose dams and reservoirs remain to be developed for the benefit of the Nation in its attempt to conserve for ultimate use that pure water we need for continued existence. Now new means and places must be investigated for the purpose and hope of obtaining additional water.

The people of South Dakota, with varied rainfall from adequate to arid, are pleased to acknowledge the fact that their congressional Representative, the late Francis Case, originated and sponsored, and worked with another former South Dakotan, Senator Clinton Anderson of New Merico, those programs that are bringing and might bring us more notable water through the desalination program and the weather modification program, which our present South Dakota congressional delegation is working for assiduously.

Eastern South Dakota is more blessed than most areas of the world with their Great Lakes of the Missouri River which can irrigate up to 3 percent of our farmlands. Yet thus leaving millions of farm acres dependent on capricious nature and her annual more or less precipitation. This same situation exists to a lesser or greater degree in all the States of the reclamation West from Canada to the Rio Grande and the Missouri to the Pacific. Although the percentage of land irrigated is small in comparison to all the cultivated lands in the United States they are highly important because of the high yields and on which a great diversity of crops can be grown.

The question may be asked: "Of what value is the small increase in precipitation possible through weather modification?"

The answer is that a small additional precipitation at the right time, can, and noted by a Minneapolis newspaper several years ago: "An inch of rain can make 'a whale of a difference' in crop yields."

In our neighboring county of Adams in North Dakota, as reported by the Crop & Livestock Reporting Service, the following records appear:

Average wheat yield, 1951–60	bushels	11.50
Average precipitation, 1931–60 (June)	inches	3.40
Dominant months of wheat growth, July	do	2.01
Year 1962 wheat farmers reported excellent yields—county average	bushels	24.10
Below average of rainfall (June)	inches	1.84
Above average July precipitation	do	3.97
Above average wheat yield	bushels	12.60
Twice normal yield made additional at right time	inches	1.96
June-July average total	do	5.41
1962 June-July average total	do	5.71
Difference—plus	do	.30

Thus, thirty hundredths of an inch of rainfall above the normal average precipitation for the two dominant wheat growing months of June and July doubled the yield.

The National Reclamation Association has listened to the advocates of every type of program to increase our water supply in the West looking to ease the burden of the lack of water behind the great dams to fulfill every year's appropriation to each irrigator.

Storage in the larger reservoirs with their usable capacity of over 100 million acre-feet are seldom filled with more than 55 million acre-feet of usable storage (1) the reservoir storage on the smaller dams seldom reaches 75 percent with an average of from the year 1943 to 1957 of only about 50 percent (2) this, then leaves space for many millions of acre-feet of usable water—practically one-half of the capacity of our presently built reservoirs.

How are these reservoirs to be filled to their usable capacity? By NAWAPA (North American Water and Power Alliance); by desalination of the oceans' waters; by towing icebergs from the Arctic? Hardly in the foreseeable future.

It then appears that an adequate scientific study of the atmospheric water resources, as proposed in S. 2875, for the purpose of finding out whether or not precipitation can be increased by any substantial amount is of the utmost present exigency, and a hope for our dire need for water in the future.

An increase in the mountain snow pack of 10 to 20 percent (as indicated in your background report of S. 2875, p. 4) during the winters would tend to eventually help fill the usable capacity of reservoirs.

Although S. 2875 relates generally to atmospheric water resource development, it is our thought and belief that it should be extended beyond this to other associated weather modification phases—i.e., hail suppression and storm suppression.

South Dakotans and we in these Plains States are most pleased to note that this year an additional grant has been made to the Division of Atmospheric Sciences, School of Mines and Technology, in Rapid City, for the study of hail suppression.

At Lemmon, S. Dak., a city of 2,500 population, a 20-minute hailstorm in 1958 caused an estimated damage far in excess of a million dollars. Here in Rapid City storms have been more frequent and as severe, in fact so severe and frequent that insurance underwriters are

reluctant to insure against these storms and increased their rates. In a rating service dated June 1965, they note:

> Add $16.00 per dwelling item to premiums for dwellings located West of Missouri River ($32.00 for Rapid City and surrounding townships). $50.00 Windstorm and Hail deductable is mandatory on all classes (dwellings and mercantile) West of River ($100.00 for Rapid City and surrounding townships).

Hailstorms are hazards of the agricultural economy of these reclamation States, too, in both irrigated and so-called dryland farms that cause millions of dollars crop loss every year.

It is hoped that this type of study will be continued under S. 2875 and that solutions may be had to these devastating storms.

Five weeks ago on March 2, 1966, a storm called a blizzard struck this Northwest area of the United States and swept across the northern half of the Nation with snow and high winds. Many people lost their lives. Up to 100,000 head of livestock valued in the millions of dollars were lost. Transportation was stopped for days. Millions of dollars were spent by private, county, State, and Federal agencies in attempting to correct the action and effects of the storm. Flood resulting from it are today driving people from their homes.

These storms of the north and the hurricanes of the ocean border States are a part of the atmosphere. It is hoped that in this bill, S. 2875, in its comprehensive program it can also seek a solution and be able to truly modify weather.

The Bureau of Reclamation of the Department of the Interior, under whose jurisdiction this program will be administered, have presented to the world an outstanding accomplishment of conservation and utilization of our limited reclamation States water supply. A similar achievement in the field of atmospheric water resources, with the outstanding scientific staff they now have and will be able to attain, seems assured.

It is a privilege to appear before your committee today in support of S. 2875 in seeking scientific solutions to the beneficial utilization of the atmospheric water resources.

Senator McGovern. Thank you very much, Mr. Svendby, for a most interesting statement. I was impressed at the statistics you cited on the second page of your statement where you demonstrate that by an increase of just a half an inch of rainfall at a crucial time in Adams County would double the wheat yield above the average year. Just in broad terms, and I realize no one can answer this question in specific terms, what do you see as to the impact on the South Dakota economy if we could add 10 to 20 percent to the precipitation of our State in areas where it was needed at the proper time?

Mr. Svendby. It is my belief that it would change the economy from just barely making a living to a much more profitable, more livable life for the farmers and ranchers.

It would increase the income and improve the economy of our whole region as it would place us in a more of a semiarid region with a better chance for annual crops; it would lessen the need for larger ranches and farms and tend to increase instead of decreasing our farm population; it would tend to stabilize our farm-ranch economy on higher firm base of livable income; instead of a next-year country it would be an every-year crop country.

Senator McGovern. You referred to Senator Case's leadership in this field. I might say that he is the first person that ever talked to me about weather modification. As you very properly state, he has had a lot to do with some of the steps that were taken in recent years. As you know, this bill now before us calls for a very significant expansion in the investment of Federal resources in weather modification. Do you think the Secretary of the Interior should now be authorized to move ahead on a program as large as the one envisioned in S. 2875?

Mr. Svendby. I believe so. I heard the question previously asked whether or not there would be enough scientists to go ahead and be able to administer the program or take care of the program. I believe that you will find that there are the scientists in the United States sufficient to take care of this program and they would like to be in the program.

Senator McGovern. Thank you, Mr. Svendby. Senator Moss?

Senator Moss. Thank you, Mr. Chairman. I do appreciate your very fine statement before the subcommittee and to add to this information you presented on what a difference a half inch of precipitation makes in the wheat yield, I thought I might put into the record at this point something Senator Bible said before the Appropriations Committee when we were seeking some funds for weather modification in the Colorado River Basin as to the difference it makes there. He said, and he was quoting the Bureau of Reclamation:

> An additional one inch of precipitation in the Colorado River Basin above Grand Canyon Dam would produce a run-off of 575,000 acre-feet. This extra amount of flow through Federal power plants could boost income by established power rates $2.5 million. Naturally, this additional water could be available for agriculture, municipal and industrial uses as well. Allowing for losses in run-off, this added inch of precipitation would still provide 500,000 acre feet of water for irrigation which, based on the 1962 water crop benefit formula, would produce a gross crop income of $24.7 million. Municipal and industrial uses, of course, would increase the value of this extra precipitation even more.

I thought that that might be added to your statistics to show that a relatively small amount of water in precipitation, spread out over a great area can have just immense economic value. And that is one reason I found it very interesting for you to have those figures in there. Thank you.

Senator McGovern. Senator Burdick, do you have any questions?

Senator Burdick. No; except that Mr. Svendby and I have been in the water program together for many years. I certainly value his opinions and views.

Mr. Svendby. Thank you.

Senator McGovern. Thank you, Mr. Svendby, for your statement.

Our next witness is Marion Bruce who is the chairman of the South Dakota Weather Control Commission from McIntosh, S. Dak. Mr. Bruce, we'll be glad to have your statement at this time.

STATEMENT OF MARION BRUCE, CHAIRMAN, SOUTH DAKOTA WEATHER CONTROL COMMISSION

Mr. Bruce. Senators, ladies and gentlemen. My name is Marion Bruce, I am a farmer from McIntosh, S. Dak., and chairman of the South Dakota Weather Control Commission.

Before making my statement, I would like to comment that we have a fellow father here today. He is justified in being proud. President Partlo is the father of the Institute of Atmospheric Sciences. I have a statement that I wrote. I will read it. I cleared this with Senator McGovern. This is two farmers speaking about a speech that a Senator made. The first farmer said, "The Senator sure made us a whopping 2-hour speech, didn't he?" The second farmer: "Ya, but a half an hour's rain would have done us farmers more good."

Before I begin my statement I would like to add a few remarks about a Bowman County project. I am a neighbor of Bowman County. Carson County is about 40 miles downwind, and I have watched the hail suppression effort there in Bowman County for the last 5 years. I have also done some statistical study on this, and I believe that these men are doing 90-percent suppression. Thomas Henderson, of Fresno, Calif., who did some work for us in South Dakota last year and who has had a considerable amount of experience in hail suppression, made a statement that he thought that this one hail project has been the most successful of any that has been tried in the United States to date.

The South Dakota Weather Control Commission is very pleased to note the intent of Congress to increase funds for research in weather modification.

Our State lacks some 5 inches on the average of sufficient rainfall for maximum crop and grass production. We suffer from severe hail losses.

We are anxiously awaiting the day when enough is known and proven about weather modification to justify our State of South Dakota entering into a statewide program of weather modification to increase rain, decrease hail, and perhaps suppress tornado activity. It is logical that such a program would be handled for the State by the Institute of Atmospheric Sciences of the School of Mines.

The Bureau of Reclamation and the Institute of Atmospheric Sciences of the School of Mines have underway a good program of research. Dr. Schleusener has assembled a very competent staff to carry on the work. The line of research that has been started needs to be continued without hindrance or delay.

Therefore, our commission is most concerned, that if Senate bill 2875 is not passed, and the responsibility and direction for research is given to another department, Federal funds to continue the work here in South Dakota shall not be unduly delayed, or unwarranted change of plans imposed. We ask Senator McGovern and other friends of weather modification, in case Senate bill 2875 is not accepted, to make known the needs of South Dakota and the Bureau of Reclamation to continue the programs in which they are now engaged.

Our commission will continue to give preference and protection of territory for research seeding, as we have for the past 3 years. We have required and will continue to require all private groups to keep good data, so our State will know what is being seeded, how much and where.

Speaking personally, not having cleared this part of my statement with the commission, I see the need to expand field testing as rapidly as feasible, as I anticipate a rising demand from farm and county groups for full-time applied seeding. Pressure, if you will.

For the same reason, I advise any bill passed by Congress to be broad enough to permit some research outside our own borders, for example, Canada. It is reasonable to think any answers or information we might obtain in an area extending 100 miles north of the Canadian line would apply to an equal area south of the line. Attached are three exhibits relating to weather modification.

Senator McGovern. Mr. Bruce, if I could just break in here while we are waiting to get this set up, I think we can assure you that even if this legislation is not enacted this year, and we hope it will be, that I see no reason why that would result in a cutback in the Bureau of Reclamation program.

Mr. Bruce. The title of my first study, exhibit A, "The High Cost of Hail." (Exhibits projected onto screen.)

Losses from hail are very high for western Dakota land and adjacent areas. Not only crops suffer, but buildings, automobiles, and sometimes livestock and game. For example, for Rapid City alone in 1962–63, insurance adjusters estimated the damage to Rapid City was about $3 million. One year, I have been told, the damage to Air Force airplanes at the Ellsworth base was in the millions. Mobridge, Lemmon, and Isabel are towns that have taken high damage in recent years and forced a rise in insurance costs.

CORSON COUNTY, S. DAK.

Average cost to insure $100 of crop, 1964 rates, $11.40.
Rates vary from $10 to $15 by townships.
Problem:
Cost to insure a crop worth $10,000, full value.
Cost is $1,140 per year.
Cost for 9 years, $10,260.

In effect, this is equivalent to losing one crop in 9 years from complete drought.

BUTTE COUNTY, S. DAK.

Commercial rate averages, cost of hail insurance: 15.41 percent. In a little over 6 years, farmer would lose one crop.

BOWMAN COUNTY, N. DAK.

The 1964 commercial insurance rates were from $16 to $22 for $100 of insurance; first 10-percent loss deductible. Averge rate, $19.50. It would take 5 years to lose one crop plus taking 10 percent of any losses.

Losses for 15 years, 1949–63, by the North Dakota State Hail Insurance Department in Bowman County over premiums collected: $867,436.42. Slope County: $1,398,844.97.

We need hail suppression.

Exhibit B, Corson County weather modification project

Question: What effect would weather modification have on net farm income assuming 5-percent gain of gross production for South Dakota?

Assuming we find we can increase gross production of salable crops, livestock, and livestock products for the State of South Dakota by

rain increase, hail decrease, or better distribution of rain by 5 percent; further assuming, this cost could be done for 1 cent per acre for the 44 million acres of croplands. How would it affect net farm income? Cost of seeding estimated for about 30 airplanes under one control. About half of the $440,000 for cost of planes and pilots, the other half for supervision. Taking the 1963 South Dakota agriculture report by the Crop and Livestock Reporting Service, page 45, we find:

Years of 1960 and 1961

		Million
(*a*)	Average annual gross cash income from farm marketings	$626.80
	Average production expense	425.75
	Average annual net income	161.75
(*b*)	Add 5 percent to gross	$31,340,000
	Subtract cost	440,000
	Net gain	[1] 30,946,000

[1] $30,946,000 of $161,750,000 equal gain of 19 percent to net income.

NOTE.—Net income to gross income or $161,750,000 of $626,800,000 equals 25.69 percent.

Comment on costs: One airplane should be able to take care of over 1 million acres where supervision has control of an umber of planes and can move planes to needed areas. A statewide program should have at least four radar units. Perhaps two-thirds of the pilots could be obtained locally and would have other income in addition to the 50 to 70 hours flying time they would need to be available for.

Our seeding program for Corson County will cost us about one-half cent per acre. This does not include cost of radar, help from School of Mines, and technical assistance. Costs could run 2 cents per acre.

Exhibit C, Corson County weather modification project

Study of the effect of additional rainfall on yield of spring wheat:

A. All data taken from Bulletin 383, "Rotation and Tillage Investigations at the Dickinson Experiment Station, Dickinson, North Dakota." Forty-five years experimentation, 1907–52. Yields of wheat taken from Rotation 19, page 89, spring wheat on disked corn ground. Years of rust, hail, and grasshopper damage eliminated. No credit given for carryover moisture.

Ten wet years in which wheat yields were 25 bushels or more, compared to 8 years in which yields were 10 bushels or less.

B. Average bushels yield and seasonal rainfall (inches):

	Average yield (bushels)	Seasonal rainfall (4 months) (inches)
(*a*) 10 wet years	31.54	10.53
(*b*) 8 dry years	5.26	5.74
Difference	26.28	4.79
Divide	26.28	4.79

Indicated 1 inch of rain good for 5.48 bushels of wheat.

C. Questions:

(*a*) Would ½-inch rain give us 2.74 bushels of wheat?

(*b*) Would ¼-inch rain give us 1.37 bushels of wheat?

(*c*) What effect does additional rain have on native grass, tame grasses, and other crops?

D. Other data:

(*a*) 60-year record of annual precipitation	inches	15.63
(*b*) 60-year record of seasonal, 4 months (April, May, June, July)	do	9.17
(*c*) 60-year record of seasonal, 5 months	do	10.89
(*d*) 45 average yield wheat on disked corn ground, Rotation 19	bushels	18.60

Comment: Better yielding wheat varieties, rust free, grasshopper and weed control plus hail suppression, same weather conditions, should be able to boost the 18.6 average to about 25 bushels or more.

This closes our statement for the weather commission. I might make this remark, if we could increase rainfall by 1 inch for the State of South Dakota, for the 44 million acres, it would amount to 440 million acres of water.

Senator McGovern. Thank you very much, Mr. Bruce, for your statement. It is going to be very helpful. The bill under consideration, as you probably know, provides for Federal licensing for Federal regulation of operators. I wonder if you think the States ought to be given opportunity first to license projects?

Mr. Bruce. I think the State laws that we have and will probably have will take care of our own licensing here. For one thing, I was glad to see that the National Science Foundation got a ruling through requiring all pilots to keep data, and I think that is very important. That needs to be done.

Senator McGovern. If you had a situation where a project in one State seemed to jeopardize or hamper a project in another State, how would you resolve that?

Mr. Bruce. When we get to that point there would have to be Federal supervision.

Senator McGovern. Mr. Bruce, have you had good cooperation in the past with your operations from the Weather Bureau or have they generally opposed your efforts?

Mr. Bruce. Well, I would guess in 1961 we had a seeding project in our own county of Corson and I wrote a letter to the Weather Bureau chief at Bismarck asking if I could get some weather reports that he might have of hail and if it would be a good time to seed, and he did not answer the letter. I think he was a little afraid to, and so the letter was sent to Washington and the Chief of the Bureau answered it. And I got a nice, polite turndown. I noted that I seemed to have pretty good cooperation on the weather with the chief here at Rapid City at that time. He apparently got this letter right after that. He has been a little bit more careful about what he did for us and in talking to the State climatologist, who is under the Weather Bureau, I think they had a long period of brainwashing. Now I understand the Weather Bureau people at the head are changing their attitude and maybe it would be all right, but there was a long time when they were not helping any. You can go back to 1951 and 1952, we had that feeling then.

Senator McGovern. You have the idea the situation is improved, then?

Mr. Bruce. I think it has under the present chief. But I think some of the others are due for a change.

Senator McGovern. Thank you very much, Mr. Bruce. Senator Moss?

Senator Moss. I have no questions. Thank you.

Senator McGovern. Senator Burdick?

Senator Burdick. No questions.

Senator McGovern. Our next witness, then, is Mr. Charles Undlin, executive vice president of the First National Bank, Rapid City. We are happy to have your testimony now, Mr. Undlin.

STATEMENT OF CHARLES UNDLIN, FIRST NATIONAL BANK, RAPID CITY, S. DAK.

Mr. Undlin. Mr. Chairman and members of the committee:

My name is Charles T. Undlin, I am executive vice president of the First National Bank of the Black Hills. The banking organization I represent has customers and banking relationships with every facet of our economy in western South Dakota, eastern Wyoming, and eastern Montana. There are two areas that vitally concern us in the field of weather modification. The two areas I am referring to are increased precipitation and reduced or suppressed hail.

In the area of increased precipitation, I am convinced that increased rainfall would help our agriculture, our forests, our tourist industry, and our industrial prospects. It is difficult to develop specific figures on the benefit to agriculture or these other areas from increased rainfall. This region is predominantly range country and the normal economic indicators have many variables to contend with other than rainfall. Livestock prices vary from year to year as do other marketing factors, but it seems obvious that with increased rainfall our range conditions will improve and our stock dams will hold more water enabling us to better use our range and livestock resources. It is also very evident that increased rainfall will help stabilize the production of those crops which are grown in this area.

In the Black Hills area we have large reserves of forest and timber resources. These reserves are a very valuable natural resource and it is obvious that more precipitation will help maintain this asset, both from the standpoint of stimulating growth and reducing the danger to persons and property from forest fires. This same area also has a large tourist industry, and it is very important to have adequate water supplies both for personal and recreational purposes. Increased rainfall in the summertime will help the streamflows and the water levels of the lakes and in the wintertime the ski slopes would benefit from increased snowfall.

Another potential of this area which would be enhanced by more precipitation is the needs of industry. Many of our areas are seeking to attract new or additional industries and in most cases those industries have substantial water requirements. A larger supply of water would very definitely help in this attempt to diversify our economy.

I cannot give a specific dollar benefit which would result from a 10- or 20-percent increase in precipitation in this area, but I am convinced it would be very substantial. The investment required is large but the potential benefits are enormous. It would help a great deal to improve the personal income levels of the people in this region and help provide a greater stability for our economy.

The advantages of hail suppression are somewhat easier to document. Some of my friends in the insurance industry have provided facts on losses in recent years which are very impressive.

A major adjustment bureau in Rapid City reports that in 1949 they set up the first disaster storm office for hail in Rapid City. Since 1949 disaster storm offices have been established in 1954, 1956, 1958, 1959, 1960, 1962, and 1963. The insured losses from the two hailstorms in 1963 are estimated to total well in excess of $2 million based on an estimated 9,000 losses averaging $254 each.

From 1961 to the present time insurance rates in western South Dakota and especially a small area slightly larger than Rapid City have increased substantially. In Rapid City a typical $10,000 homeowner policy which cost $161 for 3 years in 1961 now costs $269. The rate for Sioux Falls in the eastern part of our State remains the same as in 1961 or $161. On a new $3,000 automobile the rate for comprehensive insurance is $42 in Sioux Falls compared to $69 in Rapid City. The rates for crop hail insurance vary in this and nearby counties from $11 to $18 a hundred—rates which are very nearly prohibitive. It is my understanding that because of excessive hail losses over 40 insurance companies have pulled out of our area in the past 4 years. These statistics should make it obvious that we are in an area subject to large and very damaging hailstorms, and suppression of these storms would have a very definite beneficial effect on our economy.

The entire upper Great Plains area is an area of relatively low precipitation and because of this the people are conscious of, and aware of, the tremendous importance of adequate water. As evidence of the public support there have been a number of small privately financed cloud-seeding efforts over a number of years. These smaller groups are willing to step aside for more scientific efforts on a larger scale by groups who are able to make field tests and applications as soon as practical.

This area of the country is sometimes referred to by ranchers as "next year" country. The implication is that when some disaster such as a blizzard, or drought, or hail occurs the normal reaction is to say that next year will be different. It is my belief that weather modification through research in the laboratory and carried through with practical application in the field will help reduce the need to always rely on next year.

Thank you.

Senator McGovern. Thank you very much, Mr. Undlin. I think we especially appreciate your giving your time to these hearings today because you are not active with any organization directly involved with weather modification. As your statement very properly points out, this is a field in which all of us ought to be interested. I intended to ask you some questions about the broad impact of the program on the economy, but I think your statement is so complete that it answers those things fully so that it is not necessary to ask you any further questions on that order.

Senator Moss, do you have any questions?

Senator Moss. I really have no questions. I concur it is a very fine statement and states very concisely what the effect would be if we could modify our weather to increase our precipitation or dissipate damaging hails.

Senator McGovern. I think it is important to make the point that this is not special interest legislation for any one group. It has an impact on the cities as well as on the rural areas and I am sure it has been demonstrated on the banking and insurance business, on all of this. Senator Burdick?

Thank you very much.

Our next witness is Mr. Roland Veren, who is the chairman of the Black Hills Conservancy Subdistrict, of Sturgis, S. Dak.

STATEMENT OF ROLAND VEREN, CHAIRMAN, BLACK HILLS CONSERVANCY SUBDISTRICT, STURGIS, S. DAK.

Mr. Veren. Senator McGovern, gentlemen of the committee, honored guests, ladies and gentlemen; I am Roland Veren of Sturgis, S. Dak., a native of western South Dakota for more than 50 years. I have farmed and ranched on some of the poorer land in western South Dakota and also have owned and raised wheat and cattle on some of the very best land in this area. Always there has been the problem of not enough rainfall to produce the grass and crops which the soil is fully capable of producing.

I know what it is to live on land where you have to haul your drinking water and even drive your livestock several miles to a community watering place. So I am very conscious of our water problems.

In 1951 when cloud seeding for rain increase was first considered I joined with my neighbors in the surrounding counties and we raised the money to hire a reputable contractor to seed the clouds for rain increase.

Those of us who had the opportunity to accompany the meteorologists in their fieldwork and also see the detailed and precise office computations necessary to carry on such a program, never had any doubts as to the integrity of our contractor or to the fact that we were receiving some benefit from our program but as the years went by many of those who were paying for the program became discouraged because most of the beneficiaries either did not believe we were getting results or preferred to have a free ride at the expense of a few.

After 4 years of this program financed by individuals we gave up and decided we would have to produce more conclusive evidence of rain increase before the general public would support weather control and modification.

These early experiences in weather modification must be considered experimental research even though paid for by private organizations.

These projects were given thorough study by the U.S. Advisory Committee on Weather Control and while the evaluations were encouraging they did indicate that much more research was needed not only to successfully seed the clouds but also to prove the results.

In 1962 the National Science Foundation sponsored a conference here. This conference brought together the top leaders in the atmospheric science field. It was brought out at this meeting that here in the Black Hills of South Dakota and the surrounding area we have the ideal outdoor laboratory to carry on a comprehensive research study.

Dr. Vincent J. Schaefer pointed out our excellent natural advantages. We are located far from the air pollution of the industrial centers.

Here in the center of a semiarid region we have a group of isolated mountains reaching to over 7,000 feet elevation.

