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WEATHER MODIFICATION

GOVERNMENT
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HEARINGS BEFORE THE COMMITTEE ON COMMERCE UNITED STATES SENATE NINETIETH CONGRESS

SECOND SESSION

ON

S. 373

TO PROVIDE FOR A WEATHER MODIFICATION PROGRAM

AND

S. 2058

TO PROVIDE A PRACTICABLE WEATHER MODIFICATION
PROGRAM FOR THE UPPER COLORADO RIVER BASIN

JUNE 14 AND 17, 1968

Serial No. 90-83

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RELATING TO WEATHER MODIFICATION

FRIDAY, JUNE 14, 1968

U.S. SENATE,
COMMITTEE ON COMMERCE,
Washington, D.C.

The committee met at 10 a.m., in room 162, of the Federal Court House Building, Denver, Colo., Hon. Howard W. Cannon presiding.
Present: Senator Cannon.

OPENING STATEMENT BY THE CHAIRMAN

Senator CANNON. The hearing will come to order.

This is the first hearing held by the Senate Committee on Commerce during the 90th Congress on pending bills to advance weather modification programs. The bills are S. 373, a bill to provide what would be an effective and coordinated national program in weather modification; and S. 2058, a bill that may be of particular interest to this area, which proposes to provide a practical weather modification program for the Upper Colorado River Basin.

S. 373 is similar to S. 2916 of the 89th Congress, which passed the Senate late in the second session, too late for action in the House of Representatives. Many of you will recall that hearings on previous weather modification bills were held here in Denver on March 30 and April 1, 1966. Several of those scheduled to testify at today's hearing were also important witnesses at the hearing here 2 years ago.

We are honored today to have with us the distinguished Senator from Colorado, Hon. Peter Dominick, who will be the first witness. The Senator is the author of bill S. 2058, which he introduced in June 1967, and he is a cosponsor of S. 373 with Senator Magnuson, Senator Scott, and myself.

Hearings on proposed legislation similar to S. 373 and H.R. 9212 have been held by the Subcommittee on Communications and Power of the Committee on Interstate and Foreign Commerce of the House of Representatives, and the bill is now pending before the standing committee.

Weather modification has many aspects. Perhaps the greatest goal of mankind has been to produce moisture, rain or snow, when the normal precipitation is insufficient. A start toward obtaining this objective has been made, as I believe the witnesses here today will confirm, but there is still much to be done and a long way to go. Congress has been alerted to the need to increase precipitation, particularly in the West, for nearly three-quarters of a century. In 1890 it provided funds for experiments in producing rainfall by floating balloons in the clouds. In mid-Texas, where they were made, these

tests were discouraging, although light patterns of rain for 20 to 30 minutes were known. The tests were abandoned in 1893. Today, in Soviet Russia, antiaircraft guns are battering clouds with projectiles charged with silver iodide, and the U.S.S.R. claims that in one area last year 15 hail focuses were destroyed by antiaircraft shells. Perhaps we should take that report with a grain of salt. We do not project that method in the bills before us today.

Use of silver iodide crystals was borrowed from us in the 1946 experiments by the late Dr. Vincent Shaffer of the State University of New York. A few months earlier Dr. Shaffer produced snowfall by dropping 6 pounds of dry ice from an airplane over an altocumulus in Massachusetts. In every Congress since then bills have been introduced relating to weather modification. Many of these fell by the wayside, but in the 83d Congress, 15 years ago, legislation was enacted to create a committee to study and evaluate public and private experiments. The 84th Congress established the advisory committee on weather control for 2 years, and the 85th Congress enacted legislation to provide for an experimental research program in cloud modification. Incidentally, the above bills originated in the Senate.

The 1958 act, now 10 years old, is still the basic authority for administrative activities in the field of weather modification, and this in turn has limited the potential effectiveness of scientists engaged in weather modification research activities.

At the hearings which I conducted in Washington in 1966, in my opening remarks I touched on the inadequacy of the program under existing law and I listed these as, (a) frustration of the attempt in Public Law 85-510 of 1958 to centralize responsibilities; (b) failure to develop conclusive results on the effects of cloud seeding; (c) a failure to develop proper designs for experiments and evaluation; (d) a failure to develop a coherent program on goals; and (e) a failure to study inadvertent weather modifications, such as increased air pollution and the social, economic, legal, and international implications of weather and climate modification.

These are inadequacies which are indeed to be corrected, and to assure correction of legislative action is necessary. Whether S. 373 will accomplish this or S. 2058 will be effective in this region is a matter for congressional determination. These hearings are held to assist the Congress to make that determination.

During the past 10 years the scientific community and the administration have not been dilatory in carrying out their mission to conduct an experimental program in weather modification. In 1963 the Committee on Atmospheric Science of the National Academy of Science appointed a committee on weather modification to undertake a deliberate and thoughtful review of the present status of activities in this field and of its potential limitations for the future. The panel of 14 distinguished scientists did this, and the report and recommendations are available from the National Academy.

In 1964, the Director of the National Science Foundation appointed a special Commission on Weather Modification, and this Commission and its seven subgroups also made a valuable contribution.

In 1966 the Interdepartmental Committee on Atmospheric Sciences of the Federal Council for Science and Technology appointed a select

panel on weather modification headed by Dr. Earl Crossler, vice president for research of the State University of New York. This panel proposed an excellent report entitled "Present and Future Plans of Federal Agencies in Weather Climate Modification."

S. 373 reflects some of the conclusions and recommendations in that report, and I will ask that it be included in the hearing record when it is published.

In this same area the ICAS requested Dr. Homer Newell, Associate Administrator for Space and Science Applications of NASA, a distinguished weather modification scientist, to develop a national weather modification program along the lines delineated in the panel's report. Dr. Newell was assisted by weather modification scientists from NASA, the Bureau of Reclamation, the National Science Foundation, and the Department of Agriculture. As a member of the Senate Committee on Aeronautical and Space Sciences, I have great respect for Dr. Newell's scientific accomplishments and I am impressed with his report and recommendations. I shall not attempt to recite the numerous recommendations in the report. Many of them are, however, reflected in S. 373, but I will note several. There is sufficient potential payoff indicated by the results of past research to justify continuing basic and applied research in the area of weather modification. A formal procedure must be developed to achieve continuing advisability and coordination with the total weather modification program. There must be regulation and control of weather modification control activity, especially as those activities increase in magnitude and frequency and become international in scope. This is required especially to provide a mechanism for protection against harmful consequences of weather modification activity, but also to permit valid experimentation. I am placing in the record at this point copies of the bills and agency comments thereon.

(The material referred to follows:)

WEATHER MODIFICATION ACT OF 1967

Mr. MAGNUSON. Mr. President, I introduce, for appropriate reference, a bill to promote a comprehensive national weather modification program.

This bill is identical to the one approved last session by this body. The legislative history is as follows: November 5, 1965, hearings, Las Vegas, Nev.; November 10, 1965, hearings, Elko, Nev.; February 21, 24, and 25, March 7 and 8, 1966, hearings, Washington, D.C.; March 31 and April 1, 1966, hearings, Denver, Colo.

April 27, 1966, a report by the Legislative Reference Service entitled "Weather Modification and Control."

October 13, 1966, considered in executive session by the full committee and ordered reported favorably.

October 14, 1966, passed by the Senate.

As this history indicates, this bill has received many days of attention and hearings. The importance of the subject cannot be overstressed. Foreign nations are conducting programs which dwarf ours, both in scale and in organization. The economic impact of feasible comprehensive weather modification can be favorably measured in hundreds of thousands if not millions of dollars. National weather modification programs have significant international implications.

Weather modification is not new—only deliberate weather modification has new implications. The Christian Science Monitor recently carried a story headlined "Effect on Weather of Sprawling Smoky Cities Pondered." The Washington Post recently carried a story headlined "Auto Gases Suspected of Changing Climate." Everyday sees a continuation of inadvertent weather modification experiments.

Commercial weather modification programs have been carried on for some time. These operations are increasingly more scientific. The Federal Government is increasingly conducting weather modification programs on an engineering as

well as a research scale. The following is a statement from the Bonneville Power Administration.

"To further alleviate the tight power supply situation, BPA and the Bureau of Reclamation plan this winter a pin-point cloud seeding program at Hungry Horse Dam. Such a program was found feasible by outside consultants who also assure us it can be pin-pointed so as to increase the snowpack above Hungry Horse Dam and therefore, inflow to Hungry Horse Reservoir without adversely affecting agricultural operations or increasing flood danger."

Plans such as this are of great significance, but it is essential that this environmental subject be coordinated in the most efficient manner. The Legislative Reference Service described the matter as follows:

"Weather modification, in spite of the number and variety of processes and activities that generally are included in this expression, as well as the popular, political, and professional attention that it has received over the past 20 years, remains today, one of the smallest areas of science and technology, considered in terms of Federal support. This is particularly surprising in view of the manifest needs and benefits, social and economic, that can be associated with the subject."

This bill does not represent a dramatic new departure; it does not authorize a "race to the moon" crash program. It is an attempt to organize and slightly enlarge existing programs. It is an attempt to put a new science program on an orderly basis before the inevitable scientific breakthroughs require a crash program.

I urge all Senators to give this bill the favorable consideration that they gave it in the 89th Congress. I am pleased to have as cosponsors, Senator Scott, Senator Cannon, and Senator Dominick, who have shown great interest in this subject.

The VICE PRESIDENT. The bill will be received and appropriately referred.

The bill (S. 373) to provide for a weather modification program, introduced by Mr. Magnuson (for himself and other Senators), was received, read twice by its title, and referred to the Committee on Commerce.

[S. 373, 90th Cong., second sess.]

A BILL To provide for a weather modification program

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may cited as the "Weather Modification Act of 1967".

TITLE I—DECLARATION OF POLICY AND DEFINITIONS

DECLARATION OF POLICY

Sec. 101. (a) The Congress hereby declares that it is the policy of the United States to develop, encourage, and maintain a comprehensive and coordinated program in weather modification in order to contribute to—

- (1) the protection of life and property,
 - (2) the maintenance of adequate water resources for the United States, and
 - (3) the enhancement of commerce, transportation, agriculture, natural resources, health, and security in the United States.
- (b) In order to achieve the objectives of this Act, the weather modification activities of the United States shall be conducted with full consideration of:
- (1) the development of the necessary scientific basis in a strong and balanced program in the atmospheric sciences;
 - (2) the mutual dependence of weather modification, weather forecasting, climatology, and other aspects of atmospheric sciences and meteorological services;
 - (3) the effective utilization of all applicable scientific and engineering resources of the Nation, including those in industrial, academic, and other public and private organizations, in all regions of the United States;
 - (4) the close cooperation of all agencies and organizations concerned in order to avoid waste or unnecessary duplication of effort, facilities, or equipment;
 - (5) the effective utilization of scientific and technical knowledge, instrumentation, equipment, and techniques in all scientific and engineering disciplines applicable to weather modification;
 - (6) the advancement of education and training in the atmospheric sciences and meteorology; and

(7) the cooperation of the United States with other nations and international organizations, whenever such cooperation is in the national interest, in order to facilitate the exchange of scientific and technical information and the peaceful and beneficial application of weather modification.

(c) Whenever the President deems any transfer of a function of any department or agency of the United States to any other Federal agency having responsibilities under this Act is necessary to carry out the provisions of this Act, he shall accomplish such transfer under the provisions of the Reorganization Act of 1949.

DEFINITIONS

SEC. 102. As used in this Act—

(a) The term "weather modification" includes any intentional or inadvertent artificially produced changes in the composition, behavior, or dynamics of the atmosphere.

(b) The term "operational activities" means the construction and the use of devices and systems for weather modification primarily designed to achieve a planned and continuing substantial result of social, economic, commercial, biological, or medical significance.

TITLE II—WEATHER MODIFICATION

FUNCTIONS OF FEDERAL AGENCIES

SEC. 201. In order to carry out the purposes of this Act—

(a) The Secretary of Commerce is authorized to—

(1) carry out a comprehensive program in the field of weather modification, which shall include a specific program designed to control or modify tornadoes, hurricanes, and other severe storms; and

(2) furnish technical assistance and information in the field of weather modification to any other Federal agency requesting such assistance or information.

(b) The Secretary of the Interior is authorized to carry out a program in such aspects of weather modification as relate to the augmentation and improvement of the usable water resources of the United States;

(c) The Secretary of Agriculture is authorized to carry out a program in such aspects of weather modification as relate to the control of lightning and hail, and to the protection of vegetation from the effects of other weather phenomena;

(d) The Secretary of Health, Education, and Welfare is authorized to carry out a program in such aspects of weather modification as relate to the control of air pollution and other similar deleterious effects of urbanization upon the composition of the atmosphere; and

(e) The Administrator of the Federal Aviation Agency is authorized to—

(1) carry out a program for the effective and beneficial dispersal of fog and cloud cover interfering with airport operations or air transportation in the United States; and

(2) conduct operational activities for such fog or cloud cover dispersal.

(f) The National Science Foundation is authorized to advance the state of knowledge in weather and climate modification through the initiation and support of basic and applied research, and programs of education and training, at universities, colleges, and other appropriate institutions, in those sciences which relate to and underlie weather and climate modification technology.

ADMINISTRATIVE POWERS

SEC. 202. In order to carry out the provisions of this Act, the head of any Federal agency charged with responsibilities under section 201 is authorized to—

(1) adopt, amend, and repeal regulations governing the exercise of his duties under this Act;

(2) acquire by purchase, license, lease, donation, or otherwise such inventions, patents, patent applications, licenses, real property and interests therein as he deems necessary;

(3) accept as a gift, money, material, or services, and notwithstanding any other provision of law, use of any such gift, if the donor so specifies, may be restricted or limited to certain projects or areas;

(4) enter into and perform such contracts, leases, cooperative agreements, or other transactions, including the making of grants, as may be necessary

to carry out his duties under section 201 and on such terms as he may deem appropriate; and

(5) use, with their consent, the services, equipment, personnel, and facilities of other Federal agencies with or without reimbursement, and on a similar basis to cooperate with other public and private agencies and instrumentalities in the use of services, equipment, and facilities, and each department and agency of the Federal Government shall cooperate fully in making its services, equipment, personnel, and facilities available to an agency charged with responsibilities under section 201 and, with the approval of the Director of the Bureau of the Budget, each department or agency is authorized, notwithstanding any other provision of law, to loan to such agency, without reimbursement, property, equipment, and facilities required for the performance of its duties under this Act.

HEARINGS

SEC. 203. (a) The head of any Federal agency charged with responsibilities under section 201 or any employee of such agency designated by him, may for the purpose of performing his functions under section 201 hold such hearings and sit and act at such times and places and take such testimony as he deems advisable. The head of any such Federal agency or any employee of such agency designated by him may administer oaths or affirmations to witnesses appearing before the head of such agency or such employee.

ACCESS TO INFORMATION

SEC. 204. Information contained in any statement, report, record, other document furnished pursuant to section 203, and information developed by any agency in the performance of its functions under this Act shall be made available at all reasonable times for public inspection except (1) information authorized or required by statute to be withheld and (2) information classified in accordance with law to protect the national security. Nothing in this subsection shall authorize or require the publication, divulging, or disclosure of any information described in section 1905 of title 18 of the United States Code, except that the head of any Federal agency charged with responsibilities under section 201 may disclose information described in such section 1905, furnished pursuant to section 203, whenever he determines that the withholding thereof would be contrary to the purposes of this Act.

COMMERCIAL OPERATIONS

SEC. 205. (a) The Secretary of Commerce is authorized, after notice and opportunity for a hearing, to issue regulations governing the weather modification activities of private business concerns not engaging in such activities pursuant to contract, lease, cooperative agreement, grant, or other transaction, which conflict with or impede any activities conducted under this Act and to encourage compliance with such regulations by such business concerns.

(b) The Secretary of Commerce, in cooperation with the Secretary of State, the Secretary of Defense, and the heads of other Federal agencies charged with responsibilities under section 201, and after consultation with representatives of such business concerns, shall conduct a thorough study of the need for the regulation of weather modification research, development, and operational activities, and report to Congress not later than one year after the enactment of this Act recommendations for additional legislation concerning such regulation including enforcement of such regulation.

TITLE III—FEDERAL COORDINATION AND PLANNING

THE PRESIDENT

SEC. 301. In order to achieve the objectives of this Act, the President is authorized to—

- (1) direct the planning and supervision of the weather modification program authorized by this Act;
- (2) establish the goals to be achieved by such program;
- (3) establish priorities and resolve conflicts between agencies engaged in such program so that the activities of one agency conducted under this Act

will not conflict with or impede activities of any other agency conducted under this Act;

(4) coordinate the activities of each agency engaged in such program in order to insure an effective and balanced effort and to avoid waste and duplication;

(5) consult with the National Academy of Sciences, the National Academy of Engineering, private scientific and educational organizations and individuals on scientific and technological developments and new opportunities for the beneficial application of weather modification; and

(6) conduct a thorough study and investigation, in cooperation with all Federal agencies engaged in such program, including the National Science Foundation, of the need for new national facilities for weather modification research, including a consideration of the adaptability of existing Federal facilities, and shall report to the Congress not later than one year after the effective date of this Act such recommendations for such additional legislation as he deems advisable.

INTERNATIONAL COOPERATION

SEC. 302. (a) The Secretary of Commerce is authorized to cooperate in any international activities relating to weather modification consistent with the provisions of this Act. The authority to cooperate in international weather modification activities shall be exercised only with the approval of the Secretary of State to assure that such authority is exercised in a manner consistent with the foreign policy objectives of the United States. Subject to the provisions of this section, if negotiation with foreign countries or agencies thereof becomes necessary, such negotiation shall be carried on by the Secretary of State.

(b) The Secretary of Commerce shall cooperate to the fullest practical extent with the Secretary of State in providing representation at all meetings and conferences relating to weather modification and climate control in which representatives of the United States and foreign countries participate. The Secretary of State shall designate the Secretary of Commerce, or his designee, as a member of the United States delegation attending such meetings and conferences and also as a member of the negotiating team of any such delegation.

CONDUCT OF FEDERAL OPERATIONAL ACTIVITIES

SEC. 303. (a) Before any Federal agency conducts any weather modification activity which is intentionally designed in whole or in part to affect the atmosphere more than one hundred and fifty miles from the source of such activity, the President shall transmit to the Speaker of the House of Representatives and to the President of the Senate and to the Committee on Commerce of the Senate and to the Committee on Interstate and Foreign Commerce of the House of Representatives a written report containing a full and complete statement explaining the goals, operation, precautions to be taken, and other appropriate information on such weather modification activity.

(b) Notwithstanding any other provision of law, unless otherwise specifically authorized in this Act, before any Federal agency conducts directly or by contract, lease, cooperative agreement, grant, or other transaction weather modification operational activities, it shall obtain the prior approval of the Congress enacted into law.

INVESTIGATIONS

SEC. 304. (a) The Secretary of Commerce, in cooperation with the Secretaries of the Interior, Agriculture, Health, Education, and Welfare, the Attorney General, and the National Science Foundation, shall conduct a thorough study and investigation to determine under what circumstances the United States and private parties should be liable for damages attributable to weather modification activities, including indemnification and insurance of contractors and grantees of the United States engaged in such activities, and report to the Congress not later than one year after the enactment of this Act recommendations for additional legislation concerning such liability.

(b) The Secretary of Commerce, in cooperation with the Secretaries of Agriculture, Interior, Health, Education, and Welfare, and the National Science Foundation, shall conduct a thorough study and investigation into the social and economic effects, both deliberate and inadvertent, of weather modification activities and report the results of such study to the Congress not later than two years after the enactment of this Act.

(c) The Secretary of Commerce, in cooperation with the Secretaries of Agriculture, Interior, and Health, Education, and Welfare, and the National Science Foundation, shall conduct a thorough study and investigation of the biological and ecological effects of weather modification and report the results of such study to the Congress not later than two years after the enactment of this Act.

TITLE IV—GENERAL

AMENDMENTS TO NATIONAL SCIENCE FOUNDATION ACT OF 1950

SEC. 401. (a) Section 3(a)(2) of the National Science Foundation Act of 1950 (42 U.S.C. 1862(a)(2)) is amended by adding "atmospheric," immediately after "engineering."

(b) Section 3(a)(7) of such Act is amended by adding "and" after the semicolon at the end thereof.

(c) Section 3(a)(8) of such Act is amended by striking out the semicolon at the end thereof and inserting in lieu thereof a period.

(d) Section 3(a)(9) and section 14 of such Act are repealed.

REPORTS

SEC. 402. The President shall transmit to the Congress in January of each year a report which shall include (1) a comprehensive and detailed description of the activities and accomplishments of each Federal agency under the provisions of this Act during the preceding fiscal year; (2) an evaluation of such activities and accomplishments in terms of obtaining the objectives of this Act; (3) an analysis of recommended expenditures for all weather modification activities authorized by this Act for the succeeding fiscal year; (4) a description of non-Federal weather modification activities; (5) a description of weather modification activities carried out by foreign countries; and (6) any recommendations for additional legislation which the President may consider necessary or desirable.