We have caves going deep into these mountains.

We have mine shafts going down below sea level.

We have the jetstreams.

The air currents moving over the plains sweep upward when hitting the mountains, and clouds form giving opportunities for seeding and cloud study.

It was pointed out to us that this research must be carried on in connection with a good college but most important of all was to get top men to do the job.

Now wih Dr. Richard Schleusener heading our present atmospheric research staff at the South Dakota School of Mines and Technology, we feel that we stand second to none in ability and natural advantages to carry on an expanded comprehensive atmospheric research program for the entire northern Great Plains region.

As a farmer and rancher I can say that we really need this program. As proof of our need and our determination to move ahead with a long-range research program, following this 1962 conference we again went to our own people, the counties and municipalities and raised enough money to add to that of a small contract with the Bureau of Reclamation and got a start on a long-range research program.

We feel that our present program of research is making progress but in order to meet the needs of a large area and help the economy of our Nation we need the passage of S. 2875 to move this research along at a faster pace.

As a farmer I have learned that even a very small increase in precipitation can make a considerable increase in crop yield.

When farmers visit at harvesttime, a very common remark is, "We got a little more rain on the west end of the place and you can sure see the difference in the grain coming out of the combine."

Studies made by the U.S. Department of Agriculture and information published in Bulletin No. 636 by J. S. Cole indicate an increase in wheat yield of 3 bushels per acre from an increase of 1 inch annual precipitation. If this additional moisture had come during the growing season it would no doubt have shown much greater benefits.

If you multiply 3 bushels times the number of crop acres in the northern plain States you can easily see what an impact it would have on our economy.

We must remember that it is not just in the dry years that we can benefit from increased precipitation because even when we have good crops our soil is capable of producing much more with more rain.

Our experience with cloud seeding is that we not only get more rain with less hail but it comes down in fine drops and soaks in better with less runoff.

Our Meade County records show that we had much less loss due to hail during the years of our program.

Certainly hail suppression or modification should be a very important part of this research program.

We had a real bad blizzard in this area last month and many ranchers had heavy losses of livestock, but most farmers and ranchers can add up their hail losses and the amount will be much greater than those suffered in the blizzards.

The loss of 100 acres of wheat would equal 25 or 30 head of cattle.

On my ranch I raised both wheat and cattle with about equal income from each and my losses from snowstorms was negligible while my losses from hailstorms amounted to many thousands of dollars.

Another great benefit from increased precipitation is that it holds down the insect pests. In the dry years we have heavy losses from grasshoppers and other insect pests but when we have fair to good moisture we are not bothered.

While agriculture is the major industry in this region, the benefits derived from an increase in precipitation would reach every individual and industry in the area.

We are losing many miles of fishing streams each year and our lakes and recreational areas are getting more pressure from the constantly increasing number of tourists and our growing population.

Most of our cities and towns have water restrictions during the summer and most of the artesian wells that were flowing a few years ago now have to be pumped.

We face serious water problems in the future and we realize it.

We have organized our Black Hills conservancy subdistrict and are in the process of setting up a watershed district to fully utilize the water we now have.

Atmospheric research is expensive but cloud seeding is not and the investment of Federal funds to speed up this research could easily bring a better return for the dollars spent than rural electrification or the multipurpose dams on our large rivers and I am sure we can all agree that those investments by our Federal Government are paying big dividends.

In addition to my previous remarks I speak with authority for the directors of the Black Hills subdistrict in urging your full support of this bill (S. 2875) and ask that the atmospheric research program now being carried on at the South Dakota School of Mines and Technology be expanded to serve the northern Great Plains region.

I thank you.

Senator McGovern. Thank you very much, Mr. Veren. That was a thorough and thought-provoking statement. I want to congratulate you, not only on your interest in weather modification, but on the leadership you and your associates provide through the Black Hills conservancy subdistrict and the whole field of resources development. Senator Moss, do you have a question?

Senator Moss. I really don't have any questions. I agree it is a very thorough statement and certainly it helpful. It makes the record strong, and what we are trying to have is a good, complete record here so that we can get some action in the Senate.

Senator McGovern. Senator Burdick? Thank you very much, Mr. Veren.

Now we will call Mr. Homer Schwentker, executive secretary of Western South Dakota Rain Increase Corp., which has its office here in Rapid City.

Those of you who are keeping track, we have just one witness after Mr. Schwentker, Mr. Phil Sheldon, of Scottsbluff, Nebr., who has a

brief statement that he wishes to make, and we will conclude our testimony this afternoon.

Mr. Schwentker.

STATEMENT OF HOMER SCHWENTKER, EXECUTIVE SECRETARY, SOUTH DAKOTA RAIN INCREASE CORP.

Mr. SCHWENTKER. Senator Burdick, we are very happy to see that you have changed your mind and want to stay in Rapid City a little longer.

Senator BURDICK. It is due to weather modification.

Mr. SCHWENTKER. Oh, I see. Thank you.

I am Homer Schwentker, the secretary of the Western South Dakota Rain Increase Corp., a big name for a very small organization. And you will note that I was last on the program. Now, I am so used to being last that this is just normal. I spent many years in Rapid City in various bands and if we were the only band in the parade we headed the parade. If there was another band or a dozen other bands, we were at the end of the parade, which is perfectly fine except when there are horses in the parade. You can't see where you are walking.

The Western South Dakota Rain Increase Corp. covers the counties of Pennington, Custer, and Fall River which are located in the southwest corner of the State. It is controlled by a board of directors who are elected to represent each county and take care of all matters concerning the corporation. It was in 1951 that an effort was made to increase the rainfall by seeding the clouds by the use of a plane, and, since that time this work has been going on every year except for a few years when, for various reasons, no seeding was done. For the last 5 years seeding has been done each summer even though some seeding seasons have been short because of a lack of funds, which, until 3 years ago were all donated by businessmen, farmers, and ranchers. At the present time the three counties pay the bill.

Since the establishment of the Institute of Atmospheric Sciences under the direction of Dr. Richard Schleusener at the school of mines and technology we have tried to cooperate and be as helpful as possible, and, in return we have received the same kind of fine treatment. We have had Dr. Schleusener or a member of his staff in attendance at several of the meetings held quarterly by the board of directors, and, we hope to continue this for we feel that we have much to gain. And we hope that information that we can pass on will be of value to Dr. Schleusener and his group.

It is impossible to estimate the value of increased rainfall for too many factors are involved. However, we do believe that we do increase the rainfall but in an amount unknown. And we believe that the dividends of increased rainfall can be very large when compared to the cost. The cost of the present operation is less than $10,000 per year for the three-county total. When more is learned about hail prevention we think that the dividends will go up sharply.

And in connection with the work with the hail, we have found that pilots are just a little shaky about getting into a hailstorm. They don't seem to want to get beat up, but when we learn more about it I think we will be able to do considerable in that line. Thank you.

Senator MCGOVERN. Thank you, Mr. Schwentker. One of the important purposes, as you may know, of S. 2875 is to make certain that

the resources and experience of private business and private organizations be applied along with that of universities and private individuals and agencies in securing information that will be helpful to us as we move along.

Mr. SCHWENTKER. That is what we are doing, trying to stay just as close as possible to Dr. Schleusener.

Senator MCGOVERN. What kind of relationship have you had with the program of atmospheric sciences here at the School of Mines?

Mr. SCHWENTKER. If I understand you correctly, our experience has been just very, very fine.

Senator MCGOVERN. You have worked rather closely?

Mr. SCHWENTKER. Oh, yes. And regarding the weather bureau, we get just top cooperation with the boys at the airport here where the weather bureau is located. They are very fine to work with.

Senator MCGOVERN. Thank you very much. Senator Moss?

Senator Moss. How long has your organization been functioning, Mr. Schwentker?

Mr. SCHWENTKER. Well, it was started in 1951 but it was not until 1961 that we actually got operating every year and we thought then we were going to get in trouble because our funds kept going down. We never got enough money each year, and also we had to change the State law. After we got that changed the counties could enter into this.

Senator Moss. The counties do make some contribution to you corporation?

Mr. SCHWENTKER. Yes. That is right. That is where we are getting our money now. Since we are getting that we seem to be all right.

Senator Moss. Well, do you get it also from individuals?

Mr. SCHWENTKER. Not any more.

Senator Moss. It all comes through the counties?

Mr. SCHWENTKER. All counties, yes.

Senator Moss. Thank you.

Senator MCGOVERN. Senator Burdick?

Senator BURDICK. Yes, I have one question on techniques. You are familiar with the association, I am sure, and the techniques they employ. I asked this question this noon and I got a fairly good answer. I will try it again. As an old cub pilot, I know how these pilots feel about getting near the turbulence in those storms. How much work has been done in using a projectile on the ground to deposit this material?

Mr. SCHWENTKER. I don't know. Let's see, this was in either a Denver paper or a Phoenix paper and I read about something being done along that line just a year ago in Texas. I didn't save the article.

Senator BURDICK. They are thinking about it, too?

Mr. SCHWENTKER. Oh, yes; they are thinking about it and this was in actual operation. This individual said for so much money I will do such and such for you and he guaranteed not to make a million but to do so much work for them.

You made me think of a story of the fellow, the old hillbilly out in the hills. He found a pencil and he found out he could make some marks and so he ran home in a hurry to tell his wife. He said, "I can

write. Look at this, Mom". And she looked at it and she says, "So you can, Jeb, but Jeb, what does it say?" Well, now, I am something like Jeb, because he had to answer: "Hell, Ma, I ain't learned to read yet." And that is the reason I can't answer your question.

Senator McGovern. We come now to our final witness, Mr. Phil Sheldon, of Scottsbluff, Nebr. If you will come to the witness stand we will be glad to hear your statement.

STATEMENT OF PHIL SHELDON, SCOTTSBLUFF, NEBR.

Mr. Sheldon. Gentlemen, it is my understanding—I will be brief and I will let you know who I am and a little material I have here. My name is Phil Sheldon. I represent the Weather Control Committee in Scottsbluff Valley. I was the first agricultural agent in Scottsbluff Valley. I am connected with a farm newspaper and I operate quite a little land so I am just saying that so you will know I am not a greenhorn from eastern Nebraska. Now, I have a little data here on some of the damage and I won't read all of it but it does tell some of the damage we have over there.

Senator McGovern. If you want to submit any of those to the committee in their entirety——

Mr. Sheldon. Well, I am not going to read them. I have one from the Chester Brown Co., large bean operators in which they estimated last year damage to beans from hail from $600,000 to $1 million. I have a statement from Mr. Lionel Harris from the experimental farm which shows that they had $120 an acre loss on beans, actual count, and gives the losses other years from beans pounded out in the windrow. And I have a statement from the Great Western Sugar Company which shows the data for 2 years of hail suppression work compared to 2 other years. In 1951 and 1952 we had no hail suppression, we had 42,000 acres in 1951, 34,000 in 1952, a total of 76,000 acres of crop damage. In 1953 and 1954 when he had hail suppression work, we have only had 14,000 in 1953 and 24,000 in 1954 or a total of 38,000 acres of damage. Since we are in favor of carrying on the work and since the gentleman before me told a story, I will tell this one which I think is the attitude of both the Government and the people in the territory should have. It shows the spirit the cowboys had in our upper North Platte Valley. A girl was visiting at a dude ranch and she kept begging this cowboy to tell her his experiences. He got tired of it so he told her finally, he said. "Well, one morning I got on that gray mare over there and see that steep hill that runs down there almost straight down with the fence along it?" He says, "I got on her and she started to run away with me, and she bucked and bucked down the hill and got about halfway down and," he said "she threw me off and I lit right astraddle of the fence." "What did you do?" He said, "I did the only thing a man could do." He said, "I let out my stirrups and rode to town."

Senator McGovern. Well, I think that is a good note to conclude on. Mr. Svendby reminded us a little while ago that a half inch of rain is worth more than a 2-hour speech. We have taken a good deal more than 2 hours here today, but I would like to think that out of these hearings and others like them there will eventually come more than a half inch of rain.

Before we conclude this hearing I would like to include a letter from J. R. Smith, executive vice president of Raven Industries, Inc., of Sioux Falls.

(The letter referred to follows:)

RAVEN INDUSTRIES, INC.,
Sioux Falls, S. Dak., May 5, 1966.

Hon. Senator GEORGE MCGOVERN,
Senate Office Building,
Washington, D.C.

DEAR SIR: I want to thank you for the courtesy you extended to me during my recent visit to Washington. I am especially interested in the legislation which is being considered in the area of weather modification. Not only will the benefits which result from success in the programs being considered be of extreme value, my personal feeling is that such success has at least a reasonable chance of being realized. I do not believe that weather modification is impossible. At the same time, I do not believe that operating programs can be particularly successful until such time as the basic processes which are being modified are understood.

In some areas such as atmospheric pollution, there is no question as to what is going on. On the other hand, however, there is not now a mechanism for production of rain which is understood and accepted by scientists in general. There are various theories and most of these can be proven not to cover all of the cases under which rain falls in nature.

I would like to add my voice to that of others who have urged that continued research be carried out into the basic mechanisms which are in operation in the atmosphere, either in advance of or concurrent with the so called operational programs. I have read the statement made before the Senate Committee on Interior and Insular Affairs by Dr. Bernard Vonnegut (March 23, 1966), and his statement to the U. S. Senate Committee on Commerce presented March 8, 1966. These two statements express very well my feelings on this program and I must commend Mr. Vonnegut for presenting his viewpoint in this manner. His contributions to the scientific understanding of atmospheric processes are probably more important than those of any other single scientist.

I would like to amplify one thought which Dr. Vonnegut expressed. From my own experience (a professional meteorologist since 1943, and a contractor involved in spending public funds on various research programs since 1947), I believe that the development of useful knowledge in this field, as in many others, can best be accomplished if a number of directing or sponsoring agencies are involved. Specifically, the Department of Interior and Environmental Sciences Services Administration are both staffed with people who have the right to direct the expenditure of public funds in this area. In addition, such organizations as the Office of Naval Research have sponsored good programs in the past. I would hope that a number of independent federal organizations might be involved in future weather modification programs. History contains too many instances of the domination of thought by an all powerful, sole administrative or governing body. There may be concern about the duplication of efforts if more than one organization is allowed freedom of program management. I cannot agree that there is any serious problem involved in this prospect. If indeed duplicate efforts are mounted, and similar results are obtained by more than one group, this is not a waste of effort. It is the standard scientific procedure to validate data taken by one set of experimenters, through the use of completely independent investigators. If there is no duplication whatsoever, I think the programs would be subject to criticism for that very reason. On the other hand, with the actual communications which are available in this day and age, it is unlikely that extremely large amounts of money would be spent on duplicative efforts.

Again, may I thank you for the active interest you have shown in promoting a program which offers so much promise to the public.

Very truly yours,

J. R. SMITH,
Executive Vice President.

Senator MCGOVERN. I do want to thank Senator Burdick for the effort that he made to be with us, coming over here from North Dakota, Senator Moss who flew in from Utah, and Senator Metcalf who

was with us this morning. And we thank President Partlo and the staff, Dr. Schleusener and others here at the school, for making the arrangements for our hearing and hosting us today. I think we are all grateful to the chamber of commerce for the luncheon they provided for us this noon. I want to thank each person here for your patience and your interest and participation at these hearings. That concludes our hearings for Rapid City. Thank you very much.

(Whereupon the hearing at Rapid City, S. Dak., was adjourned.)

WEATHER MODIFICATION

THURSDAY, APRIL 14, 1966

U.S. SENATE,
WATER AND POWER RESOURCES SUBCOMMITTEE OF THE
COMMITTEE ON INTERIOR AND INSULAR AFFAIRS,
Albuquerque, N. Mex.

The subcommittee met, pursuant to call, at 10 a.m. in the Old Federal Courthouse Building in Albuquerque, N. Mex., Senator Clinton P. Anderson, chairman of the subcommittee, presiding.

Present: Senators Anderson, Bible, and Jordan of Idaho.

Also present: Jerry T. Verkler, staff director, and Roy Whitacre, professional staff member.

Senator ANDERSON. The meeting will be in order. I want to put into the record a statement concerning this work.

Organized scientific efforts to influence the weather began in the 1940's. Doctors Irving Langmuir and Vincent Schaefer of General Electric were the first to demonstrate that clouds could be modified and rain produced by scientific methods. Afterwards Dr. Langmuir, in urging Government control, said:

The effect of 30 milligrams of silver iodide under optimum conditions equals an atomic bomb.

On March 20, 1951, I visited the laboratory of these two scientists and came away more than ever convinced that man could produce rain.

Commercial rainmaking was attracting much attention in 1950, especially in New Mexico. The claims or Dr. Krick of the Water Resources Development Board of Pasadena that he had doubled the yield per acre of wheat by cloud seeding on the ranch of a Prosser, Wash., man stirred up nationwide discussion. Farmers and ranchers in eastern New Mexico even considered a $155,000 contract with Krick's commercial rainmaking firm. At that time the Middle Rio Grande Valley faced a serious shortage of irrigation water, but I was convinced uncontrolled cloud seeding was not the answer.

In December 1950, I introduced S. 4236, giving the Federal Government control of all rainmaking activities. No action was taken on the measure.

Senator Joseph O'Mahoney's bill, S. 1300, to authorize the Secretary of the Interior to construct and operate demonstration plants to produce potable water from sea water, also died when the 81st Congress adjourned. The provisions of his bill were incorporated into S. 5 in the 82d Congress, and a companion measure, H.R. 6578, was signed into law July 3, 1952, with the ardent support of the Secretary of the Interior, Oscar Chapman.

The 82d Congress also brought the introduction of two measures in addition to S. 5—S. 222 which I introduced on January 8, 1951,

and S. 798, introduced by Senator Francis Case of South Dakota. Joint hearings were held on all three bills March 14, 15, 16, 19, and April 5, 1951, before the Subcommittees on Interior and Insular Affairs, Interstate and Foreign Commerce, and Agriculture, which I chaired.

During the testimony of W. F. McDonald, of the Weather Bureau, I suggested the Bureau's position was that there wasn't anything to rainmaking. He said that wasn't quite right. The Bureau's position amounted "to conservative agnosticism, not atheism."

However, other witnesses—including Dr. Bernard Vonnegut—provided affirmation of his belief in man's ability to increase precipitation in the atmosphere. In New Mexico a State water resources development commission headed by Robert McKinney was working with Dr. E. J. Workman at the New Mexico Institute of Mining and Technology on weather modification. The Army Signal Corps also had launched several rockets equipped with weather instruments at White Sands.

In 1953 Congress, through legislation introduced by Senator Case and cosponsored by other Senators, including me, created the Advisory Committee on Weather Control (Public Law 256). In the advisory committee's final report to the President on December 31, 1957, recommendations were made to step up weather modification activities and for passage of S. 86. This bill became the Water, Cloud Modification Research Act of 1957 (Public Law 85–510) on July 11, 1958. At that time no Federal agency had specific legislative authority to carry out basic and applied research in weather modification. The study of flood, drought, hail, lightning, and fog was put under the direction of the National Science Foundation. In conducting its studies the NSF was ordered to consult with several other agencies and private scientists and meteorologists interested or affected by weather modification. During fiscal year 1959 the Foundation expended $1,141,000 for research projects. It did not get into the large, direct research effort many of us wanted undertaken because of the scientific "agnosticism" about the effort. The NSF confined its activity to giving financial support to a few college and university efforts in the atmospheric sciences field.

Two more efforts were made to accelerate weather modification in the next 6 years. I cosponsored two bills introduced by Senator Engle on February 5, 1959 (S. 943), and on January 14, 1963 (S. 152). The first measure would have set up a weather modification program under the Interior Department and the National Science Foundation to increase substantially the annual average of usable supply of water available in the Colorado River Drainage Basin. S. 152 (in the 87th, S. 1577) would have created a National Weather Council to provide coordination and central direction for an accelerated program of weather research. This latter measure died in the Commerce Committee.

Early in 1963 the Senate Select Committee on National Water Resources, on which I served, issued a report urging greater research on weather modification.

On March 7, 1964, I introduced S. 1020, a bill to direct the Secretary of the Interior to conduct a program in five areas of the United States to increase usable precipitation. This measure, patterned after the

saline water demonstration program, was never reported out of the Commerce Committee, dying there as other bills had died.

On January 6, 1965, I introduced S. 23 which also was referred to the Commerce Committee and was never reported out.

My new bill (S. 2875) introduced February 4, 1966, authorizes and directs the Secretary of the Interior to conduct a comprehensive program of scientific and engineering research, experiments and tests and operations for increasing the yield of water from atmospheric sources. This legislation, carrying a $155 million authorization for the next 3 years, has the support of 20 other Senators and has been referred this time to the Committee on Interior and Insular Affairs.

The bill, and the program it would authorize, is based on the finest scientific and administrative advice anyone could obtain.

It implements the recommendations of two outstanding panels of scientists, one set up by the National Science Foundation and the other by the National Academy of Sciences. They found that weather modification efforts do get results and recommended that the Federal effort be expended sixfold by 1970, from around $5 million a year to $30 million annually. Additionally, both panels recommended a like increase in atmospheric studies backing up the weather modification work.

When the two panel reports came out in January, I obtained the help of another group of specialists, including men like Vincent Schaefer, the weather modification pioneer, and Dr. Julian Bigelow, the great mathematician at the Institute of Advanced Studies at Princeton University, to develop a specific program, list the facilities, the equipment, and the personnel that it would require and estimate costs for 10 years. I then had their program embodied in an authorization bill, now S. 2875, on which this hearing is being held.

We have already had 3 days of hearings in Washington. Scientists from six States testified Monday at Rapid City, S. Dak. This is the last scheduled hearing here today. When the record is completed, the verbatim proceedings of all 5 days of hearings will be assembled and printed. Copies will be sent to all witnesses and anyone else who requests a copy.

Testifying here today are scientists from several Southwestern States who rank high among the experts in the field. I have taken a little time to go into this background so participants, as well as those who are here to observe, can have some understanding of the occasion, of the long and rather persistent effort that has brought us here, and of the importance of the subject.

Scientists have told us that they have identified a few situations in the atmosphere where a modest amount of energy may change the nature or course of atmospheric movements that involve enormous volumes of energy, comparable to a single match starting a great forest fire.

Here in New Mexico, where we are developing the last of our available water resources, it is easy to appreciate the enormous benefit that ability to modify the climate could bring to us. It could be the basis for economic development and growth far beyond the present limitations imposed on us by limited water supplies.

Weather modification may very easily become a scientific undertaking comparable in importance and size to our atomic and space

efforts. It will have a much more direct effect on the lives of ordinary citizens.

As a member of the Joint Committee on Atomic Energy and chairman of the Senate Aeronautical and Space Sciences Committee, I have had a ringside seat at both of those developments. I can tell you that I regard the advancement of this scientific effort, in relation to the atmosphere, of fully equal importance and well worth equal support by our Government.

I have here a letter from Dr. Neyman, professor and director of the Statistical Laboratory at the University of California in which he outlines the need for a statistical weather modification facility. It's a pretty good letter and without objection I will put his letter and his outline of facilities into the record at this point.

(The letter referred to follows:)

UNIVERSITY OF CALIFORNIA, BERKELEY,
DEPARTMENT OF STATISTICS, STATISTICAL LABORATORY,
April 6, 1966.

Hon. CLINTON P. ANDERSON,
Senate Office Building,
Washington, D.C.

DEAR SENATOR ANDERSON: This is in connection with the bill, S. 2875, you introduced providing for a comprehensive program of scientific and engineering research on artificial stimulation of precipitation. I am confident that your bill will become law and that it will result in much fruitful experimentation on this very important problem.

The purpose of the present letter is to suggest the necessity of certain steps to insure that the results of the proposed experimentation are not lost but are preserved for use of all qualified scientists concerned with the problem.

As of now, the data collected in the course of certain completed experiments, financed from public funds, appear irretrievably lost. Yet these data contain precious information, the availability of which could speed up the solution of the problem of weather control. This is the information on questions which were not asked at the time the experiment was performed but which, with the progress in our knowledge, became very relevant. When data on old experiments is lost, in order to answer these new questions new experiments must be performed at the cost of perhaps millions of dollars and, even more importantly, at the cost of another period of 5 years or so.

Considerations of this kind suggest that, in parallel with the broad program of experimentation visualized in your bill, a special unit be set up, perhaps to be called statistical weather modification facility, with the following two related purposes.

(1) To preserve in usable form the data on completed weather modification experiments, and

(2) To conduct statistical research with the use of collected data on already completed weather modification experiments.

Enclosure A outlines the functioning of the proposed facility. Enclosure B indicates some arguments in favor of the facility.

Yours respectfully,

J. NEYMAN,
Professor and Director of the Statistical Laboratory.

[Enclosure A]

OUTLINE OF FUNCTIONS OF THE PROPOSED STATISTICAL WEATHER MODIFICATION FACILITY (SWMF)

(1) DATA COLLECTION AND STORAGE

The SWMF would collect, sort, organize, and store, on punchcards, magnetic tapes, or on microfilms, relevant data relating to all publicly funded weather modification experiments conducted in the United States and also relating to such other weather modification experiments in the United States and abroad

that may be judged sufficiently significant and that the collection of data on them will be found feasible.

The data in question would be not only those that the experimenters concerned would collect on their own initiative, data intended to answer questions formulated by these experimenters, but also collateral data, the relevance of which may be only suspected, but which later on may become invaluable as a source of information on questions that may be asked in the future. The success in this respect will depend very much on the scientific initiative, alertness, and foresight of the directing body of the SWMF.

(2) LEGAL BASIS

The basis for the activity of SWMF must be a law requiring (*a*) that the facility be informed of each incipient publicly funded weather modification experiment, including the design of the experiment, its purpose, and the data collection program; (*b*) that photocopies of the original data on every such experiment be routinely made available to the facility as they are collected, perhaps within 3 months of each completed experimental season.

(3) COLLATERAL DATA

The SWMF would be authorized to seek cooperation of the appropriate Federal and State agencies in collection of the relevant collateral data, such as photocopies of radiosonde data, precipitation records in areas adjoining the weather modification experiments, etc.

(4) USE OF DATA

The purpose of data collected and organized by the SWMF would be to create the possibility of using the weather modification experiments already completed in order to answer questions which were not formulated at the time when these experiments were planned and executed. For this purpose, and subject to the restriction explained in (5) the data collected by the SWMF would be available, at cost, to all agencies of the United States and to all authorized individuals and research institutions.

(5) PRIORITY RIGHTS OF THE EXPERIMENTERS

The availability of data on completed experiments would be subject to the restriction designed to protect the priority rights of the experimenters: the latter must be allowed a reasonable time, perhaps a year, to analyze and to evaluate their experiments themselves. Thereafter the results of the experiments would become public property.

(6) OWN RESEARCH OF THE SWMF

In addition to collecting, organizing, and preserving data on completed weather modification experiments, the SWMF would conduct its own research in the following domains:

(*a*) Theoretical research aiming at the development of particularly efficient statistical techniques for the evaluation of weather modification experiments.

(*b*) Development of experimental designs with which significant results on weather modification might be obtained through a shorter period of experimentation, and therefore, at a savings expected to be substantial.

(*c*) Evaluation and reevaluation of selected experiments already performed.

(7) CONSULTING SERVICE

The SWMF would provide statistical consulting service to all research workers and institutions who may request it, particularly with reference to evaluation techniques and to planning of new experiments.

(8) GOVERNING BODY

The SWMF would function under policy decisions of a governing body composed of representatives of research institutions concerned with weather modification problems, to be determined by a separate regulation.

(9) AUTONOMY

The SWMF must have a degree of autonomy and be free to collect and, when the occasion arises, to publish data and evaluations at its own discretion. In particular, SWMF should be financially independent of the institutions engaged in actual experimentation with weather control. This would insure impartiality in the analysis performed by a group which would have no vested interests in the results.

Perhaps the best way to achieve this autonomy is to locate the SWMF within the academic community rather than to have it attached to a governmental agency.

[Enclosure B]

MOTIVATION FOR THE PROPOSAL TO CREATE THE STATISTICAL WEATHER MODIFICATION FACILITY

(1) USEFULNESS OF "COLLATERAL DATA" ON WEATHER MODIFICATION EXPERIMENTS

The usefulness of collateral data on weather modification experiments may be dramatically illustrated by the following fact: As revealed at the recent meeting "Weather Modification Section of the Fifth Berkeley Symposium" (see attached program), the first and, thus far, the only unambiguous evidence that cloud seeding with silver iodide can increase precipitation came from the hail-prevention experiment, so-called Grossversuch III, performed in Switzerland from 1957 to 1963. Here, then, precipitation amounts were "collateral" to the purpose of the experiment and it is pure luck that they were published in the annual reports. The significance of the precipitation data was largely overlooked. Thus, for example, the 1964 preliminary report of the NAS Panel dismisses the Swiss experiment in one sentence to the effect that no significant effect of seeding on hail incidence was found. (In actual fact, a more detailed analysis revealed that seeding increased the incidence of hail.)

(2) A SPECIAL AGENCY TO ASSEMBLE AND TO PRESERVE DATA ON COMPLETED EXPERIMENTS IS NEEDED

Here, again, Grossversuch III is bound to be considered as an intrusion and be resented. A special agency, established on the principle that the results of an experiment performed from public funds are public property, an agency established for the specific purpose of preserving this property, would be treated differently.

(3) NEED FOR THEORETICAL RESEARCH IN STATISTICAL METHODOLOGY AND THE DESIGN OF EXPERIMENTS

Experiments in physics and chemistry are as old as these sciences. They were going on without special theory and with great success, because in the laboratories it was possible to isolate the factors studied and to eliminate extraneous sources of variation. This was not and is not the case in the domains where great variability is an inherent feature of the subjects of study. Cases in point are agricultural, medical, and, more generally, biological studies. Here the variability from one plot of land to the next, from one patient or from one rat to another is so large as to hide the effects of treatments studied. In these domains, scientific experimentation was born in the 1920's and 1930's with the foundation, by R. A. Fisher, of special discipline: theory of experimentation. Through the work of Fisher and of his numerous followers, the theory of experimentation spread over many domains of science. However, thus far very little has been done with reference to weather modification experiments where there are special specific difficulties. In parallel with the extension of the theory of experimental design, there are other statistical theoretical problems to be solved. Such work as has been done already indicates that merely by a change of a statistical technique and/or by a modification of the experimental design, the time of experimentation necessary for detecting a significant effect of cloud-seeding may be shortened by a factor of two or more.

Research of this kind requires special qualifications, those of a mathematical statistician. However, it cannot be conducted in the abstract, but requires contacts with live experimental and observational data. The creation of the proposed Statistical Weather Modification Facility would provide an appropriate ground for such contacts.

Senator ANDERSON. We are very happy to have here today Senator Alan Bible, a longtime advocate of the causes of the West, and Senator Jordan of Idaho, whom I've found to be one of the most knowledgeable men on the committee. He represents the minority. I would like Senator Bible to make a statement for the record.

Senator BIBLE. Mr. Chairman, as I have on so many occasions during my years in the U.S. Senate, I want to congratulate you on the leadership that you provided in initiating hearings on S. 2875.

My interest in this program goes back, not quite as long as yours, but it does go back to 1957. As a member of the Interstate and Foreign Commerce Committee, I chaired hearings on a bill at that time for experimental research in cloud modification.

Again in 1959 I cosponsored legislation designed to improve our knowledge in this very, very interesting field.

In view of the lack of urgency which was indicated by the National Science Foundation, I proposed, in 1964, that the Bureau of Reclamation appropriation be increased from $100,000 to $1,100,000 to implement a full-scale campaign to increase precipitation on the Colorado River.

Data supplied by the Bureau of Reclamation indicate the benefits of increased rainfall through weather modification could be tremendous. An additional inch of precipitation in the Colorado River Basin above Glen Canyon Dam would produce a runoff of 575,000 acre-feet.

This extra amount of flow through Federal powerplants could boost income, at established power rates, by $2.5 million. Naturally, this additional water could be available for agricultural, municipal, and industrial uses. Allowing for losses in runoff, this added inch of precipitation would still provide 500,000 acre-feet of water for irrigation which, based on a 1962 water-crop benefit formula, would produce a gross crop income of $24.7 million. Municipal and industrial uses, of course, would increase the value of this extra precipitation even more.

These funds were utilized by the Bureau both as grants to universities, including the Desert Research Institute, and for a field program in the basin. Because of the effectiveness of the Bureau's program, the Appropriations Committee approved funding of this program for the present or current fiscal year in the sum of $2,980,000. This is but a step in the right direction. The legislation now before you, Mr. Chairman, would prove whether or not weather control is presently within the grasp of our scientists.

As you, yourself, have well said, and I quote you from your statement made in the hearings in Washington, D.C., on March 21:

> It is readily apparent that it is vital to the public interest to reassess the position of weather modification research with a view toward paralleling Government-supported basic research with more extensive field applications.

Again, my congratulations to you, Mr. Chairman, in your initiative in introducing this legislation. In calling the hearings, you have again, as is so often the case, my pledge of complete cooperation in securing enactment of the present bill.

Senator ANDERSON. Thank you very much.

Senator Jordan.

Senator JORDAN. Thank you, Mr. Chairman.

I would just want to join Senator Bible in paying tribute to you in your leadership in this area. I am pleased, indeed, to be a cosponsor

of S. 2875 which really works in an area, a new frontier, of which we know not enough. With the enactment of this legislation—we hope it will be enacted—it will enable us to probe into this very important matter of weather modification.

I would like to say, too, that I follow you in other committee work. I am pleased to serve on the Senate Space and Aeronautical Sciences Committee, under your leadership, and I find it inspiring and constructive indeed.

Senator ANDERSON. I am pleased to have you there.

I noticed as I came in a friend of mine, Don Diego, a Navajo Indian. He asked us to put a resolution in the record which I ask be included at this point.

(The resolution follows:)

RESOLUTION

Whereas Pueblo Indian people of New Mexico have contributed to the economy and growth of the State and rely upon the purity of the waters therein for domestic and agricultural uses; and

Whereas some of the important rivers and streams, such as the Rio Grande, and the Rio Jemez, and the Rio San Jose, serve domestic, commercial, and irrigation needs for our people; and

Whereas there exists a genuine concern over the pollution of the streams in the Rio Grande Valley and other areas, posing a threat to the health and safety of the people who depend upon these waters for their use; and

Whereas the Pueblo Indian people have found that this water pollution seems to occur mostly when the natural flow of the water is low, at which time more refuse from storm sewers and silt, etc., flow into the main streams, as well as the contributions of waste from the ever-growing trend toward development of properties upstream without regard to welfare of water users downstream, thus increasing the seriousness of this problem: Now, therefore, be it

Resolved, That we hereby take official notice of this possible threat to the health and safety of the Pueblo Indian people in the Rio Grande Valley, and elsewhere in the State of New Mexico where this situation exists, being aware of the possible adverse effect on the agricultural and economic future of water users in our pueblos, do hereby respectfully request that a serious study be made into this matter of pollution of our streams to insure the health of our people and the natural growth of our agricultural crops, and to the end that this problem be eliminated.

(Signed) DIEGO ABEITA,
Chairman, Irrigation Committee, All Indian Pueblo Council.

Senator ANDERSON. The first witness is from the New Mexico State University, the vice president of research, Dr. Duncan. We are very happy to have you here and appreciate your coming. I was very pleased yesterday to have a fine conversation with Dr. Corbett, the president of the university, and a longtime friend and a wonderful man. I am sorry that his situation was such that he could not come. But we welcome Dr. Duncan in his place.

STATEMENT OF DR. RICHARD H. DUNCAN, VICE PRESIDENT OF RESEARCH, NEW MEXICO STATE UNIVERSITY, ACCOMPANIED BY DR. RALPH STUCKY, DIRECTOR, WATER RESOURCES RESEARCH INSTITUTE; AND DR. NERANDA GUNAJI, PROFESSOR OF CIVIL ENGINEERING

Dr. DUNCAN. First, I was asked by Dr. Corbett to express his regrets for not being here, Senator Anderson, as he has taken such an interest in this legislation.

I will read through our statement and then answer any questions you may have.

New Mexico State University welcomes this opportunity to present this statement to the Subcommittee on Water and Power Resources of the Senate Interior Committee in Albuquerque, N. Mex.

New Mexico State University is well qualified to make an opinion on this subject by virtue of its large research and development program, its long concern with agricultural research, and the fact that it is the designated State agency in water resources research. The subject is one of interest to the whole Nation, but it is especially important to the arid regions of the Southwest and New Mexico.

It is necessary that water in the atmosphere, as well as water in rivers, lakes, and oceans, be considered as an important natural resource. Augmentation of water from the atmosphere is one of the important facets of the overall effort on weather modification and control of climate. It must be recognized that weather modification seeks to change the efficiency of natural processes in order to create a better environment for all people. The complexities of problems involved, therefore, will encompass many diversified fields of science and engineering and each field will require the same competence and concentrated efforts of those who are to solve the problems. When approached by the Nation in this manner, overall scientific advancement in the area of weather modification will be assured.

The initial effort in weather modification was in the fulfillment of the requirements of the Department of Defense. This was followed by research in the universities largely sponsored by the National Science Foundation and by pilot projects supported by industry to fulfill their own specific needs. The time has now arrived for a coordinated national program relative to accelerating the development of scientific knowledge and to apply the available knowledge to the welfare of mankind. This requires the highest level of national support and coordination.

Senate bill S. 2875 recognizes the need for increased water resources from the atmosphere. It also incorporates within the same agency the operative and regulatory functions. Since separation of power is a recognized principle of American law and to avoid conflict of interest which may eventually develop, it is suggested that regulatory powers of this bill be separated and be made the topic of another bill. Regulatory powers of weather modification should be assigned to a board or a commission established by the Federal Government and independent from any operative body of the Government. The Federal Power Commission and the Civil Aeronautics Board are examples of separately appointed regulatory bodies of the Federal Government now in use. During the formative period of such a board, it is recommended that the responsibility of regulatory activities of weather modification remain with the assigned responsibilities of the National Science Foundation, where it was placed under Public Law 510. This will insure continuance of the existing programs without interruption and confusion.

This bill also recognizes the problem of liability. It is, therefore, necessary to pass appropriate legislation at the earliest possible opportunity to protect the individual, the Government, and other agencies who are engaged in weather modification efforts.

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Areas of weather modification which are of human necessity and of great interest to specific mission-oriented agencies of the Federal Government are as follows: general circulation modification, U.S. Weather Bureau; severe storm modification, U.S. Weather Bureau; hurricane dissipation, U.S. Weather Bureau and Department of Defense; hail and lightning control, Department of Agriculture; and supercooled fog suppression and modification of warm fog, Federal Aviation Agency and Department of Defense.

The appropriate committees in the Senate and the House of Representatives should recognize the importance of weather modification and encourage other mission-oriented agencies of the Federal Government to fully explore the potential benefits of climate control for the welfare of the Nation.

In conclusion, New Mexico State University recommends that—

1. S. 2875 be the first realistic engineering step toward increased national efforts to fulfill those portions of conclusions presented in the two reports of the National Academy of Science and a report by special commission of the National Science Foundation.

2. The Department of the Interior be the agency of the Federal Government for those aspects of weather modification related to increasing the yield of water from atmosphere as a part of its responsibility in the management of the Nation's water resources.

3. The other scientific mission oriented agencies of the Federal Government who might benefit from climate control be directed to formulate their plans and requirements and apply for support directly from Congress.

4. An independent regulatory board be formed to deal with licensing and legal problems of weather modification.

5. Appropriate legislation concerning liability be enacted at the earliest possible opportunity.

6. The National Science Foundation be directed and encouraged to expand its research activities and continue its present responsibilities in the field of weather modification and climate control.

7. The universities, research centers, and industries concerned with atmospheric science be encouraged to continue their activities as predominant forces in the Nation's program in climate control.

8. The coordination of those Federal agencies involved in weather modification be performed through the Office of the Science Adviser of the President.

This bill, upon its enactment, will greatly affect and enhance the management and production of the Nation's water resources.

New Mexico State University wishes to express sincere thanks to this committee for this opportunity to state its views in relation to S. 2875. Thank you.

Senator ANDERSON. Dr. Duncan, you say: "The National Science Foundation be directed and encouraged to expand its research activities and continue its present responsibility in the field of weather modification and climate control." Does that mean that the new work on weather modification would be in the National Science Foundation?

Dr. DUNCAN. No, sir.

Senator ANDERSON. It has it now.

Dr. DUNCAN. It has it now.

Senator ANDERSON. And they are going to continue. You wouldn't have any activity in the Department of the Interior, would you? Isn't that what you mean?

Dr. DUNCAN. I think this is not necessarily what we mean. We would like to see the Department of Interior certainly have a weather modification program. Water resources is a part of it. The National Science Foundation has a certain amount of responsibility now for weather modification research and it is quite possible that they could continue with the programs of a fundamental nature rather than the applied ones. I think this is essentially what we mean by number six.

Senator ANDERSON. Earlier you suggested also that the regulatory authority be a separate group. You recognize that one of the reasons why regulatory authority was proposed to be with the agency in control was if you are going to have weather modification, you probably are going to have cloud seeding and you need to know if national experiments get any results. The great trouble in the early days of cloud seeding was that somebody else came along and seeded, too. You had no way of judging how the experiment came out. Dr. Workman at one time was in charge of some work here in the State and he was working in the general direction of Project Cirrus. He would seed the clouds here regularly but a rancher also seeded at the same time and neither one of them had knowledge of what the other one was doing. I think the regulatory part is to prevent conflict with a nationwide experiment. Do you think the regulatory agency should be what?

Dr. DUNCAN. I did not understand your question.

Senator ANDERSON. What group do you think should regulate it? Look at No. 4:

An independent regulatory board be formed dealing with licensing and legal problems of weather modification.

Now, that's the stumbling block we hit in 1952, because people were doing cloud seeding under contract with counties and farm organizations and so forth and they were objecting to any regulation by the Federal Government. Do you object to regulations?

Dr. DUNCAN. Well, I think that some kind of regulation is necessary.

Senator ANDERSON. You said it should be a separate agency. What sort of agency would you set up to do that?

Dr. DUNCAN. I am not sure, sir.

Senator ANDERSON. The hope was, in the minds of many people, that the agency which had charge of trying to increase rainfall and hence benefit agriculture should also have some power of regulation so those who were doing private experiments would conduct them in such a fashion that would not interfere with a national experiment. You remember that Dr. Langmuir was trying to find the effect of seeding once and he couldn't find out because one man did more seeding than the Federal Government did and it completely nullified the effects of Langmuir's experiment.

Dr. DUNCAN. We appreciate that point.

Senator ANDERSON. What about the increase in precipitation in this valley, in this State, in this area?

Dr. DUNCAN. Twenty percent.

Senator ANDERSON. Ten or twenty percent?

Dr. DUNCAN. Twenty percent would be a tremendous boon to the entire State I should say.

Senator ANDERSON. Is manpower available to conduct a greatly expanded program?

Dr. DUNCAN. In this State?

Senator ANDERSON. Yes.

Dr. DUNCAN. Yes, sir.

Senator ANDERSON. Senator Bible.

Senator BIBLE. Thank you very much, Mr. Chairman. I have, I believe, the same concern that you did with Dr. Duncan's statement. I have difficulty in reconciling his second conclusion with his sixth because I cannot see, maybe you can make it clearer on this, Doctor; your second conclusion is:

> The Department of the Interior be the agency of the Federal Government for those aspects of weather modification related to increasing the yield of water from the atmosphere * * *.

The sixth one says that the National Science Foundation is directed and encouraged to expand its research activities and continue its present responsibility in the field of weather modification. Where is the distinction between those responsibilities?

Senator ANDERSON. Dr. Gunaji can answer if he wishes.

Dr. DUNCAN. Dr. Gunaji and I have discussed this and he helped me prepare it and I believe he has a statement which amplifies what he would like to say.

Senator BIBLE. My question may be premature.

Dr. GUNAJI. No.

Senator ANDERSON. It is a very important question. It is very different from what we are suggesting and what you are suggesting.

Dr. GUNAJI. I positively feel that lots of things need to be done in the area of basic research in weather modifications and cloud physics. The National Science Foundation has supported this work, this basic work, and they should continue to support basic breakthroughs in the area of weather modification. This has now been changed to some other agency. We would like to see them play some kind of a role in the basic science on what we have been doing and this is what we intended to be in that statement because I feel that we should distinguish between basic science efforts and applied projects, or applied research, and the National Science Foundation would probably be the agency that would continue its work of basic sciences as they have been doing in the various sciences.

Senator BIBLE. And you would limit the Bureau of Reclamation to the applied sciences? Do it directly or through various universities, is this what you are saying?

Dr. GUNAJI. You can interpret it so, I think.

Senator BIBLE. This has been a longtime conflict and we must come to grips with this problem. This is where we always seem to head: Is this controversy between NSF, the Weather Bureau and the Bureau of Reclamation or another agency? The attempt of this bill is to reconcile it and knock some heads together so we are all working in the same direction.

Dr. GUNAJI. Yes. I hope the Interior Department, or the Bureau of Reclamation, has a separate mission as far as weather research is

concerned to increase the precipitation and to increase the water resources of the Nation.

Senator BIBLE. I certainly agree with you on that.

Dr. GUNAJI. So, if you assign it to that agency, the basics, then the controversy will come up: Why should an agency like the Bureau of Reclamation do basic research? This is the point I am trying to make, that there is enough work to be done in the area of weather modification overall, including the five different areas that we mentioned, and each mission or agency that has this particular item should identify themselves with the particular kind of weather modification. The Bureau of Reclamation or the Department of the Interior, by the nature of the work, let us say, has been the Nation's water resources agency and has had the management of it. So, the responsibility or part of that responsibility should stay with the Department of Interior. This is the point I am making.

Senator BIBLE. Thank you, Doctor. I might ask just for information: What type of contract does the New Mexico State University have with the Bureau of Reclamation? Do you have a participating contract to do certain research? Is that basic research?

Dr. GUNAJI. I would say from the viewpoint that it is applied and basic both, because there are certain facets—well, we are not having results that are there. We need to know some more basic things. We are investigating the basic nature of the problem but I would say more or less in applied research. We have a mission that we intend to assume over a period of 10 years.

Senator BIBLE. What is that mission? Is this cloud seeding?

Dr. GUNAJI. Yes; increasing precipitation through cloud seeding in the State of New Mexico. We are at the moment making a physical study to determine the areas where this could be profitably conducted and from where we could get some kind of information to see how our experiment turns out.

Senator BIBLE. Does the research institute actually do cloud seeding by airplanes?

Dr. GUNAJI. At this time we have not done any airplane cloud seeding. We are thinking in terms of high mountain elevations where we can reach low clouds, so we still use cloud seeding but not through aircraft at the moment.

Senator BIBLE. I have only one further question, Mr. Chairman, if I might ask it. I don't want to cut into the time of the witnesses. Is it possible, Dr. Duncan, to give an estimate of the total price tag to move weather modification studies forward? Can you do that? How much is this going to cost? You break it into missions and maybe this is as good a way as any to do it. You give the Weather Bureau a mission. You give the Department of Agriculture a mission. You give the Interior Department a mission. You give National Science Foundation a mission. Now, we put all those missions together, can you translate that into dollars as to total cost per year?

Dr. DUNCAN. I had not made any attempt——

Senator BIBLE. It is a difficult question.

Dr. DUNCAN. It is a very difficult question. I haven't made any attempt to put any kind of cost estimate on our national program for all possible missions.

Senator BIBLE. Can you put a timetable on it? That would depend a great deal on the funding, I'm sure. I would like any thoughts that you may have. Is this a 5-year program, 10, 20, or 25?

Dr. DUNCAN. The only aspect of this that we have put very much attention to is a possible research project which we might do involving investigations of New Mexico weather and seeding for purposes of building up snowpacks at mountain levels and this sort of thing. I would suspect that we could produce within a period, in that particular research program, of 4 to 5 years. It would cost $200,000 to $300,000 a year for that one program.

Senator BIBLE. This would be for the New Mexico program?

Dr. DUNCAN. Right.

Senator BIBLE. Within your own New Mexico State University?

Dr. DUNCAN. That is right. But as for attempting to put a cost on a national program, I would make no attempt to do this. Now, I did notice that there was some mention in the bill of essentially that same recommendation in one of the reports of the National Academy of Sciences.

Senator BIBLE. Thank you, Doctor, and thank you, Mr. Chairman.

Senator ANDERSON. I am just wondering Doctor. You said you were doing basic and applied research. Why do you think that the Department of Interior could not do the same thing?

Dr. GUNAJI. We can the same way as is being done in the space program. There are a lot of space projects which we are doing without the basic research. We don't have the pattern to move and we don't get it from the price tag but the space agency doesn't do basic, it has enough applied work; others do basic at the same time. As a taxpayer I don't care how much it costs. I'd rather have a man on the moon. I will pay my taxes, let me put it this way.

Dr. DUNCAN. I would like to draw another parallel here which would clarify and help to resolve the difficulty between two and six. Let's consider laser, in which various agencies now are backing a great deal of engineering as well as some basic research attempting to get information to be applied. At the same time, the laser studies in gas physics and solid physics goes back to the National Science Foundation. It was not our intent here to exclude the National Science Foundation from basic studies in climatology and atmospheric physics and this sort of thing. But certainly the subject of weather modification itself, we agree, should be with the Department of Interior.

Senator ANDERSON. Senator Jordan.

Senator JORDAN. Dr. Duncan, how long has the New Mexico State University been engaged in weather modification research?

Dr. DUNCAN. At the present time we have a right to get in this field. We have done a great deal of work in water resources but to my knowledge we have not done any weather modification research yet.

Senator JORDAN. You have not done any weather modification research?

Dr. DUNCAN. This is correct.

Senator JORDAN. I see. You have a strong department of water resources?

Dr. DUNCAN. This is right: a strong school of agriculture; a strong engineering capability in our physical science laboratory. We have all of the basic staff and facilities to move ahead with this kind of research but we have, as yet, not done any.

Senator JORDAN. Thank you. As you envision this organization at the Federal level, planning various aspects of the work, to involve several departments, and you end up with your recommendation No. 8:

> The coordination among mission-oriented Federal agencies involved in weather modification be performed through the Office of the Science Adviser of the President.

Now, what is your idea of putting this coordination in he office of the President? I think I agree with you that it has to be in the White House. It has to be someone topside. Will you elaborate a little and give me an answer?

Dr. DUNCAN. Well, all of these things, from one on, are intended to be suggestive and I certainly don't feel that I am sufficiently an expert on Government organization to recommend the best possible place for this, but it seems to me that various agencies have a valid interest in some kind of climate modification. Now, it isn't always true that this interest is related to using the atmosphere as a resource for water. For example, smog control, fog control, is an entirely different kind of thing. It would seem to me also that various agencies are going to be engaged in climate modification research and there is very likely to be some overlapping or some controversy and somewhere along the line this has to be resolved. It would probably have to be resolved at a fairly high level.