RECORDS AND AUDIT

SEC. 403. (a) Each recipient of a contract grant or party with whom a cooperative agreement is entered into under this Act shall keep such records as the head of the appropriate Federal agency shall prescribe, including records which fully disclose the amount and disposition of the funds received under the grant or cooperative agreement, the total cost of the project or undertaking in connection with which the contract or grant was made or cooperative agreement entered into, and the amount and nature of that portion of the cost of the project or undertaking supplied by other sources, and such other records as will facilitate an effective audit.

(b) The head of each Federal agency charged with responsibilities under section 201 and the Comptroller General of the United States, or any of their duly authorized representatives, shall have access for the purpose of audit and examination to any books, documents, papers, and records of the recipient of the grant or party to the cooperative agreement that are pertinent to the grant received or cooperative agreement entered into, under this Act.

APPROPRIATIONS

SEC. 404. There are hereby authorized to be appropriated for the purpose of carrying out the provisions of this Act, not to exceed \$12,000,000 for fiscal year 1967; \$30,000,000 for fiscal year 1968; and \$40,000,000 for fiscal year 1969.

COMPTROLLER GENERAL OF THE UNITED STATES,
Washington, D.C., February 9, 1967.

HON. WARREN G. MAGNUSON,
*Chairman, Committee on Commerce,
U.S. Senate.*

DEAR MR. CHAIRMAN: Your letter of January 23, 1967, requests our comments on S. 373.

The bill would assign responsibility for specific aspects of weather modification activities to the Secretary of Commerce; the Secretary of the Interior; the Secretary of Agriculture; the Secretary of Health, Education, and Welfare; the

Administrator of the Federal Aviation Agency; and the National Science Foundation. Overall responsibility for directing the planning and coordinating the activities of the various agencies would be vested with the President.

We are pleased to note that section 403 of the bill includes a records and audits provision relating to recipients of Federal funds under grants and cooperative agreements.

The desirability of the proposed legislation involves a matter of policy for determination by the Congress, and therefore we make no recommendation as to its merits. From a technical standpoint, we note that section 404 authorizes appropriations for fiscal years 1967, 1968 and 1969, although fiscal year 1967 is now more than half over.

Sincerely yours,

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

NATIONAL SCIENCE FOUNDATION,
OFFICE OF THE DIRECTOR,
Washington, D.C., June 14, 1967.

HON. WARREN G. MAGNUSON,
*Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.*

DEAR MR. CHAIRMAN: This is in further reply to your letter of January 23, 1967 requesting the Foundation's comments on S. 373, 90th Congress, to provide for a Weather Modification program.

In general, the National Science Foundation is heartily in favor of the purposes of this Bill, but we are troubled by one section, namely, Section 303 which limits the conduct of certain weather modification activities. Section 303(a) would prevent any such activity which is intended to affect the atmosphere more than 150 miles from the source of such activity without a prior report transmitted by the President to the Congress. This, we believe, would seriously impede some of the most effective contemporary research which has promise of finding ways to reduce the destructiveness of storms. Severe storm systems such as hurricanes and tropical storms have a diameter of at least 300 miles. Any effective seeding within this area would be intended to affect the entire storm system. With respect to lightning and hail suppression, research experiments will often be concerned with storm patterns which could easily exceed 150 miles. Treatment of these storms is usually performed by silver iodide seeding from aircraft supplemented by ground-generated seeding. Guidance of the seeding aircraft is performed in-flight based upon radar evaluation of the storm development as hail cells form and dissipate. To confine the aircraft operational radius to 75 miles might abort the entire experiment since cell development may fluctuate rapidly over a 200 to 300 miles front, requiring complete freedom on the part of the experimenter to follow the locations where the actions is taking place.

I should add that even commercial cloud-seeding for rainfall intended to be effective within 30 or 40 miles has been found by the Weather Bureau to modify rainfall patterns as far as 150 miles down wind.

We are entirely sympathetic with the concern expressed by the Senate Commerce Committee Report No. 1725 accompanying S. 2916, 89th Congress, at Page 10 regarding the possibilities of irreparable long-range effects of weather modifications research activities upon what might be described as climate rather than transient weather conditions. Perhaps this concern might adequately be allayed by substituting the word "climate" for the word "atmosphere" in Line 9 on Page 11 of the Bill. In any case, I hope that any fixed geographic limit on research activities can be removed from the Bill.

Section 303(b) would, without further legislation, prevent any Federal agency from engaging in "weather modification operational activities" except for fog and cloud dispersal activities under the aegis of the Federal Aviation Agency (permitted by virtue of Section 201(e) of the Bill). Again, we can understand the feeling that excessive or ill-conceived operational activities might result in irreversible undesirable effects, but we believe that the present limitation may give rise to some confusion.

Under the definition of the term "operational activities" in Section 102(b), it may sometimes be difficult to make a sharp distinction between research and development activities and operational activities. With respect to some aspects

of weather modification, evaluation of theories or hypotheses to a reasonable degree of accuracy may require field experiments lasting several years during which period significant effects may be produced.

I assume that the intention of the Bill is to permit weather modification activities carried on for the purpose of research but to reserve judgment with respect to such activities carried on primarily for their intended effect. I suggest that this intent could be achieved by suitable language in the Report accompanying the Bill or by amending Section 102(b) to read as follows:

"The term 'operational activities' means the construction and the systematic use of devices and systems for weather modification with intent to achieve a planned and continuing substantial result of social, economic, commercial, biological, or medical significance."

The intention of Section 205(a) of the Bill, according to the Senate Commerce Committee at Pages 11 and 14 of its Report No. 1725, 89th Congress, is to authorize ". . . the Secretary of Commerce to issue regulations governing weather modification activities by commercial organizations which interfere with activities which would be authorized by this bill . . .". In order to carry out this intention and to make clear that the object of the regulations is to govern the weather modification activities of private organizations not having contracts, grants or other agreements for conducting weather modification activities for the Federal agencies authorized to carry out the purposes of the Bill, it is suggested that in the fourth line of Section 205(a) the phrase "for Federal agencies under this Act" be inserted after the word "activities".

One minor point might be made to the effect that in Section 101(b)(6) the word "meteorology" is redundant since that field is included in the term "atmospheric sciences".

Subject to these suggestions we strongly endorse S. 373 and recommend its enactment.

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

Sincerely yours,

LELAND J. HAWORTH, *Director.*

DEPARTMENT OF AGRICULTURE,
Washington, D.C., June 15, 1967.

HON. WARREN G. MAGNUSON,
*Chairman, Committee on Commerce,
U.S. Senate.*

DEAR MR. CHAIRMAN: In reply to your request of January 23, 1967, this is our report on S. 373, the proposed "Weather Modification Act of 1967," to provide for a weather modification program.

This bill would declare the policy of Congress with respect to a comprehensive and coordinated weather modification program. It would define the functions of several Federal agencies engaged in specific aspects of the program, including: Commerce; Interior; Agriculture; Health, Education and Welfare; the Federal Aviation Agency; and the National Science Foundation. Federal coordination and planning would be achieved by the President in consultation with the National Academy of Sciences, the National Academy of Engineering, and private and educational organizations. A thorough study and investigation would be conducted in cooperation with all Federal agencies engaged in such a program, including the National Science Foundation, of the need for new national facilities for weather modification research, including a consideration of the adaptability of existing Federal facilities. An appropriate report would be made to the Congress within the year after the effective date of this Act.

Provisions for international cooperation, prior approval of Congress for certain weather modification activities, and investigations of social, economic, biological, and ecological effects would be enacted.

Under Title II, the Secretary of Agriculture is authorized to carry out a program in such aspects of weather modification as relate to the control of lightning and hail, and to the protection of vegetation from the effects of other weather phenomena. This provision seems entirely appropriate to our interests. The specific authorizations for other agencies included under this title seem apropos, if acceptable to them.

Sec. 303(a) specifies that before any Federal agency conducts any weather modification activity which is intentionally designed in whole or in part to affect

the atmosphere more than one hundred and fifty miles from the source of such activity, the President shall report to the Congress thereon. We respectfully submit that this would be an impractical requirement, as interpreted by the Interdepartmental Committee for Atmospheric Sciences.

The provisions of Public Law 85-510 and Executive Order 10521 have provided a framework under which the National Science Foundation has given effective leadership and coordination to such research. The proposed Act would more specifically delineate the role of this and other executive agencies and could expedite the development of a coordinated weather modification program.

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.*

DEPARTMENT OF THE AIR FORCE,
OFFICE OF THE SECRETARY,
Washington, June 19, 1967.

HON. WARREN G. MAGNUSON,
*Chairman, Committee on Commerce,
U.S. Senate.*

DEAR MR. CHAIRMAN: Reference is made to your request to the Secretary of Defense for the views of the Department of Defense with respect to S. 373, a bill to provide for a weather modification program to be carried out by the Secretary of Commerce. The Department of the Air Force has been designated to express the views of the Department of Defense.

The proposed legislation would authorize the Secretary of Commerce to carry out a comprehensive program in weather modification and to furnish technical assistance and information in weather modification to any other Federal agency requesting such. It would also authorize the Secretary of Agriculture, the Secretary of Interior, the Secretary of Health, Education, and Welfare, and the Administrator of the Federal Aviation Agency to carry out research and development programs in weather modification related to their functional areas. It would permit the Federal Aviation Agency to conduct operational activities related to its own research and development program and would authorize the National Science Foundation to initiate and support basic and applied research, and programs of education and training in those sciences related to weather and climate modification. Further, the bill would provide for Federal planning, coordinating, reporting, regulating, and international cooperation concerning certain weather modification activities.

In establishing Federal agency responsibility for carrying out the various programs of weather modification, the proposed legislation does not specifically allocate a particular program to the Department of Defense. Senate Report No. 1725, on S. 2916, 89th Congress, an Act identical with S. 373, did recognize the Department's past efforts in the area of weather modification and indicated that the Act did not provide for explicit authorization for the Department of Defense "because of the military significance and classified nature of their work". Since the aim of S. 2916 was to establish a "civilian national program," there was no requirement to specifically identify the Department with a particular program. The Report went on to state: "The committee, however, would anticipate that research and development in important aspects of weather modification would continue to be supported by the military departments. The avoidance of duplication becomes a responsibility of the Federal coordination process." Furthermore, S. 373 also recognizes the Department's programs in weather modification developments when it provides for the Secretary of Defense's participation in a study to determine the need for the regulation of commercial weather modification programs. The Department of Defense, therefore, interprets S. 373 as containing no restrictions on its responsibilities and functions in weather modification research, development, and operational activities, subject only to the coordination process of section 301 to avoid duplication of efforts and section 303(a) requiring Congressional notice where any weather modification activity of a Federal agency is intentionally designed to affect the atmosphere more than one hundred and fifty miles from the source of such activity.