Senator JORDAN. I think that this is one of your strong points. I agree the rivalry exists among the several departments of the Cabinet and rightly so but someplace along the line it has to be coordinated by someone who carries the power of the Presidency.

Dr. DUNCAN. In drafting this, we looked for a high level place to suggest coordination.

Senator JORDAN. I think you are right. Thank you.

Senator ANDERSON. At the present time I think we are trying to coordinate through the Bureau of the Budget.

Dr. Stuckey, do you have a statement?

Dr. STUCKEY. Just in answer to your question about how much moisture might be brought into the State by a 10-percent increase in precipitation: The present precipitation in the State of New Mexico produces about 90 million acre-feet of water a year. If this were increased by 10 percent, it would be 9 million more acre-feet of water, which would be a sizable increase. We are using only about 3 or 4 million acre-feet that we are getting our hands on actually. So, it would be a major increase.

Senator ANDERSON. I do hope, Doctor, that you take the view of looking at these recommendations Nos. 2 and 6. Not long ago a very shrewd newspaper person in Washington read some statements by a certain Senator on Vietnam and he read some other statements by the same Senator on the other side of the question. He said: "I think it's important to bring these two Senators to the bargaining table." And we would have you bring these two statements to the bargaining table and compromise them.

Dr. DUNCAN. We will.

Senator ANDERSON. Thank you.

The next witness is Max Edwards. We are glad to have you here.

STATEMENT OF MAX EDWARDS, LEGISLATIVE COUNSEL, DEPARTMENT OF THE INTERIOR; ACCOMPANIED BY DR. ARCHIE B. GOODMAN

Mr. EDWARDS. Mr. Chairman, members of the committee, I am here with Dr. Archie B. Goodman, who is the coordinator of atmospheric water resources for the Bureau of Reclamation in Washington.

Senator ANDERSON. We are glad to have you here also, Dr. Goodman.

Mr. EDWARDS. Mark Twain, in a speech in New York City to the New England Society on December 22, 1876, is supposed to have quipped, "Everybody talks about the weather, but nobody does anything about it."

A newspaper reporter named Charles Dudley Warner claimed that he said it first but nobody has ever paid much attention to him. He even wrote an editorial in the Hartford (Conn.) Courant 14 years later complaining: "I guess it's no use, they still believe Mark Twain said it, despite all my assurances that it was Warner."

Regardless of who said it, of course, they were both wrong. We are doing something about the weather, and this challenge to successfully modify our atmospheric water resources appears truly as significant and exciting as anything on the horizon of the 20th century.

I wish to thank the committee for allowing me the privilege of appearing before you here in my home State of New Mexico, but more particularly for permitting me to be briefly identified with the goals of a program which will be of such tremendous benefit to all mankind. I am confident that this is the kind of a challenge Senator Anderson enjoys as chairman of this committee, and I am further confident that his pursuit and tenacity will place weather modification alongside the other great legislative milestones he has sponsored in the field of natural resources.

Now, S. 2875, being considered by this committee, was introduced by Senator Anderson, for himself and 20 other Members of the Senate from both political parties, including Senator Bible and Senator Jordan. In its broadest terms the bill directs the Secretary of the Interior to formulate and carry out a comprehensive program of research and operations directed toward greater yields of water from our atmospheric resources throughout the entire Nation.

Science has made long and rapid strides in the field of weather modification and most of the scoffers have been silenced, but ultimate success will be buttressed on a foundation of fundamental knowledge that can be realized only through scientific research of the complex physical and chemical workings of the atmosphere. This bill is designed to accomplish that objective.

The hopes of President Johnson were expressed in his message to the Congress on weather modification, February 21 of this year, and I quote:

> Highly encouraging steps are being taken toward establishing safe and effective programs for modifying weather. We can now begin to see the day when such programs may become operationally feasible. This is an exciting and encouraging development * * * not only for Americans, but for men everywhere.

S. 2875 clearly and specifically states that nothing in the bill is intended to give the Department of the Interior increased authority over water research or meteorological programs of other Federal agencies,

nor does the bill in any way limit their programs or projects. My Department's first concern and interest is in developing the capability of influencing precipitation, increasing, decreasing or relocating it, because it is an essential part of our responsibility in managing the water resources of the Nation. As this distinguished committee knows so well, almost every bureau or almost every bureau in the Department of the Interior has some responsibility to actively participate in water resource programs, and our ability to successfully carry out the comprehensive program called for in this bill will better enable us to meet those responsibilities.

Our Bureau of Reclamation first became interested in weather modification in 1947 because of its inseparable relation to the Bureau's primary objective: reclaiming lands of limited moisture. The program's initial appropriation of $100,000 in 1962 has been expanded to almost $3 million for 1966, and with the guidance of this committee we expect the program to grow according to the demands of the Nation. And these demands will not be limited to the supply and management of water in our Western States. As a nation, we are learning the hard way that even in areas which have enjoyed a traditional abundance of water, drought and pollution have no geographic boundaries.

The bill before your committee, of course, does identify a number of serious problems relating to property rights, personal injury, liability, indemnity, and licensing. You don't have to be a lawyer to recognize the complexity of the problems which are bound to arise from our efforts to modify the weather. In this connection, I might add that the Department has presently under consideration a number of proposals for studying the inevitable legal problems which we will face as the program moves forward.

I wish again to thank the chairman and the members of the committee for this opportunity to be here, and to commend you for your interest in what surely will become one of the most important scientific programs of our time. Thank you.

Senator ANDERSON. Thank you, very much, Mr. Edwards. Do you think that this is a good undertaking for this part of the world?

Mr. EDWARDS. I certainly do, sir, absolutely.

Senator ANDERSON. And the Department of the Interior supports this action?

Mr. EDWARDS. Yes, sir; we thoroughly support the objectives of this bill.

Senator ANDERSON. Senator Bible.

Senator BIBLE. The only question I would ask Mr. Edwards or Dr. Goodman is to give me their thoughts as to the proper mission for the Bureau of Reclamation within the Interior Department and its relation to the National Science Foundation. How do you see the loads of these two agencies?

Mr. EDWARDS. I will comment on that question because I think it is very appropriate and very interesting. If I don't answer it to your satisfaction, I will ask Dr. Goodman to say something.

The Department of the Interior recognizes its primary role as the manager of the water resources of the Nation. As I said in my statement, in almost every bureau there is a water management responsibility. It is not just limited to the Western States. The Bureau of

Reclamation's role and responsibility would initially, of course, be to increase the precipitation to allow more water in the reservoirs which we have constructed and will probably construct in the future. We are not concerned directly with hail suppression; we are not interested or directly concerned with that. The primary mission of the Bureau of Reclamation is with control of precipitation. We think that is a heavy responsibility. We think that hurricane studies may better be the responsibility of the Navy and that weather prediction remain at the Department of Commerce. I don't know that this is a satisfactory answer to the question or not.

Senator BIBLE. Well, I think it helps develop the difference in the missions as you envision them from a departmental viewpoint in the Department of the Interior. Is the jurisdiction of the Bureau of Reclamation limited to the 17 Western States?

Mr. EDWARDS. Yes, sir, it is, but not in their research programs or water resource management responsibilities.

Senator BIBLE. Well, if some of our New England neighbors were interested, as they might very well be because of the drought conditions in that part of the country, what could you do to help them? What if the New England States were to ask the Bureau of Reclamation for a research project or a cloud seeding project; would the Bureau of Reclamation supply it?

Mr. EDWARDS. I think the Bureau would be able to assist them; yes, sir.

Senator BIBLE. I was interested as to the overall jurisdiction of the Bureau of Reclamation. I thought it was limited to the 17 Western States. Do you think not?

Mr. EDWARDS. I think not. I think the Congress has given the Bureau broader responsibilities in this particular area.

Senator BIBLE. Do you have any comment as to the money scope of this proposal? You recognize that the authorization in the bill is proposed at $35 million for the first year, $50 million for the second year, not to exceed $70 million in the third year and such sums thereafter as may be necessary. Are those figures realistic?

Mr. EDWARDS. Well, I think it might be premature for me to have to answer that but I would ask Dr. Goodman if he might have a comment.

Senator BIBLE. Doctor, we'd be very happy to get your views on this.

Dr. GOODMAN. Thank you, very much, Senator. I certainly want to concur in the observations of Max Edwards here on the role of the Department of the Interior and the Bureau of Reclamation. With respect to the amount of funds required to carry on a nationwide program to develop our atmospheric water resources, I think it is logical to expect the need for funds in the maximum amounts contemplated in this bill. These amounts are necessary in order to make substantial progress over the next 8 to 10 years, and that is the period being considered in this bill. Expenditures on the order of $1 to $2 billion would seem to be indicated. The product or results of such research would be valued in the billions of dollars.

Senator BIBLE. Well, I am sure that is to be deductive and I recognize how difficult it is to put either time limits or money amounts on this but if I understand you correctly, you say somewhere in the

neighborhood of $1 or $2 billion to be spent in 10 years would lead us to some startling breakthroughs?

Dr. GOODMAN. That would be our objective. It should be a national objective; yes, sir..

Senator BIBLE. Would this $1 to $2 billion be moneys expended only by the Bueau of Reclamation or is this the total pricetag for all the commissions?

Dr. GOODMAN. Estimates are that it might be the total pricetag for all agencies operating in this mission-oriented field of atmospheric water resources. I would like to add here at this point that there is no significant conflict among the mission-oriented agencies in carrying out these programs. For example, we are cooperating very well with the National Science Foundation. As a matter of fact, the Bureau of Reclamation program is today where it is for two very good reasons: One, the strong support of this committee; and second, the fine basic research that has been carried on over the years by the National Science Foundation. Most of the places where we are carrying out our field projects have been selected on the basis of reports prepared for the National Science Foundation. And I would like to commend the Science Foundation for its program. It is cooperating fully with the Bureau of Reclamation program. The same thing can be said about the Department of Agriculture with its lightning suppression work and their hail suppression work. We are cooperating with all agencies and we have a feedback of information among all the agencies.

Senator BIBLE. I appreciate the answers that you have given, Mr. Edwards and Dr. Goodman. I think it is important in building a record on this bill to nail down as best we can some type of a dollar figure and some type of time limit. I am prompted to do that by the experiences that we have had in my own State with the Desert Research Institute, where they are doing remarkable work, I believe, but they do have some problems in staffing and it is very difficult to get manpower and men of scientific know-how to break old ties and come aboard, to use the colloquial expression, unless they have some idea of what the tenure is going to be. This presents a problem and it becomes a Federal responsibility, as I see it. We should not encourage the universities in these cooperative programs unless we are ready to back it up for a definite period of years because otherwise it is unfair to the university with whom the Federal Government is dealing.

Dr. GOODMAN. I am delighted to hear you bring this into the record, Senator Bible. As you will recall when the hearings were held by this committee in 1964, the Commissioner of Reclamation, Floyd E. Dominy, in essence, said to the committee, "Don't give me this new expanding program, unless you are willing to support it on a long-term basis and not jump funds up and down from year to year." We plan to carry out this program through such organizations as the ever-excellent Desert Research Institute, the University of Wyoming, and other areas. In order for them to bring teams together to carry on this program, they have to give some assurance to the people coming in that they are going to be there for 5 to 10 years or longer.

Senator Anderson's own State is now beginning to assemble teams to operate in this field. With regard to manpower, certainly there

is always a shortage of top-grade talent. We believe that such organizations as New Mexico State University can, in time, bring together a very excellent team along the lines of the Desert Research Institute in your own State. The same thing can be said of a number of States in the West.

Senator BIBLE. Thank you, very much, Doctor. Thank you, Mr. Edwards.

Senator ANDERSON. Senator Jordan.

Senator JORDAN. Mr. Edwards, most of the witnesses who testified on this bill devoted their attention to the technological, scientific, and engineering aspects. In your statement you bring in the inevitable legal problems. You make a statement:

> In this connection, I might add, that the Department has presently under consideration a number of proposals for studying the inevitable legal problems which we will face as the program moves forward.

Now, what are the nature of those problems as you see them, the legal problems?

Mr. EDWARDS. Well, problems of liability, for example, of contractors that the Department might be dealing with. They are hesitant to expand their operation unless they have some protection either from an insurance indemnity, which would be highly expensive, and in turn, be more expensive for the Federal Government, and also problems of personal liability in conducting the experiments as they go along. But this is a very appropriate question in view of the fact that right now the Secretary of the Interior is negotiating with several universities to come up with a study which will be the basis for further work that we will be doing as to what solution we might have for the legal problems involved. Traditionally, as you probably know, and I am criticizing the legal profession, lawyers tend to lag far behind actuality and it won't be until the accidents happen that lawyers will decide that they should get together and do something about it. Now, we are trying to initiate this study so that we will have the answers before the cart breaks down.

Senator JORDAN. As we move forward in this program and we do, in fact, modify the weather, isn't it quite likely that as one area benefits another area is likely to allege that "we were shortchanged because of the rain that would have come to our area," and as a practicing lawyer what do you see as a remedy that might be offered these people who allege damage by reason of man-regulated weather?

Mr. EDWARDS. Well, I think the answer is in highly sophisticating our technique so that we are actually controlling or modifying precipitation by increasing and decreasing it. However, although we have relocated it we can make mistakes by our own negligence. If you and I were trying to bring rainfall on Senator Anderson's property, we might accidentally rain out a ball game or flood another's land, and experience some liability. I can well recall back in 1947 when I had just joined law school at the University of Arizona and there was great talk about weather modification. We had a 10-minute break between the classes and we would stand in front of the law building there arguing about liability in cases just like this. It seemed to me at that time there was a law review article from Stanford University which was interested in trying to anticipate what these legal problems would be. And I think if we go to work now and try to formulate what the ex-

isting law might be and then try to establish some sort of legislative guidelines for the Congress and the State legislatures, that we would be well ahead of the game and that it would be time and money well invested.

Senator JORDAN. I think this is an area that needs a great deal of research. I had a little experience in another field. I worked on the St. Lawrence Seaway on the power well project and I know when we assumed the responsibility for regulating the level of Lake Ontario, took it out of the state of nature and manmade regulation took over, the people just lined up and said, "Who do we sue? The wave action cut the foundation out from under our homes. Where do we file a case?" So, I suggest that, as desirable as it may be to make rain in New Mexico and at the appropriate time, how do we stop the people in Texas or the people in Arizona or the people in Colorado from saying, "This is a storm that we had counted on." How are you going to do anything about that?

Senator ANDERSON. Thank you very much, Senator. That is a problem that we are going to have to wrestle with constantly. There is a theory, however, that they will be able to successfully put more moisture in the gulf and, therefore, more moisture for everybody. We hope it will work. Thank you both, very much.

The next witnesses are from the New Mexico Institute of Mining & Technology, Dr. Bertholf and Professor Jacob. We are glad to have you both here. We appreciate the cooperation of the institute.

STATEMENT OF DR. WILLIAM E. BERTHOLF, NEW MEXICO WEATHER CONTROL AND CLOUD MODIFICATION COMMISSION; ACCOMPANIED BY PROF. CHARLES E. JACOB, PROFESSOR OF HYDROLOGY, NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

Mr. BERTHOLF. Thank you, Mr. Chairman and committee members. President Colgate would like very much to have been here and he sends his warm wishes for the success of this endeavor.

I am William Bertholf, resource economist and chairman of New Mexico Weather Control and Cloud Modification Commission.

In the field of atmosphere regulation and weather modification, a coordinated comprehensive program for augmenting water yield is probably the most effective short-run approach to beneficial utilization of the atmospheric water resource, if properly coordinated with a longrun scientific program.

In order to efficiently accomplish such a program, the Secretary of the Interior will need the scientific and technological help of the private, State, and Federal agencies now operating in this and closely allied fields. To be effective, the program must comprehend both disciplinary and interdisciplinary talents and resources throughout the hydrologic cycle. Coordination must incorporate a wise balance of program effort so as to achieve reasonable socioeconomic benefits in the most prudent time and manner. This would appear to be feasible within the proposed financing of the S. 2875 effort.

Social and economic jurisprudence very much needs the expert knowledge and testimony of scientists to help in decisionmaking. Many involved closely with weather modification feel that regulation

at the present time is premature and may hamper scientific progress. Scientists and engineers may rightfully consider that nothing should be done at this time to regulate the procedures of precipitation augmentation; but such will not deter the nonscientific community from turning to laws in an attempt to solve problems that might be attributable to weather modification. Unless coordinating steps are taken to study the weather modification problem as a comprehensive whole, it will undoubtedly be solved piecemeal.

Research of the New Mexico Institute of Mining & Technology has moved from the pioneering cloud seeding efforts to its present investigations of the relationship of atmospheric electricity to precipitation. In the long run there is yet much to be learned about the conditions under which precipitation takes place or is inhibited.

Thank you for this opportunity to be heard.

Senator ANDERSON. What are you saying should be in this bill?

Mr. BERTHOLF. I believe we are at the point where we have a great deal of information around in various agencies and areas that needs to be pulled together. In the first instance, this will be a communications organization job. In our experience with the S. 2 water legislation this is what we found. Not a dearth of information, but the need to organize the information and where we were going from the present state of affairs. So to the end that this bill is setting out in this direction, we are very much in favor of it.

Senator ANDERSON. Mr. Jacob, do you have any comments at this time also?

Mr. JACOB. Thank you, Senator Anderson, Senator Bible, and Senator Jordan. We appreciate the opportunity to appear at this open hearing and express our frank opinions. There is a diversity of background and we have a respect for the opinions and views of our colleagues. I would like to enter a mild dissent if I might. I would like to paraphrase my statement with a very brief background.

I spent 11 years in the Federal Government in water resource investigation work which was of a high order and technical nature in geophysics engineering. Thereafter I became a professor over a period of 8 years at two institutions and for the last 18 years I have been a consultant and head of a small firm which has been engaged primarily in subsurface hydrological work in the development of ground water resources on an international scale as well as in this country. I have served on several consulting boards subject to the Secretary of the Interior, Department of Defense, and bureaus and agencies. I would like to say that I speak from this background. However, since most recently I have been a consulting engineer I would, perhaps, reflect that viewpoint more than any other. I have been at the Institute only since February 1 and I do not wish to impose my views as those of the university officials although they do pretty well summarize the consensus of their thinking.

Drs. Brook and Moore couldn't get away this morning from classes but will be here shortly and would like to have a small share of our time allocated if they might, Senator Anderson. It would be a very short time.

With regard to the proposed legislation, S. 2875, and its implementation, in order to appraise the result of future operations designed to increase the yield of water from the atmosphere, it would seem that we

must first have a better understanding of the present undisturbed regimen of atmospheric water circulation and its involvement with surface and subsurface waters. Accordingly, it is strongly recommended that close coordination be maintained between weather modification activities and inventories of surface and subsurface waters presently under the direction of the Secretary of Interior. It would seem obvious that combined atmospheric and land water balances must become regional in scope. In short, the hydrologic cycle, which heretofore has been dismembered, must be studied as a single body.

Although nothing new may appear in a simple recital of the history of water resource investigations in the United States, an attempt to appraise the significance of earlier reviews and evaluations of national water policy may be instructive. Of course, this material is not new to either the members of the committee or their staff.

The Water Resources Committee of the National Resources Committee reported in 1936 on its national drainage basin studies. This was the first comprehensive effort at a nationwide appraisal of water resources.

The first Hoover Commission on the Reorganization of the Executive Branch of the Government in 1947, as is well known, recommended a restructuring of the Department of Interior so as to better handle water resource and other investigations. Further recommendations relating to a transfer of the flood control activities and river and harbor improvement work of the Corps of Engineers to the Interior proved to be the greatest single obstacle to the desired restructuring. Irrespective of the propriety or timeliness, then or now, of consolidating such construction activities into one department, certainly the hydrologic research activities must be consolidated if the Federal Government is to accurately appraise its water resources.

The second Hoover Commission on Organization of the Executive Branch recommended in 1955 that "one Federal agency should be made responsible for collecting and reviewing the adequacy of hydrologic data."

By Senate Resolution 48 of the 86th Congress, the Select Committee on National Water Resources was—

> charged with making exhaustive studies of the extent to which water resource activities in the United States are related to the national interest and of the extent and character of water resource activities * * * required to provide the quantity and quality of water needed for use by the country's population, agriculture, and industry, between 1959, when the resolution was passed, and 1980 * * *.

The task of the select committee was ably carried to completion and skillfully summarized in a series of committee reports. These have served as invaluable guides to administrators and researchers in hydrology on local as well as national water resource projects. Because of the comprehensive nature of this effort, its repetition is not likely to be demanded or required for some time. However, we respectfully suggest that such information should always be currently available through the efforts of one single agency of the executive branch of the Government, authorized not only to maintain a comprehensive compilation of basic hydrological data but to provide an up-to-date evaluation of the state of development of our water resources and their future potential, together with a current and meaningful appraisal of the

state of the art and science of hydrology as practiced in the United States.

Senator Anderson, in an address before the 9th Annual New Mexico Water Conference in Las Cruces, March 19, 1964, emphasized that, and I quote:

> The solution of almost any major water problem now requires a mixture of engineering, biology, hydrology, law, chemistry, economics, and other technical subjects.

Continuing the quotation:

> Although the multidisciplinary character of water matters is generally an accepted fact, few, if any, Federal agencies are in a position to deal with them in those terms.

Senator Anderson continues—

> This is a limitation that is built in to most of the agencies, and not much can be done to modify that aspect of agency or organization.

We respectfully suggest, however, that a single Federal agency entrusted with the responsibility, not only for collecting hydrologic data but for analyzing those data, could, and wisely should embrace the full scope of water resources research. If I might interject here, such an agency should seek and use the talents such as lawyers, sociologists, and other people besides engineers and scientists, be sure to incorporate their findings into their thinking. Too often, it would appear, the objective of one Federal agency after another has been the collection of data in fragments, without the needed scientific evaluation that a comprehensive coordinated approach might provide.

In June 1961 under the joint auspices of the American Society of Civil Engineers, the Bureau of Reclamation, and Colorado State University, a symposium was convened on basic research in civil engineering fields related to water resources. Reflecting the concensus of five of the seven Panels in the symposium, it was recommended in the summary report that—

> A new Federal agency designated as a National Engineering Institute of Water Resources or some suitable equivalent organization be established to promote and coordinate civil engineering research in fields related to water resources, to receive and disburse funds for such research, and to coordinate and disseminate knowledge gained from the research.

Several of the Panels recommended that to insure effective coordination also in future water resources research activities in the Federal Government itself, a single water resources bureau or agency should be established. This report to which I make reference and from which I have quoted, together with other documents, provided part of the impetus and I feel, this is my personal opinion, provided part of the impetus that lead to the enactment of water resources research legislation.

By historical accident, some phases of resources research have been started and left behind earlier, perhaps with disproportionate emphasis, than other more critical phases of related research. We cannot emphasize too strongly the need for balance and proper timing in the initiation and expansion of these efforts. Each should be kept in proper perspective with the others.

Perhaps the implementation of weather modification or the "ingineering" of it in the field is a case in point. In comparision to the fundamental scientific phases of weather modification research and

also in comparison to the scientific and engineering research of other parts of the hydrologic cycle, the engineering research of weather modification may yet be untimely or premature except on a reduced scale until scientific principles that are established may be applied. It would seem evident that there is still the greatest need for scientific research in weather modification.

I would like to pause in order to interject, of course, you cannot draw a line between fundamental and applied research but there is a zone to distinguish it.

As an illustration of a phase of the hydologic cycle that deserves greater emphasis and one which by all odds should yield a greater return with smaller investment, I cite only one case. This relates to the great wastage of fresh ground water beneath the gulf and Atlantic coastal plains of the United States. It is conservatively estimated that more than 1 billion cubic feet of ground water is wasted to the ocean each day by seepage from deep strata extending under the sea. Research is urgently needed on reducing this leakage of fresh water to the sea and at the same time controlling salt water encroachment.

The traditional way of exploiting ground water in these areas has been to pump the near-surface or shallow aquifers first, generally causing salt water encroachment and often rendering unpotable not only the water in the top aquifers but also that in the very extensive underlying aquifers. One or two percent of sea water can render fresh water unfit. Thus, large volumes of ground water are ruined by methods which presently recover only a small proportion of the available supply. Much-needed research could lead to the recovery of many thousand billion cubic feet of water under the gulf and Atlantic coastal plains, which might be ruined if present practices were to be continued. This is just one example of ground water research that would pay immediate dividends.

To continue: In short, we urge a prudent measure of balance in newly proposed activities and a practical sense of perspective. It is our considered opinion that the empowering of a single research agency with a coordinated evaluation of water resources, including atmospheric resources, should guarantee this balance and perspective. A new water resources agency in the Department of Interior, and I might insert my personal selection, built around the Water Resources Division of the U.S. Geological Survey and, as have many other persons suggested, should include, by transfer, the hydrologic research and runoff forecast efforts of several other major agencies presently participating in these activities: for example, the Hydrometeorologic Service of the Weather Bureau. And I would like to add this note: surveys of the USGA.

In our opinion, the coordination or direction of both engineering and scientific weather modification research should not be entrusted to construction or project operation agencies. Because of the high level of the scientific research required, it must be entrusted to a scientific research agency, and, for obvious reasons, one devoting its main effort to water in all its aspects and phases.

In order to man the research program contemplated in this legislation and that involved in the Water Resources Research Act, educational institutions will be hard pressed to find qualified personnel. It would seem judicious, without disrupting Federal agency

activities, to urge some Government employees to take their place in educational and other research institutions and in the private sector of the water resources profession. As we contemplate the enormity of the task we face, not only as citizens of the United States but as inhabitants of the world, to meet the runaway demand for food, and that means for irrigated acreages, the talents of all trained persons experienced in water resource investigation and development will surely be required. Among those most ably trained are, of course, many scientists and technicians in Government service.

In keeping with President Johnson's oft expressed intention to increase the economy and efficiency of Federal Government services, we respectfully suggest that a consolidation of water resource activities would directly lead to economy and efficiency.

In conclusion, the New Mexico Institute of Mining and Technology has long been engaged in research in atmospheric physics, moving from its pioneering efforts in cloud seeding to present investigations, for example, of the relationships of atmospheric electricity to precipitation. It is our considered opinion that we yet have much to learn about the occurrence and enhancement of precipitation. Under certain conditions, seeding of clouds may even inhibit precipitation. Although I might interject, these are uncommon conditions.

I thank you very much for this opportunity to appear before your committee and express our opinions. We shall be happy to respond to any questions or to clarify our views.

Senator ANDERSON. Thank you. I am sure this statement is a very good one but just how do you stand as to S. 2875?

Mr. JACOB. I believe it is a very important piece of proposed legislation, Senator. I think this can best be done by a single agency empowered, as suggested here, of course, to work through cooperative interests by contracts through Federal, State, and local agencies. I think we can do no better than build upon a pattern which is well established in the Interior and in the departments; namely, cooperative efforts. I think you would be wrong to dismember, if I may say that, the engineering from the scientific phases of this. I think that the NSF activity is important and sound and I believe it should not be phased out rapidly. But on the other hand, I think that the time is long overdue for the Federal Government to have a single agency that has the whole hydrologic cycle in its purview and that would include precipitation and snow and runoff and everything in one agency. I think this is the only change that I would suggest where the legislation that has been drafted refers to "the authority for surveillance of other agencies." I think that it may now be timely to modify that with regard to certain of the agencies, I could name six, in different departments. Obviously, with regard to many other activities on water the authority that the agencies have would have to remain as they are now but I am speaking specifically of research. Does that answer the question?

Senator ANDERSON. Well, in a way, but you have a practical problem of recommendations that have been made by the National Science Foundation and others that don't exactly fall in line with the view that you have taken there. Now, on your paper you say:

> In our opinion, the coordination or direction of both engineering and scientific weather modification research should not be entrusted to construction or project operating agencies.

Does that mean that you would not entrust it to the Department of the Interior?

Mr. JACOB. Well, I mean agency within the Department, sir. I do not believe it should be entrusted to an agency whose primary job is to construct and operate water research projects or river regulation but rather in an agency within the Department of Interior that is a scientific research investigative agency.

Senator ANDERSON. Do you recognize that people have suggested that hurricane control should now be in the Department of Interior? But increased precipitation, which is mainly what this bill is about, where do you think it should be placed?

Mr. JACOB. I would agree, Senator, with you that increased precipitation, which is for water supply purposes primarily, should be in the Interior and it should be in such an agency, and I am talking primarily about the research developmental aspects. Quite obviously, there are going to be other people who are interested in cloud modification: the Air Force, FAA, for clearing runways, and people interested in breaking up storms if they can. But this is not the major objective in this legislation. The major objective is to understand how to make the rain fall and how to be able to prove that you made it fall and this involves the whole hydrologic cycle. This cannot be dismembered and parceled off into a corner. It has to be, in my humble opinion, in a place where there are people who understand, and I might parenthetically add there is no basic of hydrology that we have mastered. Working in the Geological Survey, the Bureau of Reclamation, you have just done small pieces but have not mastered the hydrology of a single basin in this country.

Hydrology needs to be given a push to make it a material science. It has had some push through your able assistance but it needs, I feel, a great deal more coordinating.

Senator ANDERSON. Senator Bible.

Senator BIBLE. I think its a very splendid paper, Mr. Chairman. I want to compliment Professor Jacob on it.

I only want to query on one facet which rather intrigues me. This is the first that I have heard comment on this. I haven't heard all the testimony. That is, the part of your paper that is devoted to ground-water research. It is an intriguing thought that it may be possible to save hundreds of millions of acre-feet, if I understand you correctly, if that is your position. Who is charged with that responsibility? Isn't that a work of USGS?

Mr. JACOB. That is right. It is under the Ground-water Branch of the Water Research Division of the Geological Survey.

Senator BIBLE. Well, what should they be doing that they have not been doing to bring it closer to saving all this water that we are losing underground?

Mr. JACOB. Well, I believe that they need to enlarge their research program on this. Another illustration I might offer, I think they have done an able job thus far. I might remark, of course, that this example I cited is in the humid part of our country, not available for irrigation, but it's just one example that we pulled out of many that were talked around the table at this symposium which I spoke of. Yes; I think they have done an able job thus far but I think that they are unbalanced as compared to weather modification activities

and desalting water and things of that sort. We need to bring certain things into balance and this is one that I would cite as an example.

Senator BIBLE. Well, I am intrigued with what you say about the need for greater ground-water research and the possibilities that it offers in the future as being a resource of much-needed water. I appreciate your statement a great deal, Doctor.

Mr. JACOB. Thank you, very much.

Senator ANDERSON. Senator Jordan.

Senator JORDAN. Thank you, very much, Mr. Chairman.

I think this was an excellent presentation that you have made here. I had some misgivings about how you would implement this program under a single agency such as you discussed without tearing apart a lot of the closely related activities. For instance, in Commerce, the U.S. Weather Bureau has to do with wind velocity and tornadoes and hurricanes and so on but how would you separate them if they have a water content to properly belong to your single agency but yet these people are charged with the responsibility of forecasting and researching in wind and weather as it affects the commercial fields? I see some real difficulty there in delineating a sharp line of responsibility.

Mr. JACOB. I see some difficulties also, Senator Jordan. I think these are not inseparable, however. I happen to be a private pilot and I rely very heavily on the excellent cooperation between the Weather Bureau and the Federal Aviation Agency and I think it is a similar kind of cooperation we can also have in water research. That is, the Weather Bureau would still be proponent of the atmosphere and there will have to be a cooperation. I realize also they will want to have their own activities in modifying weather for their purposes. However, I feel that the major objective of this legislation is for water supply, and I believe this should be singled out and in the hands of scientists and engineers and geologists who know and understand water in all forms. You see, the primary purpose of the Weather Bureau is differently oriented. It concerns only one link of the hydrologic cycle.

I believe, too, Senator Jordan, as you no doubt feel, one agency cannot handle all this. Of course, it is beyond my competence to remark about the legal ramifications of this. It is quite obvious to me that there may be need, in addition to a scientific body, a commission or board to handle certain problems that obviously are going to arise in this. And if the board needs, I could see that it would hire consultants who are experts to settle the problems that arise should it not be entrusted to the scientists themselves. This is always the practice of the Federal Government. I have very often served on Federal boards where the Secretary of Interior wanted to get an independent view on some matters that two of his bureaus could not agree upon and I think it is realized that this has been very successful. It has been used in the past and could be used for weather control, a commission or a board.

Senator JORDAN. One witness this morning suggested that the Office of Science Adviser to the President serve as coordinator. You would not agree that this is a strong enough organization really having coordination in one central authority?

Mr. JACOB. No, sir. I feel that you have committees of coordinators and I think it is time for water research or a water bureau with full

coverage of all water in one place. I think I one time served on a water resources committee and I know that we had excellent cooperation from bureau chiefs but committees really do not cooperate very much and I don't think that coordinators have too much influence, and all due respects to them.

Senator JORDAN. You made a good statement.

Senator ANDERSON. Dr. Horning, as Scientific Adviser to the President, has recently coordinated the patent policy and I had some participation in that. When we finished, I think we had completely dismembered all the ideas that we had started with because he had no authority to enforce what he was talking about. The President or the head of the Bureau of the Budget have a little authority over the purse.

Thank you, very much.

We welcome our neighbors from Colorado and we are very happy to have you here.

STATEMENT OF DR. WALTER O. ROBERTS, DIRECTOR, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH; ACCOMPANIED BY EDMUND L. WOLF

Dr. ROBERTS. Senator Anderson, with your permission I would like to invite my colleague and assistant, Mr. Edmund L. Wolf, to assist me.

Senator ANDERSON. We are glad to have you, Mr. Wolf.

Dr. ROBERTS. Senator Bible and Senator Jordan, it is a pleasure to be here this morning. It is a pleasure for me to have any opportunity to come to the State of New Mexico to be in this wonderful, wonderful place. I have made many trips here years ago as an astronomer to the Sacremento Peak Observatory, one of the outstanding basic research laboratories in the world in solar physics. So, it is a pleasure to be back here again.

Senator ANDERSON. They have a new telescope down in that area. You ought to try it out.

Dr. ROBERTS. Yes, sir. Well, if it hadn't been for the extraordinary atmospheric science problem I would still be an astronomer and probably be using that new telescope down on Sacremento Peak myself.

Senator ANDERSON. We still welcome you.

Dr. ROBERTS. It is a pleasure to appear before you and to discuss the promise of weather modification and of the atmospheric sciences in general. These hearings add to the evidence of a growing national interest in the atmospheric sciences and what these sciences can do for the benefit of mankind. There are few scientists, I think, who are not heartened by the prospect of a national effort to apply the fruits of their labor to practical problems.

Many highly qualified people have already appeared in hearings this year, both before your committee and before the Senate Commerce Committee. A comprehensive record has been built up through this, reflecting often conflicting views on our present state of knowledge, on our immediate ability to increase our water resources by atmospheric modification, and most important, on what kind of a national program will reap the greatest possible ultimate benefit.

The current state of the art of weather modification dictates a very high priority on ultimate benefits. You have heard that there is

statistical evidence that precipitation can be increased under certain circumstances. You have also heard that our knowledge at the present time is very rudimentary. Without further research and development, we would be wasteful and perhaps foolish to extrapolate our current experience immediately into full-scale operational river-basin-scale cloud seeding schemes. Nonetheless, we still know how to proceed along this path toward such schemes, and we are, I believe, at a stage of knowledge now sufficient to permit us to design some pilot schemes for specific river watersheds.

You have also heard that there are other potential methods of weather and climate modification that are, even though some of them are still in the speculative class, so important in their possible consequences that they merit a major scientific and engineering attack. In the next few years there is a good chance, to mention one of the least speculative of these prospects, that we can develop reliable and practical methods to lessen damage from hailstorms, especially in regions like the high plains, where such storms are frequent and damage is great.

The prospect farthest in time, and perhaps most speculative but also probably of the greatest value, if it can indeed be attained, is that of altering the dominant large-scale circulations of the atmosphere, and thus the weather and climate over whole continents or hemispheres. In connection with the problems of this region, even if our sights are set solely on the objective of increasing water available in drought-stricken or normally arid regions, the attack via modification of the large-scale circulation features of the atmosphere may prove to be the most promising. The history of past climates revealed in tree-ring records and superbly analyzed by the University of Arizona, by the migration of peoples, and by other means, amply illustrates nature's own, but still mysterious, means of climate modification. These effects can be very large.

Consequently, it is clear that we have only begun to tap the knowledge necessary to realize the full potential of atmospheric modification.

Nonetheless, we must not be concerned only with ultimate benefits when there are some significant benefits close at hand. Indeed, we have a clear responsibility to convert our current knowledge, rudimentary as it is, to reliable practical benefits in the shortest possible time, while still pursuing actively and vigorously our long-range goals. It is good to see the mounting support to pursue both long- and short-term objectives on a scale commensurate with their importance.

I might add that I feel these hearings and that this bill is a major contribution.

I would be glad to submit for the record a more comprehensive description of the current state of the atmospheric sciences; but since the committee has received many such statements already, I propose to move directly to a number of recommendations concerning a national program, as I see it. Then I shall briefly describe the work at the National Center for Atmospheric Research that is related to weather modification and the role NCAR is prepared to play in a national program.

As I see it, the following are some of the essential ingredients of a sound national program in the atmospheric sciences in general and

in weather modification in particular. Their relevance to S. 2875 is, I think, direct.

Firstly we must make a broad effort. The national effort must move forward on a broad front. The principal elements must be, first, a vigorous applied research and development program, leading to pilot operations and then, if justified, to full-scale operations, in order to follow up quickly on our current knowledge and on new discoveries as they come along; and secondly, a broad program in basic research on atmospheric processes, without which the most valuable weather modification application will never be reached.

The entire range of weather modification possibilities, both short and long run, must be attacked, including cloud modification to increase precipitation, suppress hail and lightning, and dissipate fog; including air conservation, methods to alter the atmosphere's radiative balance, and other measures to alter large-scale features of weather and climate. We will shortchange ourselves if we adopt a narrower concept.

Precipitation processes are intricately linked to the atmosphere's general behavior, and to other possible means of weather modification. It follows, therefore, that research on the augmentation of precipitation is the siamese twin of atmospheric research in general. If, for example, I were asked to set up a new national laboratory aimed at basic research in the weather modification domain, I would seek almost completely to duplicate the very kinds of talents that we have in our own NCAR today. This shows how nearly identical, in my mind at least, are the weather modification and the atmospheric research disciplines. Only when we reach the stage of developing specific applications, that is, in applied research and engineering, does it make sense, in my view, to creat separate efforts.

The following are some major considerations concerning the organization of the national effort that deserve, in my view, close attention.

For the present, diversity of effort is more important than close central management. Too much centralization at this stage of the game may prevent us from simultaneous and independent pursuit of all promising research and development leads.

It follows that we will get the most for our money through a balanced investment in basic research, applied research, development, and pilot programs. Large expenditures poured directly and immediately into operational efforts, without adequate research and engineering development, can waste a lot of money. Worse still, they can bring results so ambiguous that you could not tell whether there had been benefits or not. Though I would welcome the prospect of increased funding for the atmospheric sciences as an absolutely necessary element, I believe that the amounts stated in S. 2875 to pursue the mission of the Department of Interior would, perhaps, produce an unbalanced program unless, of course, it is the intent of the bill to assign to the Interior the lead agency responsibility for weather modification research and development, in the very broadest sense. Even so, this would be truly productive only if this leadership is achieved over a period of years by an evolutionary method in which the scientific community is an active partner.

The urgency of getting on with the job is great, of course. Therefore, we should see to it that the dollars go where the competence, the

ideas, and the plans are. These are spread widely now among Federal agencies and in the private sector. Consequently, I would like to see the efforts of mission-oriented agencies, such as the Department of Interior, Environmental Science Services Agency, FAA, and so on, grow along independent but closely coordinated lines, dovetailing with expanded support of underlying research by the National Science Foundation.

There is a critical need to use manpower as well as dollars in a balanced way, simply because the current supply of manpower is so short. There are no more than a couple of thousand Ph. D. level atmospheric scientists in the entire world today. Many of them are in the universities, not only doing research, but helping to train the far larger number of atmospheric scientists that will be needed in the coming years. Thus, it is essential that these scientists stay in the universities, not in ivory tower isolation there, but fully aware of progress in applications and the contributions that they can make. As I will describe later, NCAR is now active in helping to link the university community with the Government agencies that have mission interests in the atmospheric sciences.

Within the concept of a multipronged national program, we must increase our ability to mount large, complex field experiments. As the report of the National Academy of Sciences' Panel on Weather and Climate Modification points out, we now lack the requisite management and support capabilities for the kind of large, complex, team research experiments which will increasingly characterize this field as we move closer to applications. To achieve this capability, some integration of the national effort should be brought about; but the integration should not go to the point of creating a single national focus now.

With respect to the responsibilities of the principal agencies in weather modification, I would recommend the following for the immediate future:

The Department of Interior's program in weather modification should continue vigorously. But its focus should be sharpened, so that an integrated program is effectively pointed at its major goal: to increase streamflow into reservoirs. The program should proceed on a step-by-step basis toward this goal and each part of this program should be judged by the way it serves the central goal. For example, following the small river valley experiments such as are now being conducted, and very skillfully, by the Bureau of Reclamation's contractors, Eugene Bollay & Associates, in the Steamboat Springs, Colo., area, and this is one example of several, the effort might move to pilot projects of greater scope designed single mindedly to enhance the water resource. Then, after a thorough evaluation of precipitation enhancement, and with a clear recognition of the limits of the knowledge achieved, a decision can be made on whether or not it makes economic good sense to expand such pilot operations to the full river-basin scale. This kind of stepwise process will take a few years, but it will combine the prudent investment of the taxpayer's money with the soundest and promptest achievement of significant results.

The Environmental Science Service Administration should have the shackles removed from its conduct or sponsorship of research and development work in atmospheric modification. Whatever lack of enthusiasm the Weather Bureau may have evidenced in the past is

irrelevant. Under the leadership of Dr. Robert M. White, ESSA is building its competence and has potentially major contributions to make as an active participant. Indeed, ESSA should be encouraged to take the broadest possible view of all possible modes of weather modification, and should undertake a leading role in assessing the potential benefits to life, property, and commerce to be derived from various possible weather modification schemes. In particular, I should like to see ESSA concentrate on research on large-scale general circulation modification schemes, since research in this area is closely tied to the development of a truly adequate world weather observing and predicting system, now under active consideration by ESSA, NASA, NSF, and others both inside and outside the Government and I might say also, both inside and outside the United States. As you no doubt know, President Johnson once again endorsed a national effort to achieve a world weather system in a statement on March 23d, which is World Meteorological Day, and he stated that the Department of Commerce should take the lead in this. His endorsement is a welcome one, for the achievement of adequate worldwide weather observations would clear away a critical bottleneck in atmospheric research and its applications and I shall discuss it in more detail later in my statement.

As you, sir, pointed out in the committee print giving the background for S. 2875, the National Science Foundation should expand its sponsorship of atmospheric research in general, and on weather modification in particular. Drawing an imaginary line limiting NSF to the sponsorship of basic research, as distinguished from applied research, should be, in my opinion, avoided. Often the scientist himself cannot tell when he has crossed this imaginary line, and furthermore, a scientist should be encouraged to proceed all the way from discovery of a new piece of knowledge to a demonstration of the principle of its applicability. This, after all, is what the public wants from science.

In my opinion, the performance of NSF and the universities in the field of atmospheric research has been grossly underrated during the recent debates on weather modification. Most of what we know today comes as the result of research carried out by university groups, and a large part of it was under NSF sponsorship. This is a pipeline, if you will, of productive knowledge that is of extreme value, and it should be kept in the best possible working order.

The thorough study of the administration and support of research and development in weather modification that was recommended by the National Academy Panel, should continue—through staff studies on Capitol Hill and in the executive branch, through continuing discussion among the scientific community, and through other means that assure the most accurate sounding of the opinions of all interested parties, including the public.

Hearings like this one today are, in my view, one of the valuable first step of this progress. The success of our efforts in weather modification will depend on the extent to which all the talent available can be drawn into enthusiastic cooperation. It is therefore my hope that the process will be a completely open one, involving atmospheric science interests in the Nation throughout the Nation as a whole.

There are other problems, of course, that must be taken into account: how to avoid interference among various projects, how to indemnify

experimenters, how to protect the public from damage, and so on. I am not an expert in such problems of regulation, licensing, and indemnification, and therefore, I will not make any recommendations on these points, unless the committee specifically wishes me to discuss them.

But in closing, I should like to describe some of NCAR's programs related to weather and climate modification. And as an aside, I should say that while I'm certain you all know it, that the National Center for Atmospheric Research is a basic research institution created and responsible to the recommendations of the National Academy of Sciences some years ago and today sponsored primarily by the National Science Foundation under the control of the membership corporation operated in the national interest by some 23 universities.

First, we are participating in NCAR or assisting in several applied research projects. For example, we are furnishing assistance to Eugene Bollay & Associates, the Bureau of Reclamation's contractor who is working on a pilot precipitation enhancement project or research project in a river valley of western Colorado as I earlier mentioned. We are playing an integral role in the organization and conduct of project Hailswath this summer, the project under the prime direction of Dr. Schleusener and this marks the beginning of a national hail suppression research program. It will be of very great significance in the years ahead. Through our facilities laboratory in NCAR, which provides facilities for use by the atmospheric research community, we will continue to offer various kinds of assistance. And our scientific staff will continue to be available for joint research projects and to serve on steering groups in these fields.

Secondly, in our applications analysis program at NCAR, we will try to do what we can to shorten the time between the production of basic knowledge and its useful application, not only in weather modification but in other potential applications, too. We plan, in joint effort with a potential user agency or group—Federal or otherwise—to undertake to analyze the obstacles standing in the way of a particular application, and to help the user chart the most direct path toward the solution of those problems. In some cases, our efforts will, I expect, go so far as a pilot demonstration of applicability.

The projects will be on definite time schedules, and we intend that scientists from the universities and from the interested Government agencies, as well as scientists from our own staff, will participate. In general, we expect the user agency to pay the variable costs of the study. This program is now getting underway and it is our belief that it will be enormously useful to the mission-oriented agencies. This linkage to practical benefits will, in my view, also be highly stimulating to NCAR scientists and university scientists in their research efforts as they participate in these activities.

Thirdly, NCAR is helping to organize the research community's response to large new research opportunities, for example, in the development of a global weather observing system. Plans for this, as I've already mentioned, are now being developed by ESSA, NASA, and other Federal agencies and by scientists in private laboratories and the universities. This system will, for the first time, make possible an adequate three-dimensional observation of the weather of the entire globe. The observations, we believe, will enable us to make

improved weather predictions, and and will also furnish the data for simulated experiments of large-scale weather modifications or weather control schemes. The system of world observing, called the world weather watch, will involve artificial satellites for communications and for indirect sounding, constant-level free-floating balloons in a very interesting new style, floating in the atmosphere.

And by the way, in passing, I should remark that NCAR launched on March 30 the first new free-floating ghost. We call it "ghost," local horizontal—I can't tell you what it means exactly, an observing technique. We launched on March 30 the first balloon from the Southern Hemisphere, from Christchurch, New Zealand, in an effort to have it float completely around the world as an atmospheric tracer. This balloon returned 9 days and 23 hours later this last weekend for the first circuit of the Southern Hemisphere as a large-scale atmospheric tracer and we're very excited about this. This is the first step toward local weather observing systems. In addition to these balloons and the informational satellites, we will probably require free-floating ocean buoys tracked and interrogated by the satellites, remote ground stations and an improved conventional weather network around the globe. During the next several years, various NCAR groups, working together with scientists from the universities and the Government, will be working on many elements of this system, and on many potential research uses as well. Specifically, in our laboratory we will participate in developing the balloons and electronic packages; coordinating experiments in the tropics and elsewhere to coincide with flights of prototype satellites; in developing a supercomputer—and this is one of the main requirements for this whole thing to succeed—a supercomputer to handle the world data for research purposes; and, in concert with other groups across the Nation, to develop realistic models of the atmosphere, realistic mathematical models, by which weather modification schemes can be simulated at a fraction of the cost of the real thing and without the danger of unforeseen adverse results. Similar models will be necessary to upgrade weather prediction and, it is hoped, they will result in an extended forecast of various kinds perhaps after 2 weeks or more. The promise of such a system has been described in detail in a new National Academy of Science report entitled: "The Feasibility of a Global Observation and Analysis Experiment," produced by a panel under the leadership of Dr. Jule Charney of MIT.

The development of this world weather watch and its use for research and operational purposes, along with progress in other aspects of atmospheric modification, is the central challenge to the atmospheric sciences in the coming decade. It is, indeed, the only path, in my view, to safe and efficient realization of whatever large-scale weather modification is possible.

Lastly, NCAR's basic research program should be viewed as a contribution to the Nation's effort in weather modification. So also should be the basic atmospheric research in the universities. Obviously, some research programs have more immediate relevance to weather modification than others. But this science is far too young for us to begin ruling out possibilities. In my testimony for the Senate Commerce Committee, I prepared, at their request, a brief table showing some of the potential weather modification areas to which

various research programs at NCAR contribute and I have copies of it with me if you care to see them and will put them into the record.

To sum up, Mr. Chairman, there is a lot to be done in the atmospheric sciences. We now have the opportunity to move solidly toward applications of the knowledge that we now have concerning cloud modification, but there is still much to learn. And in that new knowledge lies, almost certainly, the expectation of far greater ultimate benefits.

Thank you, sir.

Senator ANDERSON. Thank you. I like your positive approach. Your steady push has helped get us around the scientific corner.

Without objection, the brief table you mentioned will be included in the record at this point.

(The table referred to follows:)

The following table shows various activities at NCAR (left column) and the potential applications (some of them, of course, not yet under, or ready for, development) to which the results of those activities may prove valuable (right column).