It is noted that in providing for various "Administrative Powers" S. 373 enables the agencies covered to utilize the services, equipment, personnel, and facilities of other Federal agencies. Although the bill states such utilization will

be on a consent basis, it goes on to state that "each department and agency of the Federal Government *shall* cooperate fully in making its services, equipment, personnel, and facilities available . . ." (Emphasis supplied.) The Department of Defense intends to cooperate fully with the agencies designated to carry out their respective programs, but must emphasize that such cooperation should be on a consent basis so as to insure the availability of resources and facilities within the Department to meet its primary responsibilities.

In the nature of a technical comment, it is suggested that references to the various Secretaries in section 304 (a) and (b) be restated for clarity and, to be consistent with section 304(c), to read: "Secretaries of Agriculture, Interior, and Health, Education, and Welfare."

In view of the above, the Department of Defense defers to the Federal agencies primarily concerned with S. 373.

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.

GENERAL COUNSEL OF THE
DEPARTMENT OF COMMERCE,
Washington, D.C., June 20, 1968.

HON. WARREN G. MAGNUSON,
*Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.*

DEAR MR. CHAIRMAN: This letter is in reply to your request for the views of this Department with respect to S. 373, a bill "To provide for a weather modification program."

The bill declares that it is the policy of the United States to develop, encourage, and maintain a comprehensive and coordinated program in weather modification. It also contains a "Definitions" section. Title II authorizes various Federal departments and agencies to carry out functions in the field of weather modification and prescribes their ancillary powers. Title III authorizes the President to coordinate and plan Federal activities in weather modification and authorizes the Secretary of State to cooperate in international activities in this area. It further requires the President to report to the Speaker of the House of Representatives and to the President of the Senate and to the Committee on Commerce of the Senate and to the Committee on Interstate and Foreign Commerce of the House of Representatives prior to the undertaking of any Federal agency of a weather modification activity designed in whole or in part to affect the atmosphere more than one hundred and fifty miles from the source of such activity. Further, other than as specified in the bill, any weather modification operation activity conducted by a Federal agency would require the prior approval of Congress enacted into law. The bill also calls for studies and reports on the question of liability for damages attributable to weather modification activities, on the social and economic effects of weather modification, and on its biological and ecological effects. Title IV amends the National Science Foundation Act to delete the express statutory direction that NSF conduct weather research. It further requires the President to furnish the Congress with an annual report on weather modification. It also requires recipients of Federal grants or parties to cooperative agreements to keep records on the disposition of funds and permit Federal access to these records. Finally, it authorizes the appropriation of the necessary sums to carry out the bill.

Weather modification is a new and very exciting field of modern scientific inquiry. If we in the United States can develop extensive capabilities in weather modification, the benefits to the American people would be substantial. These capabilities would permit us to expand the national economy and enhance the safety and well-being of the American people in ways and to a degree that are now inconceivable. We are today, however, a considerable distance from this goal, and it will take many years of hard work to achieve it. But there is great promise. Modern science and technology have now brought us to a point at which it is possible to mount a broad program of scientific research to determine what types

of weather modification are feasible and under what conditions. And there is already evidence that we may now be able to increase or redistribute precipitation from some types of cloud and storm systems by seeding techniques.

The Department of Commerce strongly believes that the time is at hand for the United States to move ahead vigorously in weather modification research and development to seek to open up this new area of scientific opportunity as rapidly as possible. The provisions of S. 373 are clearly an expression of this same view. If enacted into law, it would furnish a strong impetus for the rapid mounting of a national program of weather modification research. For this reason the Department favors its enactment.

While the Department of Commerce favors the enactment of S. 373, it wishes to make several comments and recommendations for amendment. The most important concerns Sec. 201(a), which authorizes the Secretary of Commerce to carry out a comprehensive program in the field of weather modification, and upon request to furnish technical assistance and information in the field of weather modification to other Federal departments and agencies. It should be kept in mind that weather modification is not a unitary concept. It has many aspects—dissipation of hurricanes and other severe storms, the augmentation and redistribution of precipitation, the suppression of hail, the suppression of lightning, the dissipation of fog. There is much science and technology that is common to these various aspects, and the Department construes subsection (a) (1) as authorizing the Secretary to mount a broad program designed to advance the common science and technology of weather modification for all Federal departments and agencies with an interest in one or another aspect. This construction of the bill is supported by Sec. 101(b) (2), which calls for the weather modification activities of the United States to be conducted with full consideration of “the mutual dependence of weather modification, weather forecasting, climatology, and other aspects of atmospheric sciences and meteorological services.” Weather forecasting, climatology, the atmospheric sciences, and meteorological services have long been paramount concerns of the Department of Commerce.

The Department of Commerce has the following additional comments and recommendations on the text of the bill which would make it similar to H.R. 9212:

Sec. 101(b) (6). Delete the word “meteorology,” in line 4, page 3.

Reason: It is contained in the term “atmospheric sciences.”

Sec. 102(b). In line 23, page 3, add the word “systematic” after the words “and the” and before the words “use of devices.” Delete the words “primarily designed” in line 24, page 3 and substitute the words “with intent.”

Reasons: To exclude the implication that the term “operational activities” may include R&D activities. It is considered that the words “systematic” and “with intent” emphasize the deliberate planning envisioned in operational activities.

Sec. 201(d). Historically, the Department of Health, Education, and Welfare has been concerned with the biological effects on man of air pollution and other aspects of inadvertent weather modification. It has looked to the Department of Commerce to study and provide it with information on the effects of pollution and urbanization on weather and climate and has provided support to this effort. This Department construes the bill as not affecting the traditional roles and relationships of the two departments in this area.

Sec. 203. Delete the words “section 201” in lines 6 and 8, page 7 and substitute therefor the words “this Act.”

Reason: The words “section 201” are unduly restrictive in that the heads of Federal agencies have responsibilities under the Act other than those set out in section 201, e.g., conducting investigations under sec. 304.

Sec. 205(a). In the title of this section delete the word “Commercial” in line 7, page 8 and substitute the word “Non-Federal.”

Reason: This section will include non-Federal agencies other than commercial such as private institutions doing research work.

Sec. 205(a). In lines 10 and 11, page 8 delete the words “private business concerns” and substitute the words “any person or persons.”

Reason: The words “private business concerns” are too restrictive. Under section 1 of title 1 U.S.C. the substituted words “any person or persons” would include corporations, companies, associations, firms, partnerships, societies and joint stock companies, as well as individuals.

Sec. 205(a). In lines 12 and 13, page 8 after the words “cooperative agreement, grant, or other transaction” add the words “with agencies of the Federal Government.”

Reason: The words "with agencies of the Federal Government" are needed to qualify the person or persons exempted from section 205(a).

Sec. 205. It is recommended that the following additional subsections be added:

"Sec. 205(b) (1). The Secretary of Commerce may obtain from any person or persons by regulation, subpoena, or otherwise such information in the form of testimony, books, records, or other writings, may require the keeping of and furnishing such reports and records, and may make such inspections of the books, records, and other writings and premises or property of any person or persons as may be deemed necessary or appropriate by him to provide comprehensive data for the studies and investigations to be carried out under this Act, including data as to the nature and result of all weather modification activities (including research) carried out or intended to be carried out by such person or persons, but this authority shall not be exercised if adequate and authoritative data are available from any Federal agency. In case of contumacy by, or refusal to obey a subpoena served upon, any person referred to in this subsection, the district court of the United States for any district in which such person is found or resides or transacts business, upon application by the Secretary, shall have jurisdiction to issue an order requiring such person to appear and give testimony or to appear and produce documents, or both; and any failure to obey such order of the court may be punished by such court as a contempt thereof.

"(2). The production of a person's books, records, or other documentary evidence shall not be required at any place other than the place where such person usually keeps them, if, prior to the return date specified in the regulations, subpoena, or other document issued with respect thereto, such person furnished the Secretary with a true copy of such books, records, or other documentary evidence (certified by such person under oath to be a true and correct copy) or enters into a stipulation with the Secretary as to the information contained in such books, records, or other documentary evidence. Witnesses shall be paid the same fees and mileage that are paid witnesses in the courts of the United States.

"(c). Any person who willfully performs any act prohibited or willfully fails to perform any act required by subsections (a) and (b) above, or any regulation issued thereunder, shall upon conviction be fined not more than \$500."

Reason: Under Sec. 401 of S. 373 the present authority of NSF (44 U.S.C. 1872) to require reports on private weather modification activities being conducted throughout the United States would be repealed and not replaced. The additional subsections would preserve the substance of the present NSF authority to require such reports. It is considered necessary to preserve this authority for the following reasons:

(a) During its first year of experience under regulations requiring reports, etc., NSF received approximately 160 notifications of weather modification activities. Analysis of these notifications will enable the Federal Government to evaluate the results of private weather modification activities. It will also disclose the nature of weather modification activities, e.g., hail, snow or fog and their effectiveness;

(b) These notifications will also provide an excellent record of how much silver iodide is put into the atmosphere by private sources. This information could be of potential value in air pollution studies;

(c) The notifications have been of great value in checking on the validity of other experiments in the same area;

(d) The information contained in these reports will be essential to conducting the investigations required under Sec. 304 and other places in this Bill.

The sanction proposed in the last subsection will aid enforcement of any regulations issued under this section of the bill.

Sec. 205(b). Should be renumbered sec. 205(d). In lines 19 and 20, page 8 of the bill the words "representatives of such business concerns" have been deleted and the words "any person or persons concerned in weather modification activities or research" substituted therefor.

Reason: As set out above under sec. 205(a).

Sec. 302(b). It is recommended that this subsection be deleted.

Reason: It merely reiterates current practice between the State Department and other Federal agencies and is unnecessary.

Sec. 303(a) and (b). It is recommended that this section and its title be deleted.

Reason: At present there are no restrictions such as those proposed in section 303(a) and (b), on Federal agencies for conducting weather modification research or development activities or for conducting operational activities. It is considered that the procedures suggested in section 303(a) and section 303(b) are unduly restrictive at this time. Such restrictions should be withheld pending the completion of the studies authorized under sec. 205 and sec. 304.

We have been advised by the Bureau of the Budget that there would be no objection to the submission of our report to the Congress from the standpoint of the Administration's program.

Sincerely,

BURT W. ROPER
(For Robert E. Giles, General Counsel).

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE,
July 5, 1967.

HON. WARREN G. MAGNUSON,
Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: This letter is in response to your request of January 23, 1967, for a report on S. 373, a bill "To provide for a weather modification program."

The bill would authorize the Secretary of Commerce to carry out a comprehensive program in the field of weather modification, including a specific program for control or modification of tornadoes, hurricanes, and other severe storms, and to provide technical assistance to other agencies upon request. The Secretaries of Interior, Agriculture, Health, Education, and Welfare, the Administrator of the Federal Aviation Agency, and the National Science Foundation would be authorized to carry out programs of weather modification relating to other matters within the spheres of competence of their respective agencies. This Department would be authorized to carry out a program in the aspects of weather modification relating to the control of air pollution and other similar deleterious effects of urbanization upon the composition of the atmosphere. The President would have overall authority for coordination and planning of Federal Government weather modification activities.

The bill also would require the President to transmit a written report to the Congress in January of each year giving a description of each Federal Agency's activities and accomplishments in weather modification during the preceding fiscal year, an analysis of recommended expenditures for all authorized weather modification activities during the succeeding fiscal year, a description of non-Federal weather modification activities and those carried out by foreign countries, and any recommendations the President may have for additional legislation.

The bill would require the President to notify the Speaker of the House of Representatives, the President of the Senate, and the appropriate committees of each house, before any Federal agency conducts any weather modification activity (for research or experimental purposes) which is intentionally designed in whole or in part to affect the atmosphere more than one hundred and fifty miles from the source of the activity.

In addition, the bill would require prior Congressional approval enacted into law before any Federal agency could conduct, directly or indirectly, any weather modification operational activities, which are defined as "the construction and the use of devices and systems for weather modification primarily designed to achieve a planned and continuing substantial result of social, economic, commercial, biological, or medical significance."

On the other hand, the bill would not provide for regulation of non-Federal weather modification activities. It would merely authorize the Secretary of Commerce to issue regulations governing the weather modification activities of private business concerns which conflict with or impede any Federal activities, and to encourage compliance with these regulations. No sanctions would be provided for noncompliance.

The bill would provide for a study of the need for regulation of weather modification activities and for a report to the Congress within a year after enactment of the bill giving recommendations for additional legislation concerning such regulation and its enforcement.

Appropriations of \$12,000,000 for fiscal year 1967, \$30,000,000 for fiscal 1968, and \$40,000,000 for fiscal year 1969 would be authorized to carry out the provisions of S. 373.

As far as this Department is concerned, we read this bill as not requiring any program of weather modification on our part except as it may become necessary or desirable in the context of our broad responsibilities in the prevention and control of air pollution under the Clean Air Act.

From the point of view of the Department, then, we would have no objection to enactment of this bill. On the other aspects of S. 373, we defer to the judgment of those agencies more directly concerned.

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

Sincerely,

WILBUR J. COHEN,
Under Secretary.

OFFICE OF THE SECRETARY OF TRANSPORTATION,
Washington, D.C., September 20, 1967.

HON. WARREN G. MAGNUSON,
*Chairman, Committee on Commerce,
U.S. Senate, Washington, D.C.*

DEAR MR. CHAIRMAN: This letter is in reply to your request for the views of this Department with respect to S. 373, a bill "To provide for a weather modification program."

The bill establishes general policy with respect to the development of a comprehensive program in weather modification and authorizes various Federal departments and agencies to carry out weather modification activities in specific areas. In the case of the Federal Aviation Agency (now Administration), the bill authorizes the conduct of a program for the effective dispersal of fog and cloud cover interfering with airport operations or air transportation in the United States. The Department has no objection to enactment of this legislation, if amended as set forth below.

The authority to conduct research and development in fog and cloud dispersal, which section 201(e) (1) of S. 373 would assign to the FAA, involves the areas of weather modification that currently hold the most promise for some benefit to aviation safety. Since fog and other weather conditions can adversely affect the safe and efficient use of ground and water transportation fully as much as it does air transportation, we recommend that the authority under section 201 (e) be vested in the Secretary of Transportation. We think that limiting DOT to fog and cloud dispersal activities, as section 201(e) would do, is too restrictive. Because of the broader implications of weather on transportation, we would recommend that section 201 (e) be amended to read:

"The Secretary of Transportation is authorized to:

"(1) carry out a program for the effective and beneficial dispersal of fog and cloud cover interfering with air, ground, or water transportation.

"(2) conduct operational weather modification activities that the Secretary considers desirable in the interest of safety in transportation."

DOT would, of course, not attempt to undertake any far reaching weather modification without full and proper coordination within the executive branch as provided in Title III of the bill, or any weather modification that is not directly related to transportation safety.

We also recommend deletion of the reference to the United States in section 201 (e) (1). Particularly if that term were interpreted to include only the fifty states, we believe that section 201(e) (1) would be too restrictive.

We have been advised by the Bureau of the Budget that there would be no objection to the submission of this report from the standpoint of the Administration's program.

Sincerely,

JOHN L. SWEENEY,
Assistant Secretary for Public Affairs.

OFFICE OF THE DEPUTY ATTORNEY GENERAL,
Washington, D.C., October 10, 1967.

Hon. WARREN G. MAGNUSON,
Chairman, Senate Commerce Committee,
U.S. Senate, Washington, D.C.

DEAR SENATOR: This is in response to your request for the views of the Department of Justice on S. 373, a bill "To provide for a weather modification program."

Based on a Congressional finding that it is the policy of the United States to develop, encourage, and maintain a comprehensive and coordinated program of weather modification, S. 373 would authorize the Secretaries of Commerce, Interior, Agriculture, Health, Education, and Welfare, the Administrator of the Federal Aviation Agency and the National Science Foundation to conduct activities in the field of weather modification, including measures to control or modify tornadoes, hurricanes, and other severe storms. The President would be charged with direction and coordination of the program.

Before any Federal agency conducts a weather modification activity which involves the atmosphere more than 150 miles from the source of activity it would be required that the President transmit a written report containing a full and complete statement regarding it to the Congress. Any Federal agency contemplating weather modification operational activity involving construction to obtain a planned and continuing result would be required to await the approval of Congress, enacted into law, before taking action.

Section 204 provides for public access to information developed by an agency in the performance of its functions, except "(1) information authorized or required by statute to be withheld and (2) information classified in accordance with law to protect the national security." It is assumed that the language of phrase (1) would make applicable any relevant statute governing the release or withholding of official information, including the recently enacted Public Records Statute, Public Law 89-487. The effect of that statute is to authorize withholding of certain kinds of information "specifically exempted from disclosure by statute" and information specifically required by Executive order to be kept secret in the interest of the "national defense or foreign policy." In addition, phrase (2) in section 204 would except information classified to protect the national security, irrespective of whether it involves national defense or foreign policy secrets. Such provision appears to be consistent with the Congressional policy expressed in the legislative history of Public Law 89-487.

Section 205(a) authorizes the Secretary of Commerce to issue regulations governing certain weather modification activities of private business concerns "not engaging in such activities pursuant to contract, lease, cooperative agreement, grant, or other transaction." The intent is apparently to limit these regulations to concerns other than those acting pursuant to arrangements with a Federal agency under section 202(4). We suggest clarification of section 205(a) by rephrasing it as follows:

"Sec. 205. (a) The Secretary of Commerce is authorized, after notice and opportunity for a hearing, to issue regulations governing the weather modification activities of private business concerns, engaging in such activities otherwise than pursuant to contract, lease, cooperative agreement, grant, or other transaction with any Federal agency, which conflict with or impede any activities conducted under this Act, and to encourage compliance by such business concerns with such regulations."

It may be noted that section 205(a) in conferring rulemaking authority upon the Secretary of Commerce requires "notice and opportunity for a hearing." This goes beyond the pertinent provisions of the Administrative Procedure Act, now contained among the provisions of section 553(c) of title 5, United States Code, which state that "After notice required by this section, the agency shall give interested persons an opportunity to participate in the rulemaking through submission of written data, views, or arguments with or without opportunity for oral presentation."

The Department of Justice has no objection to enactment of this legislation with the changes suggested, but defers on the policy considerations to the agencies charged with the implementation of the bill.

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

Sincerely,

WARREN CHRISTOPHER, *Deputy Attorney General.*

[S. 2058, 90th Cong., second sess.]

A BILL To provide a practicable weather modification program for the Upper Colorado River Basin

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Upper Colorado River Basin Weather Modification Act".

SEC. 2. It is recognized that the present and growing water shortage in the Colorado River Basin has created serious problems of national concern. Congress recognizes that there is an urgent need to find new sources of water for the Colorado River Basin to support the rapid increase in population, agricultural production, and industrial development which is being and which will be experienced in the basin. It is also recognized that the Colorado River Basin States consisting of Colorado, Wyoming, Utah, New Mexico, Arizona, Nevada, and California, rely to a significant degree upon the Colorado River for their water supply and that such States contribute significantly and materially to the commerce of the United States and to the welfare of its citizens. It is, therefore, the public policy of the United States to assist the basin in alleviating its water shortage by devising methods to augment the supply of water in the Colorado River Basin and it is the purpose of this Act to increase the supply of water in the Colorado River through weather modification programs conducted in the Upper Colorado River Basin in furtherance of that policy.

SEC. 3. (a) The President shall within ninety days of enactment of this Act, appoint a Coordinating Council on Weather Modification for the Upper Colorado River Basin (here referred to as the "Coordinating Council") consisting of the Secretary of the Interior or his designee, the Secretary of Commerce or his designee, the Director of the National Science Foundation or his designee, and four public members appointed without regard to the civil service laws by the President. Two of such public members shall be persons connected within institutions of higher education and who are knowledgeable in the field of atmospheric research, and two of such public members shall be persons connected with private concerns experienced in the practical application of weather modification techniques. The Coordinating Council shall elect a Chairman from among its members and shall meet at the call of the Chairman but not less often than four times per year.

(b) The Coordinating Council shall consult and confer with the Secretary of the Interior concerning the preparation and implementation of a plan for the practical application of weather modification techniques in the Upper Colorado River Basin.

(c) The Coordinating Council shall consult and confer with the Secretary of the Interior or his designee with respect to policy matters arising in the administration of this Act and with respect to the coordination of weather modification research and programs conducted under this Act.