Activity at NCAR	*Area of potential application*
I. Research programs:	
A. The general circulation:	
1. Numerical models of the general circulation.	Developing improved prediction method; computer simulation of large-scale weather modification experiments; probing the causes of climatic change and possible climate-modification schemes.
2. Influence of cloud processes on large-scale circulations, with emphasis on the tropics.	Impact of rain augmentation efforts on larger storm systems; prediction and modification (how the tropics influence the behavior of the global atmosphere).
3. Turbulence observations and theory	Prediction and modification (how the oceans and land surfaces exchange energy with the atmosphere).
B. Physics of clouds and precipitation:	
1. Dynamics of thunderstorms and rain showers.	Hail suppression; augmenting precipitation.
2. Cloud condensation studies	Rain "suppression" (i.e., moving rain inland).
3. Thunderstorm electrification	Electrical effects on rainfall (potential modification method).
4. Worldwide freezing nuclei measurements.	Cloud seeding (background knowledge of levels of natural nuclei on which artificial nuclei would be superimposed).
5. Cloud-seeding "carryover" effect of iodine bonding with terpenes from trees.	Cloud seeding.
6. Effect of shock waves on ice formation	Hail suppression.
C. Life cycles of trace gases and aerosols:	
1. Worldwide measures of trace gases and aerosol distribution to determine "chemical climatology" of the atmosphere.	Air pollution; prediction of climatic change.
2. Studies of atmospheric isotope distribution.	Inadvertent modification.
3. Chemical reactions in the stratosphere	Inadvertent modification.
4. Chemical sampling of tropical atmosphere.	Corrosion-prevention techniques.
D. Solar activity studies (solar particle emissions; solar plasma ejections; ultraviolet and X-ray bursts from sun; coronal variation analysis and theory; flare physics; solar radio noise generation).	Improved prediction of possible influences of sun on earth's weather; prediction of solar events during manned spaceflight; improved prediction for radio communication.
II. Facility programs:	
A. Superpressure balloon development	Economically feasible element of a three-dimensional global weather observing system (the World Weather Watch). Safer balloon sounding devices for weather observations.
B. Mathematical modeling and computing techniques.	Improved prediction methods; computer simulation of large-scale weather and climate modification schemes (see IA).
C. Weather radar development	Clear-air turbulence prediction; percipitation augmentation; hail suppression; storm-avoidance techniques for aircraft.
D. Boundary-layer sensing development	Precipitation augmentation; air pollution.
E. Program on applications analysis (analysis of knowledge gaps hindering applications; identifying new applications possible with currently available knowledge).	Project-by-project basis.

Senator ANDERSON. Doctor, at one time you favored the lead agency concept in weather modification but now there seems to be mission approach. Would you care to comment on that?

Dr. ROBERTS. Yes, sir. In my testimony before the Senate Commerce Committee, I made a statement without further amplification that in my view it would be logical to assign the major responsibility for the Federal Government's program in applied research and development to a single agency. When I said this, I had in mind that the scale and magnitude of the problem of weather modification might require the creation of an agency perhaps somewhat on the scheme of NASA or the Atomic Energy Commission to handle the research, development, and operations that may be required on this scale of operation because of the importance of weather modification. However, I feel that with the great dispersion that exists and the location of the existing talent that it is perhaps best now—although ultimately new lead agencies may be required of this character—I think it is perhaps best now to move down a multipronged attack toward this objective, stimulating the talent where it lies and bring in all available talent to focus on a specific mission responsibility of these specific involved agencies.

Senator ANDERSON. If S. 2875 is enacted, would NCAR be able to help us and in what manner?

Dr. ROBERTS. Well sir, we believe that we can indeed. For one thing I feel that the aims and scope of the bill, S. 2875, calls for an integrated approach to the problem of water increase all the way to studies of the general circulation. It is a realistic attack on the problems of water resource. At first I might say that I think it has been realistic about the probable cost of this in the long run and I feel that because NCAR and the universities with which it is associated represent a very major part of the scientific talent of our country in these fields, that we can, indeed will, participate extensively in this activity.

Senator ANDERSON. Are NCAR and the Bureau of Reclamation getting along all right?

Dr. ROBERTS. Oh, yes, sir; very much so. I serve as one member of the advisory committee of the Department of Interior's program in water resource development. We, as I have already mentioned, are providing substantial support to some of the Bureau of Reclamation's contractors.

Senator ANDERSON. Do you feel that Federal regulation and licensing are essential now?

Dr. ROBERTS. I do, sir. I believe that there are many reasons why Federal regulation is of importance, not the least of which is that, in the present imperfect state of our knowledge, there is great danger that, if unregulated seeding operations are conducted, that some very long-term, very important, controlled research experiments will be rendered inconclusive and consequently I feel that we must know when seeding is conducted. The National Science Foundation has the responsibility to collect this information and at the present time I think, also, that if we find seeding operations or weather modification experiments are going to interfere, then the best scientific judgment can be brought to bear on the problem. We should have some method of enforcing the regulation, perhaps even the postponement of the conflicting operations.

Senator ANDERSON. I appreciate that statement very much. It is the subject of a lot of controversy.

You mentioned Dr. Bollay. He appeared as a witness in Washington. He is a longtime friend. We appreciate your statement very much. Thank you.

Dr. ROBERTS. Thank you. I don't want to pose as an expert on regulations but I feel that it is very necessary from the scientific standpoint.

Senator ANDERSON. Senator Bible.

Senator BIBLE. I want to compliment Dr. Roberts for his thought-provoking statements. He has a very brilliant mind. I am a little concerned about the statement he makes on page 5. If I read you correctly, Doctor, you seem to be a little concerned with S. 2875 funding as indicated in the authorization that it would produce an unbalanced program and would make the Department of Interior, as you put it, the lead agency, simply because of sheer weight in dollars. What is wrong with that? Why is that bad?

Dr. ROBERTS. Let me amplify that statement because I realized as I read it that it might be subject to misinterpretation. My fear that the bill, as I read it, appears to separate precipitation increase from basic atmospheric science. It fails perhaps, to realize that the competence, in respect to precipitation increase, is widely dispersed and much of this competence carries on under the label of "basic atmospheric research" at the present time. If the objective of S. 2875 is specifically to increase the water reserves, then other aspects of atmospheric science may ultimately have as much to contribute for which the path is not clearly indicated today, and may suffer because of the sheer weight of dollars, indeed, may recruit away from the university or from basic atmospheric research new talent that could make new contributions as yet unrecognized.

Senator BIBLE. As I view it, the main objective, of course, is the production of more rainfall. That is the main objective. Certainly there are collaterals and offshoots from that. I don't know that your fears are completely well founded. It seems to me that some of this goes back to the constant struggle between NSF, Weather Bureau, and Bureau of Reclamation: the eternal fight for the dollar. I am hopeful that we can certainly avoid this in the future. I just want your expressions on it. You have made it very clear to me that you favor a mission-oriented agency and this would be your ideal way to proceed in this. Do I understand you correctly?

Dr. ROBERTS. Yes, sir. On the other hand, I should like to point out that S. 2875 refers specifically to precipitation increase and there are equally significant objectives of atmospheric research that must be funded, so to speak, in competition, in effect, an adequate competition with the precipitation increase objective. For example, the problem of the conservation of the air over a city in the face of the increasing pollution. The questions of the improvement of time range forecasting may result in the farmers benefiting as much if we succeed in doing 6 months in advance prediction of the average rainfall or the average temperature of a region as they will be able to benefit through precipitation increase and I don't want these objectives to suffer through efforts to promote too single minded a purpose. What I am really saying is, and what I am trying to say in another place in my testimony is that atmospheric research and precipitation increase

research are Siamese twins and we must not nurse one of these twins at the cost of the other.

Senator BIBLE. I think I understand your concern in that respect. I just want to ask you partly related questions on the overall objectives of Senator Anderson's bill. Are the universities of our country producing sufficient students to staff the research institutes with the type of expert knowledge needed in the next 5 to 10 years in this field?

Dr. ROBERTS. Briefly put, sir, they are not. Great improvements have been made in the strength of the educational process of people to make contributions in atmospheric science but they are not nearly adequate. The problem goes to the whole center of the organization and structure of the graduate schools of the universities. I feel that in some way the challenge of atmospheric science must become evident to youngsters in their sophomore, junior, and senior years of college before they have ever aimed themselves toward graduate school. The atmospheric science must appear as a challenge. I feel that the future research is now space and perhaps atomic energy, and we have not yet succeeded, through the structure of the small liberal arts college curriculum or through other means, to bring about this image of career opportunity.

One of the main objectives that we feel that NCAR must serve is to be a shining example of the exciting career in the most advanced frontier in science that a young man could face as he looks toward the atmospheric sciences.

Senator BIBLE. Are there scholarships designed to encourage the undergraduate student to follow this very challenging life that you relate?

Dr. ROBERTS. There are, but there are very few. Yes, there are not enough of them and also there are not enough programs to give college students the opportunity to visit an atmospheric science project say from summer on. These are things we are widely discussing now in atmospheric sciences. And, for example, NCAR this summer for the first time is going to bring substantial numbers of youngsters to participate in airplane experiments and the use of giant computers for atmospheric research and in other exposures to atmospheric science problems. But I think that the universities, too, have a great deal to do to expand their effort in this regard. Dr. Vincent Schaefer, one of the pioneers of atmospheric science, through a very exciting program of the stimulation of atmospheric science by college youngsters, has made a step forward in this field.

Senator BIBLE. Thank you very much, Doctor. I have one further question, Mr. Chairman, if I might take just a moment longer.

I am constantly asked—and you must be the greatest authority on this point: We have been shooting off atomic bombs and we have the problem of fallout. Now, we are shooting guided missiles up to the atmosphere, we have satellites floating all around and I am constantly asked questions from people in my State as to whether or not this is responsible for the terrible weather we are having in various areas because there are so many unknown objects flying around in the atmosphere today and this would have some causative effect. Do you have any conclusions on that?

Dr. ROBERTS. Senator, you have opened a question I would like to discuss for 20 minutes.

Senator BIBLE. I know it is provocative, but I wish you would give me an answer I can give to my constituents because they are blaming the Space Committee and the Atomic Energy Committee. I don't happen to be privileged to be on either one of those committees, but if you could give me an answer to give my constituents, I think they would appreciate it. Tell me very briefly.

Dr. ROBERTS. I will tell you what I will try to do. I will try to make a very, very brief comment now and write you a long letter about it.

Senator ANDERSON. So it can go into the record.

Senator BIBLE. I think it may be very helpful to be in the record because this comes up constantly.

Dr. ROBERTS. I will be very glad to do that.

This is a very subtle question that you ask and a much subtler question, I think, than the asker of the question usually realizes. Let me go to the specific first part of your question: Have the A-bomb experiments changed the weather? In my view there is no evidence whatsoever for a change in any major feature of the weather other than immediately around the bomb area that the A-bombs have changed the weather. But this is only the beginning of a thorough answer to the question because there are many elements in the change in the large scale circulation of the atmosphere the cause of which is unknown. We know that the atmosphere radiation—the amount of heat that is radiated back to space—has a major effect on the state of the weather circulation. For example, on the position of the jetstreams which is a major influence on weather patterns, we will say, over the United States that we know that the effective atmospheric radiation has a major effect on these circulations in a long timespan, say 10 days or more. We do not know all of the details of the atmospheric radiation balance that controls this heat source to the atmosphere. It almost certainly is involved in the change of climate, for example. Now, we do not, at the present time, know for certain the magnitude or the role played by the formation of cirrus clouds or by other effects of cloud cover and the radiative balance of the atmosphere.

And to rule out completely the possibility that appropriately designed large-scale atmospheric experiments—I won't say whether it would be an A-bomb or rocket or whether it would be some jet airplanes flying—we cannot yet rule out the possibility that large-scale features of the atmosphere might be modified by activties involving no more energy than the energy released in the A-bomb. By the way, this energy released in the A-bomb is a trivial amount of energy compared to the energy of a hurricane or compared to the energy of a jetstream flow over the United States so that the effect, if there is one, must be an indirect effect. It is a problem that requires a great deal of additional research and in particular in my laboratory we believe that it is necessary to model these processes in an electronic computer and do the experiments by simulation before further experimenting in the real atmosphere. And much of this experiment is today being done through the dust put out by the cities or inadvertently through the exhaust gases from jet airplanes put into the atmosphere.

Senator BIBLE. Thank you for a very informative answer. I certainly hope you do put a full statement in the record.

(The information requested appears on p. 364.)

Senator ANDERSON. Senator Jordan.

Senator JORDAN. Thank you, Mr. Chairman. I thought this was a most excellent statement, Dr. Roberts. I particularly liked the emphasis you put on precipitation enhancement because all too frequently we regard weather modification as simply something to do with the redistribution of a limited supply. Now, you speak about enhancement of precipitation. Could you direct a few words to the potential of the unused, useless moisture in the air that might be made available to beneficial use if you had conquered the problem of getting it down.

Dr. ROBERTS. Well, I will be glad to attempt it. That is also a very big order, sir.

The water substance in the atmosphere plays a major role in the energy processes of the entire atmospheric circulation. For example, the jetstreams that are over our heads today and affect the flights of jet airplanes, their schedules and so on, are so important, the energy for driving that in a substantial part is derived from the water that is evaporated from the surface of the ocean in the tropics.

Everyone realizes how much energy it takes on the stove to boil a kettle of water to put that water into the atmosphere as vapor. The water in the atmosphere flows easily to other parts of the world as vapor and when that water is returned to the atmosphere as water droplets rather than water vapor, the same amount of heat that it took to boil that kettle of water is returned to the atmosphere. So that there are two things involved here: One is heat supply to the atmosphere far away in the tropics where the heat source occurs and the second is the actual precipitation enhancement resulting from water falling back to the earth. Now, the amount of water that falls from these clouds and from this vapor form to the earth on the way as it passes is relatively small compared to the water transported in the atmosphere. So, I think it very unlikely that the total budget of heat or of water in the atmosphere can ever be significantly influenced by water enhancement attempts through cloud seeding in a particular river watershed. We just can't touch the magnitude of that source. On the other hand, it may be that through the release of this rainfall in the atmosphere at the right time, at the right place, by perhaps cloud seeding over the Gulf of Mexico, we may have a bigger effect ultimately on the water resources available to the Great Plains even though not one drop from the seeded clouds falls from the process of seeding and the effect of this occurrence is an indirect effect.

As you point out, this is very speculative and an enormous amount of research needs to be done so that this is not speculation but science. This is one of the important roles that water plays in the atmosphere. I do not believe that we need to worry that we are depleting through cloud seeding the supply of water for someone else.

Senator JORDAN. I think this is very important. If you would care to, I would wish that you would extend your remarks to emphasize this a little further than it has been emphasized. If you would, I would appreciate it.

Dr. ROBERTS. I would be very happy to do this. This is a fascinating problem. You know a bit of water, a molecule of water that is evaporated in the tropical oceans only remains in the atmosphere something like 10 or 20 days on the average and then falls somewhere. It

comes out of the atmosphere somewhere. And what this does to the total energy of the atmosphere is a fascinating story and I'd be glad to amplify that, sir.

(The information requested appears on p. 366.)

Senator JORDAN. You made another good point, I think, when you say that the man who does the pure research should be permitted, at times, to continue through to the application and to the experimentation stage or demonstration level of the project and I think this is very important, because too often we find people who say: "We will keep the people with the ideas separate from the ones who implement those ideas." I think you made a strong point and I would like you to elaborate a little more if you would care to.

Dr. ROBERTS. I'd be very happy to because I feel this is a very important and often overlooked fact, a point about basic research. It is my own personal view that a research scientist finds stimulation, finds satisfaction, finds much of the motivation for his entire work through seeing his work brought to fruitful results. It seems to me that we should do everything within our power to have the scientists participate in the effort to bring application all the way down to the place where the principle that he has researched and learns if the application can be effectively demonstrated. It is obviously not desirable for a good research scientist to spend his time, unless, of course, he chooses to leave science, to conduct routine operations. He should go to some other research problem and then start down the line of events until it leads finally—although in many instances he goes down a blind alley—but leads him hopefully to something that can find application. But I feel that the other side of this coin, equally important, is that the agency or group with the mission responsibility—I don't care if it is an airline company or the Bureau of Reclamation or the Weather Bureau or the Federal Aviation Agency or any of the 17 or so agencies—the other side of the coin is that the group with the mission responsibility should also be encouraged to participate in basic research that it considers relative and necessary to its mission. So, the Department of Interior, the Weather Bureau, and so on, should have the strongest possible basic research arms related to their mission.

Senator JORDAN. That is why you are suggesting diversification and diffusion at this stage of our knowledge of the air?

Dr. ROBERTS. Yes, sir.

Senator JORDAN. Thank you.

Senator ANDERSON. Thank you very much.

(Subsequent to the hearing the following additional testimony was received:)

SUPPLEMENTAL INFORMATION OF WALTER ORR ROBERTS, DIRECTOR, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Subject: Senator Bible's question: "Do A-bombs affect world weather?"

It is often suggested that nuclear explosions affect continental-scale or world-scale weather. Such things as the onset of the severe droughts in the northeastern United States or the severe European winters have been blamed, particularly abroad, on the extensive Soviet and American nuclear tests of a few years ago.

At the present state of our knowledge of atmospheric processes, a conscientious scientist cannot give an unequivocal "yes" or "no." A few things about the matter, however, are quite clear.

First, the total energy directly released to the atmosphere, even by a very large H-bomb, is insignificant compared to the weather processes of a cyclone or hurricane, or even a "squall line" of thunderstorms. Thus it is safe to say that the blast or heat energy of an A-bomb cannot possibly deflect or stall a storm system by any direct action.

Secondly, we are today essentially ignorant about the physical causes of the frequent and seemingly erratic changes of weather or climate at times beyond ten days or so. Thus, we are unable to say to what degree any given climatic or persistent weather pattern change is due to any particular ascribed cause—let alone nuclear explosions.

We presume, partly from being at a loss for more plausible causes, that the changes of climate or persistent large-scale patterns are at least in substantial part the result of changes in the average absorption and reflection by the atmosphere of down-flowing sunlight and upwelling heat (infrared) energy of the sun-warmed earth. Study of such matters goes on under the label of atmospheric radiation research—and it is a complex, fascinating and rapidly growing field of scientific endeavor to which some of the best talent of modern science has been devoted.

Changes in radiation affecting various regions of the atmosphere are sharply dependent on the clouds, gases, dust, liquid droplets, and ice particles imbedded in the atmosphere. To a surprising extent, these foreign substances are irregularly distributed geographically and in height. For example, stratospheric dust particles are mostly concentrated in layers of air, rather than smoothly mixed. Over large desert or agricultural regions, soil-dust may be present in the air, even thousands of feet above the surface. These soil particles can play an important role in cloud and rainfall processes directly via radiation effects, and indirectly through their effectiveness as "condensation nuclei," with still further effects on atmospheric radiation. City smogs alter the heat loss from the cities of their origin. And there are many other examples of the strong influence of "foreign" substances on atmospheric radiation. Considerations of all of these must enter the complex story of the radiative balance of the atmosphere.

Nuclear explosions, if they affect the weather, must also do their work indirectly, probably via effects on atmospheric radiation equilibrium. One can imagine processes by which such effects could occur. For example, it is possible that changes in atmospheric radioactivity might alter the average charged particle density in cumulus clouds—and through this one might speculate that the frequency with which fair weather clouds develop into giant thunderstorms might be altered. This indeed would be a significant weather effect. But at present, its probability is sheer speculation.

There are some signs that very small initiating-cause energies sometimes result in major weather changes, probably through subtle indirect influences on the ice or water-forming processes in clouds. In my own work of recent years, I have been concerned about a still highly speculative mechanism through which the relatively trivial energies of the aurora borealis of northern lights (similar in energy to a nuclear explosion) may possibly trigger a growth of high-level cirrus cloud decks over the Gulf of Alaska. These in turn may "blanket" the warm Japan-current-heated ocean surface, and thereby heat the air below the stratosphere sufficiently to induce a large southwards deflection of the jet streams over North America. A jet stream digging deeper into the U.S. can produce fog at Chicago, blizzards on the Gleat Plains, or killing frosts in Florida.

If such chains of events do happen—that is, if large weather changes are brought about by "trigger mechanisms" in nature, then perhaps a strategically designed and placed explosion, similar to a nuclear test, might indeed affect continental-scale weather. But much research lies between us and a secure answer. Similarly, if this chain of events indeed does operate, then man may conceivably already be in the process of inadvertently altering world-scale weather or climate significantly by jet plane exhausts, city smogs, or by soil erosion in over-grazed or over-tilled agricultural regions. Again, much research is needed to understand fully how drastic these effects may be.

But we do know what steps to take to move systematically from insecure speculations to secure knowledge on these questions. Some of the necessary steps will involve complex, global-scale measurements. Others will involve new tools of research, including a new order of speeds and capacities in computing means. But the possible practical results of such research are at least comparable in value. It is time that we got on with the task!

Subject: Senator Jordan's question: "Does augmenting precipitation in one place mean decreasing precipitation at another?"

In answering this question, let's distinguish between two geographical scales. The first is the "Farmer Jones vs. Farmer Brown" scale—that is, whether cloud-seeding to augment precipitation on Farmer Jones's land will cause a decrease in precipitation on Farmer Brown's land situated 10, 20, or 50 miles downwind. The University of Chicago's "Project Whitetop," carried out in Southern Missouri for the five summers of 1960–1964, appears to have detected a downwind decrease of approximately ten percent at a distance of about 40 miles as the result of seeding rainshowers. However, it is the opinion of the principal investigator, Dr. Roscoe R. Braham, Jr. (who has testified before your Committee), that this was not due to the fact that the water in the cloud had been prematurely "milked out." Rather, it was, Braham believes, because the processes of precipitation had had effects on the downwind clouds that made them less efficient at sending their moisture to the ground. A good deal of cloud research will be required, however, to pin down this "rain shadow" effect as real, and to explain why it occurs, if it does.

I should point out that "Project Whitetop" dealt only with cloud-seeding of summer rainshower clouds over non-mountainous terrain. We have no evidence of rain shadow effects in the seeding of mountain orographic clouds, and it is likely that any effect that does occur would be harder to distinguished because of the much larger rain shadow effect that the mountain range itself produces.

The second geographic scale we might consider is that of "Colorado vs. Kansas" or of the "Rocky Mountains vs. the Northeastern Drought Area." Briefly, there is no evidence whatever that cloud-seeding can produce a rain shadow at such a distance. Furthermore, there is little reason to believe that cloud-seeding, even on a fairly massive scale, could affect the precipitation pattern of a region several hundred miles away.

The atmosphere carries a tremendous amount of moisture. The major source, of course, is the oceans. Each day, the winds import more than 20 billion tons of Pacific Ocean water into the U.S. On the average, water vapor resides in the atmosphere something less than two weeks before returning to earth; but during that time, it can move as much as 5,000 miles. A local seeding project would, of course, have little effect on the major features of such a gigantic system.

This is why it is my belief that if we hope to change major precipitation patterns (such as those that have produced the severe drought in the northeastern U.S.) we should look beyond cloud-seeding to possible techniques to influence these large-scale patterns. And this is one reason why several groups of leading scientists, including one at NCAR, are working on methods to create mathematical models of the global circulation in a super-computer (larger than any now existing), in order to understand its workings in detail. With such knowledge, we can then simulate possible large-scale weather modification schemes without risks and at a relatively modest cost. And much of this same knowledge will also help those responsible for weather prediction to increase their skill and extend the time-scale of their predictions.

Senator ANDERSON. We will resume at 2 o'clock.

(Whereupon, the hearing was recessed for lunch, to reconvene at 2 o'clock the same day.)

AFTERNOON SESSION

Senator ANDERSON. We will be in order.

The first witness this afternoon is Dr. Kassander, who is in charge of the program over in Arizona.

STATEMENT OF DR. A. RICHARD KASSANDER, CHAIRMAN, BOARD OF TRUSTEES, UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Dr. KASSANDER. Thank you, very much, Mr. Chairman; Mr. Bible. I welcome the opportunity to express my views on S. 2875. Although

I am chairman of the board of trustees of the University Corporation for Atmospheric Research, it will immediately become apparent that the views I will express are entirely my own and cannot be interpreted as representative of those of the scientific community.

I do not care to comment on those aspects of the bill which relate to weather modification or cloud seeding as most of us understand the terms. I am familiar with much of the testimony relating to whether the sums to be provided are too much or too little with reference to the state of knowledge of the atmosphere and the number of competent scientists available. I tend to join with the more conservative position of the academic community in this regard although I do not wish to dwell on this.

I prefer to direct my comments toward an aspect of the National Academy and National Science Foundation reports which has not enjoyed much attention but is much more exciting to me as an important step in our exploiting the atmospheric water resource. It is an aspect to which your bill does open the door and which is particularly related to the very broad mission of the Department of the Interior.

I refer specifically to the field which might have been included under "Modification of the Agricultural Microclimate" in the National Academy report. However, little was said and I would like to enlarge on this.

In the Western United States, over 80 percent of our water use is in irrigated agriculture. There is now considerable concern that we simply do not have enough undeveloped water to meet existing needs without even considering the requirements of a rapidly expanding population. This is surely one of the inspiring facts for S. 2875.

In Arizona over 90 percent of our water is used for irrigated agriculture. It is generally recognized that approximately one-half of our 7 million acre-foot per year use is unrecharged withdrawal from our dwindling ground water reserve. While the delivery of 1.2 million acre-feet of Colorado River water for the central Arizona project is extremely important, it obviously is not nearly enough to balance Arizona's water budget. To maintain the economic status quo of Arizona, with no regard to expansion, will require a doubling of interior surface sources if no other alternatives are possible. This must happen in considerably less than 20 years if economic crisis is to be avoided. I do not confidently believe that we can hope for these kinds of gains from cloud seeding in the time required. I speak about water resources. The same sort of situation exists in many places outside of Arizona.

I do not wish to minimize the possible benefits to cloud seeding. I do want to emphasize important parallel possibilities.