(d) The Coordinating Council may make interim reports to the President of its recommendations on the programs instituted hereunder and shall make annual reports, commencing one year from the date of enactment of this Act, of its findings and recommendations to the President. The President shall transmit each report to the Congress, together with his comments and recommendations.

(e) Members of the Coordinating Council who are not regular full-time employees of the United States shall, while serving on the business of the Council, be entitled to receive compensation at the rate of \$100 per day, including travel-time; and, while so serving away from their homes or regular places of business, members may be allowed travel expenses, including per diem in lieu of subsistence as authorized by section 5703 of title 5, United States Code, for persons in the Government service employed intermittently.

(f) In carrying out its functions pursuant to this section, the Coordinating Council may utilize the services and facilities of any agency of the Federal Government in accordance with agreements with the head of such agency and may engage such technical assistance as may be needed to carry out its functions and as may be approved from time to time by the Secretary of the Interior.

SEC. 4. The Secretary of the Interior (hereinafter referred to as the "Secretary") shall carry out weather modification programs designed to increase to the extent practicable the annual average supply of water from rainfall and snowfall in the Upper Colorado River Basin of the United States; and shall authorize research and study programs by contract or grant with institutions of higher education to determine the effectiveness of such programs, the development of

new and improved techniques and mechanics in the operation of the programs, the effect on the ecology of the area, and such other matters as may be pertinent to the operations hereunder.

Sec. 5. (a) In order to carry out the provisions of this Act, the Secretary shall—

(1) within six months after enactment of this Act, and in consultation with the Coordinating Council, prepare a plan for the practical application of weather modification techniques in the Upper Colorado River Basin, which may include new and innovative as well as existing weather modification techniques;

(2) contract with institutions of higher education and business concerns, skilled and experienced in weather modification, weather modification operational activities in accordance with the plan developed pursuant to the preceding clause of this subsection; and

(3) conduct by grant, contract, or other agreement with institutions of higher education, skilled and experienced in weather modification, and atmospheric research, such research studies as he determines appropriate to evaluate the practicability and efficacy of the program authorized by this Act.

(b) In the performance of the duties specified in subsection (a) of this section, the Secretary is authorized to—

(1) accept gifts and bequests, including gifts or bequests restricted or limited by the donor for use in connection with certain projects or areas;

(2) acquire by purchase, license, lease, or donation such inventions, patents, patent applications, licenses, real property and interests therein as he deems necessary;

(3) utilize the property, equipment, and personnel of other agencies of the Federal Government, with the approval of the head of such agency, and pay for such property, equipment, and personnel out of funds made available pursuant to this Act, either in advance, by reimbursement, or by direct transfer; and

(4) consult with appropriate representatives of the Environmental Science Services Administration and of the National Science Foundation, and such representatives are authorized and directed to furnish such assistance as the Secretary may reasonably require.

Sec. 6. As used in this Act—

(a) The term "weather modification" includes any artificially produced changes in the composition, behavior, or dynamics of the atmosphere.

(b) The term "Upper Colorado River Basin" means that area of the United States consisting of the following States: Colorado, New Mexico, Utah, and Wyoming.

Sec. 7. (a) There are authorized to be appropriated to carry out the provisions of this Act \$3,000,000 for the fiscal year ending June 30, 1968, and for each of the two succeeding fiscal years. It is the intent of Congress that the Secretary in carrying out the provisions hereunder shall expend funds authorized hereunder in the approximate ratio of \$2 for research for each \$1 expended on operational techniques.

COMPTROLLER GENERAL OF THE UNITED STATES,
Washington, D.C., September 5, 1967.

Hon. WARREN G. MAGNUSON,
*Chairman, Committee on Commerce,
U.S. Senate.*

DEAR MR. CHAIRMAN: By letter of August 3, 1967, you requested our comment on S. 2058, 90th Congress, entitled: "A BILL To provide a practicable weather modification program for the Upper Colorado River Basin."

While we have no special information as to the desirability of this measure and, therefore, make no comments regarding its merits, we do recommend the inclusion of a new section in the bill pertaining to the audit of the program.

Section 4 and subsection 5(a) authorize the Secretary to enter into grants, contracts or other agreements. There is no requirement for the maintenance of accounting records by the recipients of assistance through grant, contract or other agreement. Furthermore, there is no provision to make the records of the recipients of assistance available to the Comptroller General of the United States or his duly authorized representatives for the purpose of audit and ex-

amination. We recommend that the bill be revised to include language similar to the following:

"(a) Each recipient of assistance under this Act pursuant to grant, contract or other agreement, entered into under other than competitive bidding procedures shall keep such records as the Secretary shall prescribe, including records which fully disclose the amount and disposition by such recipient of the proceeds of such assistance, the total cost of the project or undertaking in connection with which such assistance is given or used, and the amount of that portion of the cost of the project or undertaking supplied by other sources, and such other records as will facilitate an effective audit.

"(b) The Secretary and the Comptroller General of the United States, or any of their duly authorized representatives, shall have access for the purpose of audit and examination to any books, documents, papers and records of the recipients that are pertinent to the grants, contracts or other agreements entered into under this Act under other than competitive bidding procedures." Similar provisions are contained in various acts such as section 11 of the "Clean Air Act." Pub. L. 88-206, 77 Stat. 401, and section 8(a) of Pub. L. 89-220, 79 Stat. 894.

Sincerely yours,

R. F. KELLER,

Acting Comptroller General of the United States.

U.S. DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D.C., June 11, 1968.

HON. WARREN G. MAGNUSON,
Chairman, Committee on Commerce, U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: This responds to your request for the views of this Department on S. 2058, a bill "To provide a practicable weather modification program for the Upper Colorado River Basin."

We recommend that the bill not be enacted, for the reasons stated herein.

The bill recognizes the national concern over the water supply in the Colorado River Basin as it relates to the economy of the seven-State area and states that it is the public policy of the United States to assist in alleviating water shortages in the basin by devising methods to augment its water supply. The stated purpose of the bill is to increase the supply of water by weather modification programs in the Upper Basin in furtherance of this policy. The bill would direct the President to appoint a coordinating council consisting of the Secretaries of the Interior and Commerce, the Director of the National Science Foundation, and four public members, two of whom shall be within institutions of higher education having knowledge in the field of atmospheric research and the other two connected with private firms experienced in the practical application of weather modification techniques. The council would consult and confer with the Secretary of the Interior concerning the preparation and implementation of a plan for practical application of weather modification techniques in the Upper Colorado River Basin. The council would also consult and confer with the Secretary regarding policy matters arising in the administration of the weather modification program. The council would make annual as well as interim reports to the President on its recommendations and findings of the program. The Secretary of the Interior would be charged with the responsibility of conducting the weather modification programs called for in the bill.

The Secretary, in consultation with the council, would be required to prepare within 6 months a plan for the practical application of weather modification programs in the Upper Colorado River Basin. The plan would be carried out by contract with universities and private concerns. The bill would authorize an annual appropriation of \$3 million and would express the intent of Congress that for every \$2 spent on research \$1 would be expended on operational techniques.

Present and planned programs of the Department, conducted under existing authority, will lead to achievement of the objectives of S. 2058. Passage of the bill, therefore, is unnecessary. Also, added authority to meet the underlying water shortage problem would be granted by section 201 (a) of the House-passed version of S. 1004, the Colorado River Basin project bill, which directs the Secretary to "investigate and recommend sources and means of supplying water

to meet the current and anticipated water requirements of the Colorado River Basin, directly or by exchange, including . . . weather modification . . ."

Under the authority of general reclamation laws, the Bureau of Reclamation, of this Department, presently is conducting an expanded program of investigation and applied research into methods of augmenting water supplies through induced precipitation at a number of locations. A regional program of operational weather modification activities with accompanying research studies is outlined in the departmental report of November 1966, "Plan to Develop Technology for Increasing Water Yield from Atmospheric Sources." We firmly believe a well planned and executed comprehensive research program can develop regional operational weather modification techniques capable of producing an average of some 2 million acre-feet annually in the Upper Basin. An operational research program in this area is already included in our current planning and budgeting. In fact, research of this type is currently being conducted under the Park Range Atmospheric Water Research Program at Steamboat Springs, Colorado.

During fiscal year 1967, "Project Skywater", as our weather modification program is now called, entailed expenditure of \$3.75 million. The 1968 program is budgeted at \$4.6 million and the proposed program for fiscal year 1969 would entail expenditures of \$5.5 million to continue the work. Approximately 90 percent of this program is conducted under research contracts, principally in 10 Western States. Continued full support of our expanded program budget by the Congress will result in a program for the Colorado River Basin under existing law of the same general type as proposed in the bill.

S. 2058, although praiseworthy in objective, would unduly restrict the conduct of our ongoing weather modification program in terms of phasing and orderly development, expenditure of funds, and geographical area, as explained in the following paragraphs.

We envision the following five-phase comprehensive research project to develop a practical precipitation modification technology for the area:

1. Operational cloud seeding—Carefully controlled seeding under well-defined criteria over a number of test areas selected to be representative of the basin.
2. Evaluation—Providing a sufficient data collection and analysis system to assess the additional precipitation and runoff obtained.
3. Environmental studies—A series of general studies including investigations to determine effect on ecology, use and value of the water produced, water law involved, projected benefits and costs of expanded regular operations, economic and other social effects.
4. Comprehension of results—A research effort to determine and understand more precisely the basic meteorological conditions present when additional precipitation occurs.
5. Improvement of techniques—An accompanying research effort to field-test new equipment and techniques for finding better means of modifying precipitation in the Basin.

S. 2058 emphasizes only the first two elements, cloud seeding and evaluation. A comprehensive program is vital to the success of any such large weather modification undertaking in the Upper Colorado River Basin. Therefore stress should be placed on developing and perfecting a workable system, rather than on operational application, with incidental evaluation and research as the bill proposes.

To obtain meaningful results, operational cloud seeding should be conducted for at least 5 years. Our preliminary planning calls for a project effort lasting a minimum of 7 to 8 years, including planning, system installation, operations, studies, and evaluation. The cost for such a comprehensive project would be an estimated \$15 million to be expended on a staggered schedule over a 5-year period. The bill, on the other hand, proposes a 3-year program at an authorized annual level of \$3 million. The bill further restricts expenditure of funds to the appropriate ratio of \$2 for research for each \$1 expended in operational techniques. It would appear to be unduly restrictive from a scientific and engineering viewpoint to incorporate this type of fixed and arbitrary ratio into basic authorizing legislation for a rapidly-changing research, development and implementation program.