At the University of Arizona we are performing some experiments which I think are extremely important and which relate to climate control. We are demonstrating that an extremely productive horticulture can be economically maintained within very inexpensive plastic enclosures. Water conservation possibilities are enormous and impressive other benefits such as increased growing seasons and insect control, are possible. I believe that the economic benefits of increased productivity per acre and decreased water requirement will easily justify the plastic enclosure. We already have some good evidence of this in the efficacy of plastic mulching.

To me this is "climate control." However, the climate is controlled where it should be without all the possible social, economic, biological, and political implications of attempting any general change in climate.

This kind of research activity is getting very little attention. Moreover, it is not an activity which can be left to agriculturists. Agricultural research has already given us good guidelines on optimum climates for maximum productivity of most agricultural crops. The problem is now one of very large-scale engineering approaches to producing the structures and controlling the climate therein. We already have some small guidelines to these solutions but I know of no group that is able to concentrate the kind of effort required to make these ideas workable.

The possibilities open through this kind of an approach of "interior climate control" are very great. I can easily imagine such activities vigorously pursued by the Government department which has had a very great and productive concern with reclamation, land management, and outdoor recreation, with a special attention to water resources, saline as well as fresh.

For the above reason I am enthusiastic about S. 2875. That is not the only reason. To me all of the key words are contained in the introduction, which speaks of conducting a "comprehensive program of scientific and engineering research, experiments, tests and operations for increasing the yield of water from atmospheric sources." When one observes that over 80 percent of western water is used for irrigated agriculture, and further observes that a plant only requires for its nutrition less than 2 percent of the total water it transpires, I feel the best way to obtain maximum yield of water through atmospheric sources to is to prevent the atmosphere from carrying the water away after it has deposited it. The farmer's headgate is typically far from the watershed. In Arizona, less than 4 percent of the water falling on the watershed survives the trip. To me, the gains appear greater in pointing toward a possible fiftyfold increase in yield per unit of water delivered in the fields than toward a presently extremely optimistic 50-percent increase in rain on the watershed.

In this discussion it is not my intention to minimize cloud seeding or weather modification. I should add here with respect to your previous remark at the beginning, of course we have had a long program in weather modification from the University of Arizona. I think it is safe to say that our program, after 7 years, was the longest carefully controlled and statistically designed experiment that has ever been conducted either by academic or other groups. So, I am not anticloud seeding, but I am pro other things, too.

We must have increased snow packs and fuller reservoirs for the generation of hydroelectric power. We do need to do much more toward suppression of hail and lightning as well as fight other damaging weather phenomena which may be subject to control. However, at the same time I wish to see us push ahead on alternative possibilities which offer great hope. S. 2875 would appear to me to offer the mechanism. I hope the opportunity will be given.

Thank you, sir.

Senator ANDERSON. Thank you, Doctor. This is an interesting presentation, very interesting. Just how do you get this climate control?

Dr. KASSANDER. At the University of Arizona this started with a

program of desalting sea water, which was supported by Interior and has resulted in an operating plant on the Gulf of California in Mexico in the little town of Puerto Penasco. In the course of noting the use of desalted water for irrigation could hardly seem to be economically attractive, we tried to look at some other things and our plant physiologist friends told us that plants transpire because they can't help it. They open their stomas to get the carbon dioxide from the atmosphere that they need to produce their chloropyll and if it is dryer in the atmosphere than inside the plant the water simply runs out.

So we wondered if it wouldn't be possible to create a saturated humidity environment around the plant such that when the plant opens its stomas, the water would not run out. And we started by growing plants in enclosed plastic greenhouses. Originally the source of the water in the greenhouses was sea water which was sprayed against the circulating air of the greenhouse so that the sea water provided the humidity that saturated the atmosphere, the evaporated sea water being the fresh water. It did turn out that plants used very little water and, in fact, in the early morning hours when it was cool, more water actually condensed on the sides of the greenhouse than we had to feed the plants directly for their nutrition. And productivities can be enormous. We have already grown the equivalent of over a hundred tons per acre of tomatoes in a greenhouse and it seems quite likely that one can look to gross productivities in the vicinity of $40,000 per acre by this type of enclosure. I personally feel very confident that the capital investment of such enclosures can be justified by the increased productivity.

We are trying experiments on field crops. This, of course, is a much tougher problem because the value per pound of wheat is not the value per pound of tomatoes. But I am not at all pessimistic, when we look at the possibilities of an increased growing season, in fact a 12-month growing season in climates such as this, along with insect, weed, and disease control, that these increased benefits will support the cost of very extensive acreages covered with very thin plastics and thereby making the climate what we want in an easy way which, of course, isn't engineeringly feasible now because of the economics. It is pretty well demonstrated that cloud seeding has very favorable economic benefits but it is still hard to tell whether it can be made engineeringly feasible on a large scale.

Senator ANDERSON. This is very interesting. We have had testimony on this bill a good many times but not that particular type of testimony. I think it is very helpful.

Dr. KASSANDER. I may be the only crackpot.

Senator ANDERSON. I hope I can be a crackpot and see it through then. You think in time we might find a way that it would be commercially attractive and desirable?

Dr. KASSANDER. Of course, the truck crops—tomatoes, vegetables, and other produce—are already a very flourishing and profitable plastic greenhouse horticultural business in the Southwest, in the Phoenix area, in Yuma, and in California. There are enormously profitable truck operations so we do know even now that plastic enclosures without even the benefits of the water savings are very profitable in our area.

I personally feel and I am willing to devote a good amount of time to demonstrate that within a period of some years, if the opportunity is given and enough competent people worry about the engineering problems of these great big plastic structures, within something like 10 years we might be able to find that plastic coverings are economical. And of course, it could be pointed out now that plastic mulching for cotton crops is economically profitable and if you look at an aerial photograph of these fields you discover that half the field is covered with thin plastic sheeting and to me it is not an enormously greater step to cover the other half, put it on top and get a lot more.

Senator ANDERSON. Do you feel the bill would permit you to try experiments that you thus far have not been able to try on a large scale?

Dr. KASSANDER. I want to do this. But when one speaks of the atmospheric water resource rather than the rain in a comprehensive program, to me this is an opportunity to try some of these other experiments, which are dealing with the atmospheric water resource but not in the form of so-called seeding of cumulus clouds.

Senator ANDERSON. Well, what about a concrete-lined ditch? I wonder how much is saved by that process? You save water by this other process and it is rather interesting.

Dr. KASSANDER. I think you would want to do both, because one would not want to lose the water by conveyance loss in a ditch. It would have to be delivered to the plastic enclosure in any case.

Senator ANDERSON. What do you think is the role of the university in expanding water resource programs? What can the university do to expand this program?

Dr. KASSANDER. In the type of program that I am talking about?

Senator ANDERSON. No, in the whole program. I am trying to discover what you think the university could be doing in this work?

Dr. KASSANDER. Well, as far as the total program is concerned, the university plays many important parts. The first part is the matter of educated scientists. This is most obvious but sometimes we forget about it. The manpower resources are available to carry out experiments, even though each of us can point to a few isolated instances of productive scientists who do not have a university education. It is quite true that, although the numbers we need to require an expanded activity in the educational role and in graduate education levels, the education and research roles can be separated. Research itself is a part of graduate education. Another important part is that most universities, I think, recognize that they cannot get the bright, imaginative young people to inspire other young people and reproduce themselves unless they are offered a good research opportunity. The university's role will be one of continuing to produce a great deal of research material in addition to students. And interestingly enough I did have an opportunity to testify before the Commerce Committee in attempting to justify the university's role in the past, which has been subject to some criticism that we were a little bit slow. I pointed out that as far as the knowledge in the field is concerned that in the academy report, for example, there are 243 units or citations of which 96, or approximately 40 percent, are references to work directly generated by the academic community. So, we play our role in the development of information. We have played a smaller role in the engineering and field

aspect but this is as it should be. We are not geared to do that kind. The Government agencies are so constituted that they do operate massive programs.

Senator ANDERSON. Thank you, very much.

Senator Bible.

Senator BIBLE. This is a very fine paper, Doctor.

Dr. KASSANDER. Thank you.

Senator BIBLE. Do you feel that the bill before us is broad enough to cover the comprehensive program that you suggest?

Dr. KASSANDER. My guess is that it is. If it were handled through lawyers I would feel a little more comfortable—if a few additional words were added. If I had the opportunity to administer such a bill and wanted to do something of the type I mentioned, I could find the words in the bill. Now, whether the Bureau of the Budget would agree with me or not is another thing.

Senator BIBLE. I would think that if there were doubt in that direction, and the committee is sold in this concept of yours of going into a little field that is challenging, then it should be cleared up by the necessary language so if the bill passes, as I hope it will, it should be tightened up in that respect. The language should be made a little more specific.

Dr. KASSANDER. I would suggest in this regard, if one wanted to add only a few words to assist in this particular direction, that one might add after the words "atmospheric water resources": "to include modification of the agricultural microclimate," which not only opens the door to everything that I am talking about but to a great many more things such as plastic mulching, which all have a very close relationship to the efficacy or use of our existing water supplies.

Senator BIBLE. Something the committee would want to consider, Mr. Chairman, is any suggested language. This should be brought before the committee. I have only one other question, and I am wondering, in line with the testimony which you have just given, Doctor, whether your water resources research center, through the University of Arizona, has conducted any experiments about how to preserve, keep intact, or minimize the evaporation that comes from vast bodies of water such as Lake Mead in my State or the body of water back of Davis Dam. Have you done anything in that direction? I have forgotten the amount of water that finds its way into the atmosphere from Lake Mead daily. It is a tremendous amount of water. I know that they have had experiments by putting oil across the water. I have heard of that. I am told it has never worked out. Is this within your area of responsibility?

Dr. KASSANDER. Yes, sir; it is. Of course, as you know, the water resources centers are very young. They have only been activated for a year. However, I inherited, as part of my responsibility at the water resources center, an organization at our university known as "Water Utilization," and this group, under a Bureau of Reclamation contract, has conducted extensive studies in evaporation suppression using these fatty alcohols spread on the water and single molecule films to suppress evaporation. The general result to date has been, and this includes in particular extensive research in addition by the Bureau of Reclamation, that in the laboratory we can get substantial suppression but the economic difficulty in

maintaining intact the suppressive film over very broad areas subject to wind and waves and boat action and fishes nipping at insects, has not proved feasible. In stock tanks it is possible to save apparently up to about 30 percent of the evaporation but on the open, large expanses of water they are speaking of 10 to 15 percent possible suppression. When you get to this level and come to the cause of the problem you are down in the mud of natural statistical variability phenomena. You really can't identify an increase very well.

Senator BIBLE. Sounds as though it is most difficult to do but it can be done. It is rather a challenging field.

Dr. KASSANDER. Of course, if I were to continue the line that I discussed in my written testimony I would suggest maybe the thing to do would be to build a great big plastic dome over Lake Mead.

Senator BIBLE. And enjoy real recreation benefits. I am not sure we are ready to go that far but this would be evaporation suppression. Our neighbors put domes over football fields and baseball fields.

Dr. KASSANDER. Yes, but we will not be able to justify these by the price of the water saving. Increasingly, particularly in the Department of Interior, the value of recreational use of the water is getting a much closer look and we are discovering that we can do things with these systems with recreational use that we could not have dreamed of before and this again may be another opportunity.

Senator BIBLE. Thank you, very much, Doctor.

Senator ANDERSON. We appreciate this greatly. It is a very interesting discussion.

Dr. KASSANDER. Thank you.

Senator ANDERSON. Dr. Lange. I appreciate your coming, Dr. Lange, very much.

STATEMENT OF DR. WILLIAM A. LANGE, CHIEF HYDROGRAPHER, SOUTHERN CALIFORNIA EDISON CO.

Dr. LANGE. Thank you, Senator Anderson and Senator Bible.

My name is William Lange. I am the chief hydrographer for the Southern California Edison Co. I would like to read a statement concerning our operation.

The Southern California Edison Co. is an investor-owned electric utility operating and serving over 2 million customers in southern California and Nevada. Its annual production of energy during the past 15 years has increased from about 9 billion kilowatt-hours to over 35 billion kilowatt-hours. During this same period from 8 to 36 percent of its output has been produced by waterpower at its Big Creek-San Joaquin River development on the western slopes of the southern Sierra Nevadas east of Fresno, Calif. The water available to the Big Creek hydroelectric project, most of which comes from snowmelt runoff, is used through a series of six reservoirs having a capacity of 560,000 acre-feet and eight powerhouses having a total effective operating capacity of 690,000 kilowatts.

The company is a member of the Weather Control Research Association whose membership is drawn from private enterprise, academic, and governmental entities concerned with weather modification.

Cloud seeding experiments to increase the snowpack on the watersheds above the Edison reservoirs were begun in 1951 and have con-

tinued, without interruption, for more than 15 years. The area involved is estimated to cover approximately 300 square miles. Actual operations are under the control and director of the North American Weather Consultants of Santa Barbara, who have held the contract for this operation since its inception. This firm has a national reputation in the field of meteorology, both with respect to weather forecasting and with respect to weather modification, in which latter respect its personnel were among the early pioneers.

In February 1957, the President's Advisory Committee on Weather Control visited the Big Creek-San Joaquin River project and their subsequent report indicated an estimated gain of about 10 percent from cloud seeding experiments through 1956.

In August 1965, Edison records and data pertaining to these operations were submitted to the National Academy of Sciences for analysis. We were later informed that their evaluation confirmed our findings of about an 8-percent increase in the snowmelt runoff from the area tributary to Edison storage reservoirs.

We believe that Edison's weather modification program has been continuously in operation longer than any other such program. It is being operated now in essentialy the same manner as in the beginning, which we believe adds considerable reliability to its evaluation.

The Edison project uses 12 ground-based silver iodide generators, 5 of which are strategically located in the foothill areas west of our target area so that the generally prevailing winds will carry silver iodide smoke over such area, and 7 of which are located within the target area between 5,500 and 10,000 feet in elevation. These high-elevation generators are remotely controlled by pushbutton from our Big Creek No. 1 powerhouse by means of the company's microwave network. We also have installed wind direction, wind velocity, and light intensity recorders, data from which is transmitted by microwave to our Big Creek No. 1 powerhouse from their location on a 10,000-foot mountain crest in our target area.

The foothill area generators are maintained and operated by employees of North American Weather Consultants and the high-elevation generators are turned on and off by Edison personnel as directed by the contractor via telephone. The contractor also maintains the high-elevation nucleating generators together with the fuel supply needed for their operation while Edison maintains the microwave communication network.

We believe that this committee has already heard a full description of problems in the field of weather modification from other witnesses, and we see no need for further information which will only be cumulative. We believe that such problems cannot be resolved at the local level. The bill under consideration by this committee does not meet these problems. However, we believe that Federal legislation is needed and we believe that it should be designed to achieve the following objectives:

(*a*) To coordinate the timing and techniques of weather modification projects so as to minimize interference within the same geographical area between purely scientific experiments and mission-oriented projects, between different scientific experiments, and between different mission-oriented projects. In this connection we believe it is essential that the responsibility for coordinating weather modification activities be assigned to an independent body which bears no al-

legiance to any agency—Federal, State, or local—which itself engages in any weather modification activities. Otherwise, a conflict of interest obviously could develop which would impair or frustrate the objectives of such activities, whether such activities be purely scientific in scope or directed to the accomplishment of practical results at particular locations.

(*b*) To provide an administrative forum in which the conflicting interests of the private citizen, of the scientific experiment, of the practical mission, and of limited groups and interests represented by Federal, State, and local agencies can be reconciled with the interest of the public as a whole. We strongly believe that there is room for both pure research and the application to practical objectives of scientific principles already learned and we believe that the overall public interest can be served without sacrificing the advances already achieved in both fields and the rights of the private citizen.

(*c*) To supersede inconsistent and, in some instances, uninformed regulation or prohibition at State and local levels which have, in some cases, given no recognition of the national and international implications of weather modification.

(*d*) To accumulate data regarding weather modification activities and public dissemination thereof to increase the general understanding of techniques used in seeding operations as well as the methods and procedures used in the evaluation of these operations together with the results obtained. Obviously, information contained in reports to such regulatory agency regarding such weather modification activities ought not to be so burdensome as to interfere with the objectives to be achieved by such activities.

We believe that the body authorized by the Congress to have responsibility for achieving such objectives should include not only public members and scientists, but also representatives from private meteorological concerns who already have acquired from 15 to 20 years of experience, knowledge, and skills in applied research in weather modification. It would be a major breach of duty to the public to waste the experience and talents so accumulated.

Because of the existing uncertain state of the law as well as continuing uncertainties as to the causal connection between weather modification efforts and the result achieved, it appears more appropriate to substitute a pattern of Federal regulation insuring responsible conduct of activities for the random confusion of imposed liabilities through the courts at the local level. A review of court decisions to date shows that liability has been sought to be imposed in private litigation upon those engaged in weather modification activities on the basis of a plethora of legal theories, with a resulting uncertainty which imposes very substantial burdens and risks on those making attempts to engage in weather modification activities. A forum reconciling conflicting interests of persons and groups involved will achieve a more orderly assurance of responsible activity in the field, which in turn will encourage and promote man's understanding of the weather and of the means for adapting it to the beneficial uses of mankind.

With reference to section 201 of Senate bill 2875, which provides for compensation "for the taking of property or rights, or for damage, injury or for other just claims arising out of execution of the comprehensive program" authorized by the bill "in the manner provided in

the act of August 30, 1954, and act to amend the Atomic Energy Act of 1946," the same legal uncertainties as to whose rights can or should be recognized mentioned in the preceding paragraph make the effect of this provision equally uncertain. Moreover, a review of sections 171–172 of the Atomic Energy Act of 1946, as amended, indicates that the remedies provided therein are related to a taking by the United States, rather than for damages under some other theory,where such damages resulting from weather modification activities are not the equivalent of a permanent impairment of the right to use the property. In such latter instance, remedies for damages in eminent domain proceedings instituted by the United States applicable to a taking of real property have little relevance. It would enormously clarify the purpose of this section if it were amended to spell out more precisely the remedies contemplated and the manner and circumstances in which they are to be enforced. It would also be helpful if the section were to reflect the contemplation of Congress that such remedies also would relate to the types of damage or injury which, if done negligently, would otherwise permit an injured party to bring an action under the Federal Tort Claims Act.

Senator ANDERSON. Thank you, Mr. Lange. In the last part of this there was reference to the Atomic Energy Act of 1946, as amended, designed primarily to take care of any unusual instances that might refer to reactions. I had some interest in this. It was not designed to take care of damage to an automobile or it might be damage by explosion but an entire wave through a whole community. That is what you are getting into here. If we should succeed in ultimate climate control and cause a flood, as one particular case, you would have a real problem to try to tie this to the Price-Anderson Act. We were contemplating, in 171 and 172, merely taking property unless it was a gigantic flood that would cause some kind of damage. Dr. Schaefer told me one time that he was in an airplane that was in a hurricane off the coast of Florida. He was proceeding to the site, and for some reason the hurricane turned around and came back to the coast of Florida. They haven't seeded a hurricane from that day since. We tried in this bill to provide the basis for giving research workers on weather modification some protection by the law. Do you see any objection to that?

Dr. LANGE. No. We would like to have some protection because I am sure you are aware that most everyone involved in weather modification activities are fearful of liability actions at the same time.

Senator ANDERSON. We had a situation in the East one time where they had a very elaborate county fair and the adjoining county wanted some more rainfall and they hired a seeder. At the time that the county fair was supposed to start, they had very heavy rains and the farmers wanted to sue for destroying their fair. The fellow said: "If you can prove I did it, I'm in business."

We are very glad to have your comments, because this is a fine piece of work, presented very carefully. I put down here the word "careful." This shows with what care you have handled these things so that there won't be any disaster. On page 3, where it discusses the facilities used by Edison Co. in the first paragraph, you told how you have pushbuttons and various things put in to review the job carefully and automatically. That's the type of work we need.

I have been keeping track of this program for many years—15 at least—and Southern California Edison Co. deserves to be complimented and you, too, upon the work you have done.

Dr. LANGE. Thank you.

Senator ANDERSON. Senator Bible.

Senator BIBLE. Thank you, Mr. Chairman. I have dealt with the Southern California Edison Co. people all my life. I know the president and the manager and the lawyers and their engineers. I know some of the experiments they have conducted in that Big Creek area.

I am interested in your findings. If I understand them correctly, you have indicated by silver iodide seeding of clouds that you have increased snowmelt runoff some 8 percent; is that correct?

Dr. LANGE. That is correct.

Senator BIBLE. Can you translate that into acre-feet? From what year to what year you have created how many acre-feet of water? What is the value of that water and how much is it going to cost you to produce it?

Dr. LANGE. Well, I would not have those figures, sir.

Senator BIBLE. Could you supply them for the record?

Dr. LANGE. I could supply them for the record.

Senator BIBLE. I would be very interested in your overall experience because I think probably, of all the utilities in the United States, you are probably the leader in this field. Pacific Gas & Electric did a lot of experimenting on the western slopes of the Sierra Nevadas some years ago. I do not know if they still do the same type of work or not but your experience in this could be very helpful to the committee. I would like to have you run that 8 percent out and translate it into annual acre-feet and multiply it out to show us what this is in terms of dollars.

Now, this is production for a municipal water supply, isn't it?

Dr. LANGE. This is for power production.

Senator BIBLE. Power production.

Dr. LANGE. Of course, the Bureau of Reclamation, their reservoir for agricultural purposes could come under this, too.

Senator BIBLE. Then it is power generation, some municipal and some irrigation.

Dr. LANGE. Correct.

(The information requested is as follows:)

SOUTHERN CALIFORNIA EDISON CO.,
Los Angeles, Calif., April 27, 1966.

Senator ALAN BIBLE,
Senate Office Building,
Washington, D.C.

DEAR SENATOR BIBLE: When I appeared as a witness at the Albuquerque hearing on S. 2875, you asked if I could supply you with the annual cost, acre-feet gain and value of the gain produced as a result of our weather modification program in the upper San Joaquin River watershed.

A preliminary statistical analysis of our operations indicates that the average annual gain has been approximately 31,000 acre-feet or about 8.5 percent. The cost of this program (exclusive of overhead costs) for the past four years has averaged about $22,000 per year. While this is slightly higher than the fifteen-year average, I believe it to be more representative of current direct costs.

The dollar value of the increased water supply to the Company has not been evaluated as yet since this will involve a statistical computer study to determine what part of the increased runoff was used and what part was spilled. However, we do know that a usable gain of 1,000 acre-feet in one season would

substantially pay for the annual cost of our program at current levels. Of course, we would have no way of evaluating the economic benefits of such increased water supply for downstream water users, though such benefits would appear to be substantial.

Sincerely yours,

W. A. LANG, *Chief Hydrographer.*

Senator BIBLE. Now, for the record, how many times has Southern California Edison Co. been sued for causing floods and damage to adjoining landowners? Would you have that figure?

Dr. LANGE. We have never been sued.

Senator BIBLE. You have never been sued?

Dr. LANGE. No, sir.

Senator BIBLE. Your predecessor was California Electric Power. Didn't you succeed to the interest of California Electric Power?

Dr. LANGE. That is correct.

Senator BIBLE. My memory serves me well. They had one lawsuit filed in Federal court in my State where they had cloud seeded on the eastern slopes of the Sierra Nevadas and it allegedly flooded some ranches out in the neighborhood of where one of our staff men, Roy Whitacre, lives over in Smith Valley. Now, I don't know whether that suit was dismissed or whether it finally went to judgment but I know they have had some experience with lawsuits. You have had none? You have never had a lawsuit?

Dr. LANGE. We have never had a lawsuit and I am not familiar with the one you have mentioned on the east slopes of the Cal Electric project. I know that Pacific Gas & Electric had a suit filed against them.

Senator BIBLE. Well, the staff can run this down. Did you settle any suits out of court?

Dr. LANGE. No.

Senator BIBLE. I see; very fine.

Dr. LANGE. We go in there to increase the snowpack and we are operating up in the mountains and I think we are fairly safe.

Senator BIBLE. But in any event you have had no liability problems in your operation?

Dr. LANGE. No.

Senator BIBLE. Thank you.

Senator ANDERSON. If you did get sued, the plaintiff would have a hard time finding expert witnesses. Thank you again. That was fine work.

Our next witness is Mr. Reynolds. We are, indeed, glad you are here.

STATEMENT OF S. E. REYNOLDS, STATE ENGINEER, STATE OF NEW MEXICO

Mr. REYNOLDS. My name is S. E. Reynolds. I appreciate the opportunity to testify before this committee today, Senator Anderson and Senator Bible.

As State engineer for the State of New Mexico I am charged by statute with the general supervision and the measurement, appropriation, and distribution of the waters of this State.

For about 9 years before becoming State engineer in 1955, I was employed by the New Mexico Institute of Mining and Technology

and engaged principally in research in cloud physics including studies of weather modification.

In the period 1954 to 1957 I served as a consultant to the President's Advisory Committee on Weather Control and in the period 1960 to 1963 I served on the National Science Foundation Advisory Panel for Weather Modification.

My duties as State engineer have made it impossible for me to keep up with the literature in the field of cloud physics to the extent that I would like, and it certainly is not my intention to try to qualify myself as an expert in weather modification for the purposes of this hearing. I present this statement in support of S. 2875 principally because of my interest, as State engineer, in the enhancement of the water resources of New Mexico.

Experiments have shown that virtually any cloud, with the possible exception of those composed entirely of small ice crystals, can be caused to precipitate by the application of one or more of the known cloud-seeding techniques. But the practicability of these techniques has been the subject of controversy among competent scientists for 20 years. The recent report of the National Academy of Sciences entitled "Weather and Climate Modification Problems and Prospects" gives important new indications that cloud seeding can produce economically significant increases in the amount of precipitation reaching the ground.

While the development of our ability to modify the weather in a practical way has not met the hopes many of us held in 1946,I feel that the potentialities for achieving this ability and the benefits that would result justify a greatly expanded research effort.

It would seem appropriate and consistent with the terms and objectives of S. 2875 to give first priority in the program to research, both basic and applied, rather than to early field operations directed toward increasing precipitation. This emphasis would be consistent with the thrust of the recommendations of the National Academy of Sciences report.

The important new evidence for precipitation increases of 10 to 20 percent by cloud seeding is largely statistical and does not permit clear definition of the meteorological situations susceptible to treatment and the techniques best suited to these situations. Because of this lack of definition we still must face the possibility that efforts to increase precipitation may actually result in a net decrease in any one attempt or in a series of attempts.

Field trials of cloud seeding seem to me essential to the objectives of S. 2875 and such trials could result in useful augmentation of our water supply. I am appalled by the thought that field trials could escalate our western water controversies to the cloud tops at 60,000 feet, but even this risk seems justified by the potential benefits if reasonable caution is used.

It is my view that, at least in the early stages of the program under S. 2875, field trials should have as their primary objective increases in information rather than increases in precipitation. Such trials should be carefully designed and completely instrumented for direct observation of both large-scale and small-scale responses to seeding as well as for the collection of data for statistical analysis. No extensive field trial should be undertaken without prior and continuing

careful review of the potentialities for decreasing or adversely redistributing precipitation.

In this connection, I invite attention to a paper published in 1962 by Dr. E. J. Workman entitled "The Problem of Weather Modification." This paper suggests that generalized seeding of immature, cumulus clouds may result in a stabilization of the atmosphere that would prevent the development of mature clouds capable of producing large amounts of precipitation. Also, the recent report of the National Academy of Sciences cites evidence of "rain shadows" downwind from the target areas of seeding operations.

Section 202 of the bill would require those engaged in weather modification activities to be licensed by the Secretary of the Interior. In this connection, it is of interest to note that the 1965 session of the New Mexico Legislature enacted a statute creating a weather control and cloud modification commission. This statute requires those engaged in weather modification in New Mexico to be licensed by the commission and to report to the commission on their operations. An important objective of the legislature was to provide information about activities that might interfere with, or introduce ambiguities in scientific research. Controls such as would be instituted by section 202 seem essential to permit the Federal programs that would be authorized to proceed without interference or uncertainty. Also, these reports on commercial operations that may be required under section 202 could produce information of great scientific value.

In my work as State engineer I have had occasion to work closely with the Bureau of Reclamation of the Department of the Interior, and I have great respect for the technical and administrative competence of that agency. I am not thoroughly familiar with the work that the Bureau is currently doing in weather modification, but I am confident that the Secretary of the Interior, through the Bureau of Reclamation, could do a commendable job in administering the program that would be authorized by S. 2875.

It is my hope that New Mexico institutions will make important contributions to the objectives of the legislation. The New Mexico Institute of Mining and Technology has been engaged in studies of cloud physics and weather modifications for 20 years or more and the group there has an international reputation in the field. As we have heard this morning, representatives of the newly created water resources research institute at New Mexico State University have recently expressed to me interest in undertaking research in weather modification. They told me earlier they are interested in doing work in this field. The University of New Mexico has outstanding capability for research in engineering and the other physical sciences including meteorology and may be able to undertake work in the program that will be authorized by S. 2875.

In conclusion, I respectfully urge the committee's favorable action on S. 2875. The opportunity to present this statement is warmly appreciated. I want to express my appreciation to the subcommittee for holding a meeting in New Mexico. Thank you.

Senator ANDERSON. Thank you. On page 3 you refer to the 10- to 20-percent increase in precipitation caused by cloud seeding—in the second paragraph.

Mr. REYNOLDS. Yes, sir.

Senator ANDERSON. What would happen if you did this and this want up by 20 percent? Would you have any problems?

Mr. REYNOLDS. This would be a great blessing, Senator. Of course, whether or not there would be problems created depends on how rapidly we would receive this, and just when these increases would occur.

Senator ANDERSON. And who would get the benefit of the increases?

Mr. REYNOLDS. I think both New Mexico and Texas would receive benefits.

Senator ANDERSON. We might pay back some of our debt.

Mr. REYNOLDS. It might help a great deal in that respect. I might point out, Senator, that a 10-percent increase in the Colorado River Basin increases the runoff by the same amount and you might actually get a little more than a 10-percent runoff from the 10-percent increase in precipitation which gives just about enough to give the upper basin the amount that the Colorado River compact allocated to us.

Senator ANDERSON. I would rejoice to see that happen. Thank you, Mr. Reynolds. We are glad to have you here. You have had a long interest in this particular subject.

Senator Bible.

Senator BIBLE. There is one question that I would ask of Mr. Reynolds. I have worked closely with him for many, many years. I would ask whether you have had any experience with the 1965 New Mexico statute creating the Weather Control and Cloud Modification Commission? It was just enacted last year, I understand.

Mr. REYNOLDS. Yes.

Senator BIBLE. Have you had any experience in putting this into effect?

Mr. REYNOLDS. I can't answer the question reliably, Senator. To the best of my knowledge and belief, nobody, as yet, has been licensed under the act and I doubt whether anyone has furnished any reports on it. Some of the folks from the Institute might be able to answer your question, since the board of regents at the School of Mines is in general charge of the administration of that.

Senator BIBLE. I see, and I think it would be helpful, Mr. Chairman, if Mr. Reynolds would furnish for the record a copy of this particular statute. It might have some language that would be helpful. If you would forward this to help.

Mr. REYNOLDS. I would be pleased to do that, Senator.

Senator BIBLE. Thank you, Mr. Chairman. Thank you, Mr. Reynolds.

(The information requested follows:)

CHAPTER 235, HOUSE BILL NO. 128; APPROVED MARCH 29, 1965

An act relating to weather control and cloud modification, and providing a penalty

Be it enacted by the Legislature of the State of New Mexico:

Section 1. SHORT TITLE.—This act may be cited as the "Weather Control Act".

Section 2. DEFINITIONS.—As used in the Weather Control Act "commission" means the weather control and cloud modification commission.

Section 3. DECLARATION OF RIGHTS.—It is declared that the state of New Mexico claims the right to all moisture in the atmosphere which would fall so as to become a part of the natural streams or percolated water of New Mexico, for use in accordance with it laws.

Section 4. License Required.—No person or corporation shall, without having first received a license from the commission, conduct any weather control or cloud modification operations or attempt to control precipitation.

Section 5. Application for License.—Any individual or corporation who proposes to operate weather control or cloud modification projects or who attempts to induce precipitation, shall, before engaging in any such operation, make application to the commission for a license to engage in the particular weather control or cloud modification operation contemplated.

Section 6. Annual License Fee—Statement.—At the time of applying for the license, the applicant shall pay to the commission a fee of one hundred dollars ($100), and shall file an application in the form prescribed by the commission which shall be accompanied by a statement showing:

A. the name and address of the applicant;

B. the names of the operating personnel, and, if unincorporated, all individuals connected with the organization, or, if a corporation, the names of each of the officers and directors thereof, together with the address of each;

C. the scientific qualifications of all operating and supervising personnel;

D. a statement of all other contracts completed or in process of completion at the time the application is made, giving the names and addresses of the persons to whom the services were furnished and the areas in which such operations have been or are being conducted;

E. the objective of the operation, methods of operation the licensee will use, and the description of the aircraft, ground and meteorological services to be used;

F. names of the contracting parties within the state; including:

(1) the area to be served;

(2) the months in which operations will be conducted;

(3) the methods to be used in evaluating the operation; and

G. any other information the commission deems necessary.

Section 7. Issuance of License.—The commission may issue a license to any applicant who demonstrates sufficient financial responsibility, to the satisfaction of the board, necessary to meet obligations reasonably likely to be attached to or result from weather control or cloud modification activities, and skill and experience reasonably necessary to accomplishment of weather control without actionable injury to property or person.

Section 8. License Fee—Expiration.—A license shall expire at the end of the calendar year in which it is issued and may be renewed upon payment of the annual license fee.

Section 9. Reports Required From Licensees.—Each licensee shall, within ninety days after conclusion of any weather control or cloud modification project, file with the commission a final evaluation of the project. Each three months during the operation of any project which has not been completed, each licensee shall file a report evaluating the operations for the preceding three months in the project. Failure to file such reports constitute grounds for immediate revocation of the license. Each evaluation report shall contain such information as required by the commission in order to aid in research and development in weather modification and to aid in the protection of life and property.

Section 10. Revocation of License.—The commission shall revoke any license if it shall appear that the licensee no longer possesses the qualifications necessary for the issuance of a new license, or is guilty of a violation of any of the provisions of the Weather Control Act. Such revocation shall occur only after notice to the licensee, and a reasonable opportunity has been granted the licensee to be heard respecting the grounds of the proposed revocation.

Section 11. Judicial Review.—Rulings by the commission on the issuance, refusal or revocation of a license are subject to review only in the district court for Santa Fe county and the state supreme court.

Section 12. Operations Affecting Weather in Other States.—Weather control or cloud modification operations may not be carried on in New Mexico for the purpose of affecting weather in any other state which prohibits such operations, or which prohibits operations in that state for the benefit of New Mexico or its inhabitants.

Section 13. Enforcement.—Enforcement of the Weather Control Act is vested in the board of regents of New Mexico Institute of Mining and Technology. The board of regents shall appoint a three member weather control and cloud modification commission for the purpose of administering the provisions of the

Weather Control Act. Technical assistance, research, evaluation, and advice to the commission shall be furnished by the institute at the direction of the board of regents. The commission shall elect from among its members a chairman and other officers it deems necessary. All fees collected by the commission shall be placed in a fund to be used by the commission for the purposes of carrying out the provisions of the Weather Control Act.

Section 14. POWERS AND DUTIES OF COMMISSION.—The commission may:

A. make all rules and regulations necessary to carry out the provisions of the Weather Control Act;

B. make any field investigations and inspections necessary to the enforcement of the Weather Control Act;

C. make periodic reports on weather control and cloud modification activities in this state together with evaluations of the results of such activities; and

D. make recommendations to the legislature through the board of regents on needed legislation in the regard to weather control and cloud modification.

Section 15. PENALTY.—Any person conducting weather control or cloud modification operations without first having procured a license, or who makes a false statement in the application for a license, or who fails to file any report or evaluation required by the Weather Control Act, or who conducts any weather control or cloud modification operation after revocation of his license, or who violates any provision of the Weather Control Act is guilty of a misdemeanor.

Senator ANDERSON. Some witnesses from New Mexico Institute of Mining and Technology are here now. Professor Moore and Professor Brook, would you come forward, please. I appreciate very much your being here and hearing from you.

STATEMENT OF PROF. CHARLES MOORE AND PROF. MARKS BROOK, NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

Mr. MOORE. Thank you, Mr. Chairman and Senator Bible. We are pleased to have the opportunity to be here. We are extremely interested in the purposes of this Senate bill. We also have some concern about it. I would like to present a statement. I have with me Prof. Marks Brook. My name is Charles Moore.

As scientists at New Mexico Institute of Mining and Technology, we are actively engaged in atmospheric research aimed at understanding natural rainmaking processes. Our activities bear directly on weather modification, and several of our present projects are certainly in that category. It is thus as both active, though perhaps limited, practitioners of weather modification and as atmospheric scientists that we hold the enthusiastic hope that man will, in the future, succeed in understanding and controlling much of his atmospheric environment.

As citizens, we are also vitally aware of the great benefits that successful rainmaking techniques would have for all of us, particularly those of us in the semiarid Southwest.

For a number of years we have been studying clouds that form over the mountains of New Mexico in the summer, examining their development, the first formation of rain, and the intensity of precipitation that falls from them. During the decade of the fifties on a number of occasions we seeded some of these clouds with dry ice and with silver iodide smoke. Spectacular effects were sometimes observed when these ice-forming substances were introduced into the clouds growing over us: Updraft velocities increased, anomalous low-level cirrus clouds formed, and radar echoes appeared in the cloud earlier than usual. No readily apparent increases in the rainfall from these

clouds was noted. Further studies revealed that, when ice crystals appeared early in the development of summer convective clouds, the rainfall from these clouds was much less than was observed when intense rain formed in the effective absence of snow. I'll say parenthetically during the summer of 1962 in the observations of the rainfall on the top of the mountain was about 25 percent of the long-term mean rainfall. During this year clouds formed snow. Ice-forming substances were readily present and there was appreciably less rainfall. There was only about four one-hundredths of an inch rainfall but on other days beneath thunderstorms we got one-half of 1 inch from a thunderstorm.

From these studies it appeared that the presence of ice crystals was not necessary for the production of rain in New Mexican summertime clouds. The disappointingly small increases in rainfall suggested by recent and earlier statistical evaluations of cloud seeding operations in other geographical areas also suggests to us that the ice crystal mechanism of Bergeron and Findeisen is not as important for rain formation as was believed 20 years ago.

Since the discovery of cloud seeding by Drs. Schaefer and Vonnegut about 20 years ago, the Bergeron-Findeisen explanation has been tested adequately and has been shown to be valid as one of the precipitation growth processes. Probably, it is the dominant process over much of the country during winter snowstorms. The rate of rain formation by this process is low, however, as it is limited by the low fall speed of snow flakes. In New Mexico, rain formed by this process rarely exceeds an intensity of about one-fourth inch per hour, and during the summer, most of this rain evaporates before reaching the ground. I have a photograph if I can submit it to you showing a typical cloud in which ice is formed and from which snow can be falling in the summertime turning to rain which evaporates before reaching the ground. This is common to the clouds of central New Mexico.

Much of our summer rain falls with intensities of 1 to 6 inches per hour, appreciably in excess of what may be expected from the growth and fall of snow.

It seems clear to us that rain is formed in New Mexican summer clouds by several different and possibly competitive processes. From our data of the last few years, it appears that the presence of ice crystals early in the development of a convective storm may interfere with other and more effective processes of raindrop growth associated with the later, more mature stages. For example, the high intensity gushes of rain which often follow lightning discharges, and which contribute significantly to our total summer rainfall, seemingly do not occur when snow predominates in the cloud over our observatory.

We do not yet know the details of the effective summer rain-forming processes, nor do we yet have the techniques to manipulate them. Since at present we possess neither the understanding nor a convincing technique for increasing summer rainfall, it is premature to commence any large-scale operational program of summer weather modification. We are particularly concerned about any large scale summer operational program of cloud seeding with ice-forming nuclei in or affecting New Mexico.

The support of the Congress through the several interested Government agencies during the last decade has caused an enormous

acceleration in the scientific effort directed toward understanding the atmosphere and much progress is evident. We recommend and hope that this favorable attitude by the Congress toward the investigating and understanding of atmospheric and cloud processes will continue, for therein lies our largest hope of finding ways to modify weather beneficially.

Thank you, very much.

Senator ANDERSON. Thank you, gentlemen, very much. We appreciate your coming and adding to the remarks made earlier by your colleagues.

We will next hear from the New Mexico Cattle Growers' Association.

STATEMENT OF JACK HUNING, NEW MEXICO CATTLE GROWERS' ASSOCIATION

Mr. HUNING. Thank you, Mr. Chairman, and Senator Bible.

The New Mexico Cattle Growers' Association is vitally concerned with any attempts to modify atmospheric weather conditions, both as it relates to agriculture and secondly as it related to national defense. We wholeheartedly endorse S. 2875, but urge the subcommittee to look further into certain areas of weather modification before drafting the final version of this legislation.

We recognize this bill as a vehicle for encouraging research and experimentation in the weather modification field. This provides a licensing authority, but section 204 removes authority or surveillance over water resources research or meteorological or atmospheric research conducted by other agencies of the Federal Government under authorization other than this act. We think the central clearinghouse should actually be the clearinghouse and all research should be coordinated so duplication is avoided and the national security is not endangered.

We feel also that since agriculture is so deeply involved in any work done or contemplated in atmospheric weather control that the Secretary of Agriculture should be directly concerned. We suggest the authority for carrying out this program be vested in a Cabinet Committee including: the Secretaries of Agriculture; Interior; Defense; Health, Education, and Welfare; and the Chairman of the Federal Power Commission, or in other words, the Water Resources Council. This committee could then have the tools and the vision to work out a priority system for the distribution of precipitation. In that way, water which exceeds useful amounts at a given time in one area could be channeled to a deficient area where needed.

To cite an example let's visualize the Rio Grande watershed. A certain snowpack year after year is desirable. However, above an established amount the stage would be set for downstream flooding in the spring. Hence we would have excess moisture which might be diverted to the Arizona desert to grow winter cattle feed and increase the capacity of this Nation to grow red meats which some predict will be in short supply within the next decade. Under these conditions the Council could determine that the moisture could be intercepted and put to "beneficial use." By the same token, no area

should be allowed to be deprived of its longtime average of "useful precipitation," population or political pressures notwithstanding.

At this point, may I ask that any work performed comply with existing State laws and at least take the existing State laws that Mr. Reynolds referred to.

We feel the most urgent matter which needs attention is the question of those subjected to the results of experimentation in or attempts to modify weather. The mechanism referred to in the Atomic Energy Act of 1954, as amended, is totally inadequate in determining damages from an accident. A Geiger counter will trace radioactivity and damages can be assessed. You have no such mechanism herein. Results cannot be as easily observed, traced, and identified.

Areas of New Mexico have had the dubious honor of being the recipient of experiments in weather modification by both private and governmental agencies for several years. It is most difficult to prove damages to the satisfaction of a court, and especially against a governmental agency. It would be extremely difficult if the secrecy to which this work is entitled is enforced as it should be. The dangers to individuals, counties, and even entire States is great unless some cure is found. The injustices will be great and widespread.

We suggest several steps which could be instituted to alleviate this problem. At the request of citizens within a State, the Governor could find that some part of the State is being damaged to a significant extent. The Governor would notify the Water Resources Council of his finding, and the Council would forthwith, within 5 days, see that modification experiments or operations affecting the State were stopped for the length of time required by the Governor. If the Governor's requirements seemed unreasonable, the Council could appeal to a regular jury in Federal court. The Federal district judge would preside and he would be bound by the findings of the jury. The hearing would be held in the U.S. district court bordering, but not entering the State affected.

Another alternative possibility would be an arbitration commission set up within the executive branch of the Government. The commission would be composed of qualified persons with the power to use the investigative arms and information sources of the Departments of Justice, Defense, Agriculture, and Interior. The Council or any citizen feeling he was damaged would protest to this board. If public hearings were necessary, travel expenses would be authorized unless hearing was held in or adjacent to damaged areas. The board would have power to gain property. This board would act without charge to the individual citizen. We visualize this approach as possibly being most satisfactory because such a commission could investigate and protect experimentation which is being conducted with an eye on future warfare techniques. Such nonpublic findings could protect the national security.

Further, we suggest the law provide that most of the work in the field of weather modification be conducted east of the 100th meridian, and in fact, if possible and feasible, work so that results will be felt over the Atlantic Ocean until something concrete is developed. The intent of this provision would be to prevent damage to areas where there is little rainfall, and what little there is is critical. The

general prevailing wind pattern over the United States is west to east, thus any experimentation is carried eastward. We understand results experienced by General Electric and the New Mexico School of Mines indicate that seeding experiments caused serious heavy rainfall more than a thousand miles east of the site of the experiments. We ask the committee to examine findings of early research before final drafting of this bill.

One omission in S. 2875 is the absence of guidelines for the issuing agency to follow in licensing experimentation. This matter is of greatest national importance and, therefore, it should be possible for the greatest number of persons interested in the matter to try their hands. At the same time, the location of the experiments, the timing in relation to other work, and other considerations should be under reasonable control and coordination. The keeping of records and their submission to the Water Resources Council is extremely necessary. However, this is not to say that the developer should not be entitled to the protection of patents so he may reap a reasonable benefit from his private enterprise.

We cannot too strongly stress the need to hold this work in the greatest secrecy, and to guard successful methods as a highest public asset. The information should not be shared with any other country and those having access to any significant body of information should be subject to the highest form of security clearance.

The committee should well understand that if a good method of weather modification is developed, it becomes a tremendous power in the hands of the developer. It can be used for good or evil. It can create justice and injustice. It can be used for political purposes, to punish or to reward. In this lies the control of the water supply of cities, the ability to raise crops or destroy them or to govern their volume. It might be well for this committee to consider what sort of control should be placed over this power. A possibility we would present for consideration is a board similar to the Federal Reserve Board. The term of the appointee should be rather long, say 6 years. The membership would have to have geographical and political distribution. There would have to be broad general knowledge of the geographic area, crops, cities, forests, rivers, and so forth. The geographical distribution might be divided in four quarters: northeast, southeast, northwest, and southwest; with the 100th meridian dividing east and west, and the line running generally along the northern boundary of North Carolina, Tennessee, Arkansas, Oklahoma, New Mexico, and Arizona dividing north and south. There should be two men from each quadrant with a ninth appointed at large. The terms would be staggered. No two members should come from the same State.

The machinery herein outlined must be as free as possible from the pressure of the electorate in that volume of votes does not guarantee the wisdom of Solomon. Cities and industries need water as well as food and fiber. This board must be in the unenviable position of neatly making a proper allocation for both.

We appreciate the opportunity to be heard on this bill and hope that we have been able to add something constructive for your consideration. Our concern in this matter is that it is vitally concerned with our day-to-day operations.

Senator ANDERSON. Thank you. This is a very interesting paper, because these are questions which have not been raised as to how they are going to be operated. I am glad you referred to the fact that the cloud seeding did have an effect on the eastern part of the country. We once seeded every 8 days, for example, in Albuquerque and after 3 days they would have rain in the same intervals in Red River. We can't prove those things tie together. The mere fact that it happened indicates that there might be something to it. Similarly in the same period at this stage up in Omaha the rains from the mountains moved up and down. There is some reason to be careful about it and to have very good protection for all people concerned. We appreciate your comments related to this.

Mr. HUNING. Thank you.

Senator ANDERSON. Senator Bible.

Senator BIBLE. I think your observations cover the points I had, Mr. Chairman. There are some interesting philosophies here. I do take it that you do wholeheartedly endorse this bill?

Mr. HUNING. We do, as we stated initially. We certainly do wholeheartedly endorse the bill.

Senator BIBLE. You are throwing up some things that we had better watch out for.

Mr. HUNING. They are some thoughts that were presented to us. We are concerned because this is our business and we are depending on this rainfall in our livestock business in New Mexico. They are directly affected by the results of these experiments.

Senator BIBLE. I understand. Thank you, very much.

Mr. HUNING. Thank you.

Senator ANDERSON. Are there other witnesses?

I have a statement here of Eugene Finch, legislative director of the New Mexico Farm and Livestock Bureau. That will be included in the hearing record at this point.

(The statement referred to follows:)

STATEMENT OF EUGENE FINCH, LEGISLATIVE DIRECTOR, NEW MEXICO FARM AND LIVESTOCK BUREAU

I represent the New Mexico Farm and Livestock Bureau which consists of 9,232 family members. We deeply appreciate this opportunity to present our views on S. 2875.

As an agriculture organization, we are very concerned with water development be it underground, surface, or atmospheric. Being in a water-deficient area we are most interested in any logical research that could possibly provide a more adequate supply of water. Therefore, we are in agreement with the basic concept of S. 2875.

For years our policy, as set forth by our members, has recognized that with the tremendous advancement of science and technology in the field of meteorology and more specifically weather modification comes the realization that control measures must be taken.

I would like this committee to take note of the fact that the New Mexico Legislature in 1965 passed a Weather Control Act which farm bureau supported. Perhaps other States have also legislated in this area. We feel that provisions should be made to coordinate S. 2875 with existing State laws in the same field.

We feel that section 204 of the printed bill should be amended to give the Secretary of the Interior, or a resource council, authority to coordinate all weather modification research conducted by all agencies of the Federal Government as a deterrent to duplication.

Again, we thank you for this opportunity to appear before this committee.

Senator ANDERSON. I have received a telegram which I will include at this point.

(The telegram referred to follows:)

ALBUQUERQUE, N. MEX., *April 13, 1966.*

Senator CLINTON ANDERSON,
Albuquerque, N. Mex.:

Confirming our prior weather modification testimony at Senator Dominick's hearings, we congratulate Senator Anderson on his farsighted efforts. We share his desire to draw available water (25 million gallons per square mile) from the blue, and we have demonstrated weather engineering, Bosco technique, successfully in many New Mexico areas. References include J. C. Johnson, Tularosa and Ruidoso ski area. Share the resentment of many New Mexicans against a whole year's drought produced by other flamboyant type cloudseeding operators. This is not forgotten by many New Mexicans. Seek assurance such operators will be precluded from these operations with a maximum safe monthly ration of under 20 pounds silver iodide total State per month. Such assurance includes prior directors of such work whose unchanged procedures are still rigidly adhered to as currently reported in scientific publications. Aerial seeding or lengthy ground seeding. We welcome a chance to again prove our New Mexico-Texas snow- and rain-increasing ability, subject to past and recent successes assuring a continuing program under our close supervision.

WEATHER ENGINEERING,
By F. NEAL BOSCO.

DENVER, COLO.

Senator ANDERSON. Thank you all for being here. The hearing is closed.

(Whereupon the meeting was adjourned at 3 p.m., April 14, 1966.)

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