The shortage of water in the Colorado River Basin area is a well-recognized and serious problem. The solution, however, lies not in limitation of weather modification programs to that region as the bill proposes but in a westwide and, potentially, national or international approach, in keeping with the nature of

the atmospheric environment which we seek to modify. As stated above, our general approach to weather modification in the Colorado River Basin area coincides with the objectives of the bill. It would set an undesirable precedent, however, to authorize weather modification programs on a regional basis similar to that used for reclamation projects, when the atmospheric environment to be modified is not so limited.

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,

KENNETH HOLUM,
Assistant Secretary of the Interior.

Senator CANNON. Witnesses at these hearings will no doubt provide much further illumination on this important subject. This Denver area and its environs are particularly appropriate for these initial hearings. Denver is the headquarters of the Bureau of Reclamation and has the Office of Atmospheric Water Resources, the director of which will be a witness here today. The research laboratories of ESSA of the Department of Commerce are in Boulder, and an ESSA representative will testify. And we will have testimony also from several prominent non-Government weather specialists and engineers of high professional standing in their field. This will be a hearing that I believe will be most useful for the committee, and I have the honor and privilege at this time of introducing Hon. Peter Dominick, Senator from Colorado, as the first witness. Senator Dominick.

STATEMENT OF HON. PETER H. DOMINICK, U.S. SENATOR FROM THE STATE OF COLORADO

Senator DOMINICK. Thank you, Senator Cannon.

I know of the tremendous work you have done in this field and I just want to associate myself with some of the remarks that you have made; in fact, most of them. Of course, obviously, as a Senator from Colorado, I want to extend a particular welcome to you as the presiding member of the committee. I hope you will come back often, and I hope we get some action on this weather modification as soon as possible. As you so aptly said, we have an outstanding forum for these hearings. Of course, we in Colorado have an outstanding worldwide reputation as a technological center for weather modification. The research and development activities here are diverse and encompass Federal, State, private, and university programs.

So I appreciate the opportunity to appear today to testify in support of both S. 373 and S. 2058. As a cosponsor of S. 373, as the author of S. 2058, and as one who has been interested and active in weather modification since the early 1950's, I want to assure you of my continued cooperation and support in developing and hopefully enacting significant legislation in the area of weather modification.

My statement today will be brief as I know we are operating under a limited-time situation and I feel it is more important to hear witnesses with technical expertise and support for this legislation.

Legislation similar to S. 373 is, in my judgment, mandatory; legislation similar to that contained in S. 2058 is highly desirable.

Let me first address myself briefly to S. 373.

Clearly the time has arrived when a coordinated effort should be brought to bear on the significant problems which weather modification can alleviate.

We need a balanced effort to avoid waste and duplication.

Significant attention must be given to the biological, ecological, and legal aspects of weather modification.

S. 373 provides a vehicle for achieving each of these goals.

But S. 373 may also serve to avoid many of the frustrations of the past. I say this because I am one who openly laments the "lost decade" in weather modification—that period of "scientific silence" which extended from 1957 to 1966.

As you may recall, in 1953 Congress enacted Public Law 83-256 which created the Advisory Committee on Weather Control whose express purpose was to conduct a complete study and evaluation of experiments in weather modification. The final report of the advisory committee was issued in 1957 and it contained the conclusion that precipitation could be increased 10 to 15 percent by employing accepted weather modification techniques. The report also called for an extensive research program, both basic and applied in weather modification. Neither the research nor the applied programs envisioned in the report were pursued.

Despite the encouraging data contained in the advisory committee report in 1957 and despite a specific mandate given to the National Science Foundation in Public Law 85-510 to modify its research mission by adding an operational engineering function, our Federal weather modification programs remained in the laboratory and well within the definition of "basic research."

Then in January 1966 two authoritative reports on weather modification were issued. One was presented by the National Academy established and supported by the National Science Foundation. These reports substantially confirmed the conclusions reached in 1957 by the Advisory Committee on Weather Control concerning the precipitation increases from the seeding of certain clouds.

In retrospect, the conclusions of 1957 could well have been acted upon in 1958, for they were confirmed in 1966. Hopefully, the "lost decade" will not be repeated.

S. 373 is identical to S. 2916 which passed the Senate in October 1966. Extensive hearings were held on the bill in 1966 and I participated in these hearings as a then member of the Senate Committee on Commerce. Based on those hearings, the original bill was substantially amended by the committee before passing the Senate and I am confident that the scientific community will offer additional constructive suggestions during the course of these hearings. I am confident that this bill can serve as a vehicle not only to achieve the goals I outlined earlier but also to insure the proper application of our growing body of knowledge in the field of weather modification.

What then is the need for S. 2058? I am convinced that now is the time to move ahead more aggressively with the operational aspects of weather modification. I am convinced that we need to accelerate the shift in emphasis from one of basic research to one of application. I believe this can be accomplished with a greater degree of certainty through the enactment of S. 2058.

In fact, we are finally beginning to achieve a balance between the basic research and applied research in the area of increased precipitation through weather modification.

I envision this bill as a “nudge”—a firm nudge toward the beneficial application of precipitation-producing weather modification techniques. In a sense, it is an effort to bring us to one short step this side of tomorrow. I emphasize one “short” step because I fully realize the limitations, the problems, the unresolved questions interwoven into the body of knowledge we have acquired in weather modification.

S. 2058 would direct the President to appoint a coordinating Council consisting of the Secretaries of the Interior and Commerce, the Director of the National Science Foundation, and four public members. Two of the public members would be from universities and two from private firms experienced in the field. In my judgment, the Council represents a broad base of expertise which would insure that divergent views within the field of weather modification would share in the establishment of policy.

The Secretary of the Interior in consultation with the Council would be required to prepare within 6 months a plan for the practical application of weather modification programs in the Upper Colorado River Basin. The bill provides that the plan would be carried out by contract with universities and private concerns. The bill would authorize \$3 million for 3 successive fiscal years.

The bill expresses the “intent of Congress” that two-thirds of the funds be spent for research. This was done with the recognition that a balance is necessary between research and the operational aspects of weather modification.

The bill clearly is intended to move more boldly in the direction of application.

Frankly, the idea for the bill was conceived during the hearings on weather modification held by this committee in 1966 and by the Subcommittee on Water and Power Resources of the Senate Committee on Interior in 1967. I feel this bill is completely compatible with the atmospheric water resources program of the Department of Interior, Bureau of Reclamation, as announced in November 1966. I commend the Bureau for their relatively aggressive program and, in fact, S. 2058 should supplement this effort. For this reason, I would hope that S. 2058 would receive more than “faint” praise from the Department of Interior. As a matter of fact, Mr. Chairman, it has not. I received a copy of Mr. Kenneth Holum’s letter the other day in which it seems perfectly apparent to me that he hasn’t studied the bill with any care. He says that the objectives are all right but that they can do it within their own program now; just leave them alone, and they will get enough money and they will finally get around to it. I don’t think that this is objective nor do I think he studied the bill. Now, I will comment on that later.

I envisioned this bill as a pilot project—totally compatible with the pilot project concept announced by the Department of Interior in their program. But it would have the advantages of a pilot project specifically authorized and specifically funded.

I have been informed that the lack of adequate funding has, in fact, caused the retardation of our weather modification programs. In fact, in the hearings before the Senate Subcommittee on Water and Power Resources of the Committee on Interior held April 4, 1967, Secretary Udall, in explaining the Department’s weather modification program, stated and I quote, “And probably my own people would say

that they could use additional money, that they could use it well, and that this would make the program move faster."

The statement of Dr. Thomas F. Bates, Science Adviser to the Secretary, in the same hearings confirmed the fact that the lack of funds was retarding the weather modification program. Dr. Bates said and I quote, "Despite the great interest in the subject, the requirements for economy in Government activities precluded immediate expansion except on a very modest scale."

Again in the same hearings, Senator Bible asked Dr. Kahan, "You are basing that on the \$5 million of funding of this year? This was your request in the appropriation?" Dr. Kahan: "Yes, although we can see ways of employing wisely more funds if they are made available." And I'm sure that was true, Doctor.

Based on the hearings conducted in 1966 by the Senate Committee on Commerce and in 1967 by the Subcommittee on Water and Power Resources of the Interior Committee, it is clear that the lack of funds has retarded the weather modification program. And, of course, S. 2058, if enacted, would supply more funds, \$3 million per year, which I think is critically needed to move the application of our weather modification program forward.

S. 2058 provides that the applied aspects of the pilot program would take place in the Colorado River Basin. I believe, Mr. Chairman, particularly you and I and those of us who live out here know of the critical need for water in our region. And of equal importance is the fact that this is where the Bureau is currently conducting its field research. It should be further noted that Dr. Kahan in the 1967 hearings, when discussing areas which would have early operational capabilities stated, "The area most likely to be in this condition early is the Colorado River Basin."

To further underscore the compatibility of S. 2058 with the programs now being conducted by the Bureau of Reclamation, I would like to quote from the 1966 hearings held in Denver which I had the privilege of presiding over. In discussing an operational program, I asked Dr. Kahan—

How much money and mechanics are we talking about?

Dr. KAHAN. There is not now at the present time an adequate network of observation in the Colorado River Basin to undertake the kind of observations on a large scale. We have invested several hundreds of thousands of dollars in our program in instrumentation, and the job is really just beginning.

I would say that there would need to be at least as much money spent in the evaluation effort as was spent in the operational aspect, and probably several times as much.

Senator DOMINICK. Do you feel that from the operational point of view you could set up a meaningful program at a million dollars a year?

Dr. KAHAN. Yes, sir.

Senator DOMINICK. From your observational point of view, how much money would be needed?

Dr. KAHAN. I was thinking that I could take that million dollars and divide it between observational and operational. If you are asking how big a program I would mount if a million dollars had to be spent in just paying for the operation of silver iodide generators, I would want three times that much to observe what was going on.

This above-quoted testimony formed the basis for S. 2058. To conform with Dr. Kahan's statement, the funds contained in the bill would have to be spent on a 3-to-1 ratio for observation and evalua-

tion purposes. Actually, I contemplate spending a million dollars a year over 3 years for operational purposes and \$2 million a year for 3 years for evaluation and observation, new techniques, and so on.

Senator CANNON. Conforming to the ratio that Dr. Kahan mentioned?

Senator DOMINICK. That's correct, yes.

Now, the previous hearings held by this committee as well as the hearings held by the Senate Committee on Interior clearly demonstrated the economic and scientific justification for the program suggested in S. 2058.

Again, Dr. Kahan, I seem to be using his testimony rather fully here. I would like to close by quoting a statement from him at the 1967 Interior hearings.

Speaking of Commissioner Floyd E. Dominy's views on weather modification, Dr. Kahan said, and I quote, "He has insisted from the outset that the program should be soundly grounded in science and seek to grow only as fast as sound planning and proper management would permit."

Continuing, Dr. Kahan said, and I quote, "Now the time is right to shift into high gear." And, again, I agree, now is the time to shift into high gear, and that's why I have put up S. 2058 and that's why I hope it will be enacted.

Now, I must say, Mr. Chairman, if I may just ad lib for a few minutes, that I reviewed the report which was given to the Interior Committee by Mr. Holum—signed by Mr. Holum, anyhow—dated on June 11, 1968. So it is very recent. And in commenting on S. 2058, he recommends that the bill not be enacted. And he goes into a whole group of things. Basically what he says is that passage of the bill is unnecessary, that they are already doing it.

Senator CANNON. Well, if I may interrupt, he doesn't recommend that it not be enacted, but that it be enacted with certain changes that he outlined at some length, as I interpret his letter here.

Senator DOMINICK. Well, I certainly hope you're right. I'm certainly not fixed into any specific form of bill. But he says that my bill emphasizes only the first two elements; namely, cloud seeding and evaluation. As a matter of fact, I specifically referred in the bill to the environmental studies on ecology and the water law and all these kinds of things.

Senator CANNON. If I may interrupt—

Senator DOMINICK. And new techniques.

Senator CANNON. I was referring to his statement on S. 373.

Senator DOMINICK. Yes; S. 373 he's in favor of. It's my bill that he says is unnecessary.

Senator CANNON. I'm sorry for interrupting you. I wanted to correct that. Yes; he did recommend that S. 2058 not be enacted.

Senator DOMINICK. That's correct. And I just don't know if he ever really studied the bill. And it is exasperating to me. He says on page 4 at the top, for example, and I quote, "It would appear to be unduly restrictive from a scientific and engineering viewpoint to incorporate this type of fixed and arbitrary ratio into basic authorizing legislation for a rapidly changing research, development, and implementation program."

And I just finished reading Dr. Kahan's statement saying that this is exactly the ratio that they would need in order to put a meaningful program together. As I say, he quotes five points but he says I only covered two of them. As a matter of fact, I covered at least four, maybe all five of them, in the bill. This is why I said I wonder whether he really studied it.

In any event, I would hope that we could have a review and I could take this up again with the Department and go into it, solely because I think the Interior Department, in an effort to say, "We're going to go our own way and not do anything else," are cutting off their own nose to spite their face. And I say it very frankly.

Now, S. 373 is an excellent bill, but if we are going to go into the operational phase, which I think we need to do, we're going to have to make a start somewhere and we're not making any starts now.

I thank you, Mr. Chairman, and I appreciate you letting me take this time. I would like to sit in and participate with you on the rest of the hearing.

Senator CANNON. I would be very happy to have you sit in and participate completely in the hearing.

Senator DOMINICK. Thank you, sir.

Senator CANNON. The next witness is Dr. Werner A. Baum, Deputy Administrator of ESSA.

**STATEMENT BY WERNER A. BAUM, DEPUTY ADMINISTRATOR,
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION**

Dr. BAUM. Mr. Chairman, I am Werner A. Baum, Deputy Administrator of the Environmental Science Services Administration, ESSA. I might point out that I will be leaving that post in 3 weeks to assume the presidency of the University of Rhode Island. So I speak as an about-to-be-taxpayer and scientist of broader interest than that represented by my agency.

Senator CANNON. If people would refer to someone like Senator Dominick and myself in such a position, they would say that you are a lame duck at this time.

Dr. BAUM. Precisely correct.

I would also, Mr. Chairman, like to introduce Dr. George S. Benton, who is with me today. Dr. Benton is Director of the ESSA research laboratories which conduct our research program in weather modification and related fields. Dr. Benton will attend your hearings in Reno next week and at that time will discuss the ESSA technical program in some detail. For this reason I will limit my remarks today to the growing need for a logical organization of Federal research in weather modification and the need for a unified national effort.

I have submitted a prepared statement for the record, and to conserve time today I will merely provide a short summary of that statement now.

Senator CANNON. The statement will be included in the record in full, and you may summarize from it as you wish.

Dr. BAUM. Thank you, sir.

S. 373 authorizes a broad national program in weather modification and recognizes the importance and relationship of modification to the needs of a number of Federal agencies. The bill authorizes the

Department of Commerce to conduct a comprehensive program in weather modification, in addition to research directed toward eventual amelioration of severe storms, including hurricanes and tornadoes. The bill also authorizes the development of modification techniques to serve the missions of other agencies: augmentation of precipitation by the Department of Interior; control of lightning and hail by the Department of Agriculture; application of modification techniques to relieve air pollution by the Department of Health, Education, and Welfare; and dispersal of fog and cloud cover at airports by the Department of Transportation. Further, the bill would assure the continued support by the National Science Foundation of basic and applied research in atmospheric sciences, including those aspects underlying the advancement of weather modification technology.

Very importantly, the bill establishes the authority which will insure an orderly development of a coordinated research program which will provide for maximum efficiency. The bill further looks beyond the technological aspects of weather modification, and provides for full consideration of the social, economic, ecologic, and legal problems which could arise both from the conduct of large Federal research programs and from the widespread application of modification technology—studies of these problems to be carried out on an interagency basis. Also the important problems or regulation of weather modification are recognized, with the granting of initial regulatory authority to minimize interference with Federal experiments and the provision for studies of the broader problems of more general regulation.

The bill is responsive to the recommendations of the recent intensive studies of weather modification carried out by the Panel on Weather and Climate Modification of the National Science Foundation. It is also in accord with the recommended plan of attack on weather modification problems contained in the study conducted by Dr. Homer E. Newell for the Federal Council for Science and Technology.

At this point I would like to note that section 401(d) repeals the authority of NSF with respect to the reporting by private persons of weather modification activities and does not assign this function to any other agency. We believe such authority is essential, and strongly recommend the inclusion in S. 373 of a section similar to section 205(b) of H.R. 9212, which would authorize the Secretary of Commerce to require such reports.

Senator CANNON. Why do you deem that authority to be essential there? What are some of the reasons?

Dr. BAUM. Mr. Chairman, it's exceedingly important that we have thorough knowledge of what is going on across the country in the way of attempts at atmospheric modification. It's a necessary part of the documentation in terms of analyzing any particular experiment. In the absence of such reporting we could be engaging in experiments which might be contaminated by others going on, and we wouldn't necessarily know that they were actually going on. This reporting procedure precludes that possibility.

S. 2058 is of quite a different nature. It is aimed at a program for augmenting the precipitation over the Upper Colorado River Basin through cloud seeding and other weather modification techniques,

and directs the Secretary of Interior to carry out programs "designed to increase to the extent practicable the annual average supply of water from rainfall and snowfall" in the basin. It also provides for research and study programs to determine the effectiveness of the programs and to develop new and improved modification techniques. The bill would authorize the appropriation of \$3 million for each of 3 years, with expenditures divided between research and operations in the ratio of 2 to 1.

Considering first the provisions of S. 373, it is our view that if enacted this bill would provide the logical structure within the Federal Government for the development of the potentialities of weather modification at an optimum pace. The need for such a structure is highlighted by the rapidly expanding efforts of the several interested agencies and the proposals for an even greater level of activity. The national program must be geared to the needs of these agencies; it must in addition be designed to serve the general interests of the Nation, both public and private. Also the future efforts must take into consideration the needs of the entire country, each section of which stands to benefit from the achievement of successful modification technology of one type or another. S. 373 is designed to further these important ends. In addition, it will prevent undesirable duplication of effort and at the same time assure that no serious gaps in the research program will develop. It will accomplish the objectives expressed by President Johnson in transmitting the last annual weather modification report to the Congress:

To develop the full potential of weather modification, we must continue our research and experimentation. We must bring to the effort our best skills and our most advanced technologies. We must better organize our efforts in this area.

And we must join with other nations in the search for solutions, for the weather respects no national boundary.

In view of its timeliness, its aim of establishing a rational approach to solving the problems of weather modification, and its responsiveness to the broad needs of formulating a comprehensive national program, I am pleased to affirm the strong support of the Department of Commerce for the enactment of this legislation.

I would now like to discuss briefly the role that we expect that ESSA would play in advancing the realization of weather modification under S. 373. As mentioned, the bill authorizes the Secretary of Commerce to carry out a comprehensive program in this field. We interpret this authorization to include research aimed at explaining the basic physical processes occurring in the atmosphere, knowledge of which is absolutely necessary to the rational development of weather modification potentialities and techniques. Such knowledge will allow us to avoid the "hit or miss" approaches so often attempted in the past, and which have proved costly and unsatisfactory. ESSA's approach will be concerned with the broad spectrum of weather modification potentialities which will be found to occur throughout the Nation. It will emphasize a "systems" approach which will consider the overall effects of weather modification and the recognition that modification techniques will often produce multiple effects, both those primarily intended and secondary effects which may or may not be desired. The accomplishment of these objectives and the pursuit of methods for

severe storm modification will involve a well-defined research program, which I will outline briefly in a moment.

The broad responsibilities of the Department of Commerce under S. 373 will be met as a vital element of its mission as the leading Federal agency in meteorological science. ESSA is at the forefront in weather prediction and in the gaining of new understanding and insight into weather processes. The bill recognizes the mutual dependence of weather modification, weather forecasting, climatology, and other aspects of atmospheric sciences and meteorological services. ESSA plans to exercise its leadership in the Nation's meteorological field to the fullest advantage in advancing the science of weather modification. This we believe will provide the most efficient use of our Nation's meteorological resources, already great. The close relationship between weather modification and the other aspects of meteorological science and weather services recognized by the bill requires that the efforts and facilities in other areas of meteorology be taken advantage of to the fullest extent. This would include ESSA's satellites, radar networks, research aircraft, ocean and land observations, and meteorological upper-air soundings. Many aspects of the world weather program will directly support the weather modification research effort. These will include the Barbados oceanographic and meteorological experiment, now in the preparatory stage under ESSA leadership, and the forthcoming global atmospheric research program, to be carried out internationally under the International Union of Geodesy and Geophysics and the World Meteorological Organization. The full-scale effort already underway to simulate the entire atmosphere and its components using giant computers will permit preliminary modification experiments to be carried out initially in the laboratory. In all of these areas ESSA will continue to play a leading role.

The need for strong international cooperation in furthering the goals of weather modification is recognized by S. 373, both in the declaration of policy (sec. 101 (b)) and in section 302, which provides that the Secretary of Commerce is authorized to cooperate in any international activities relating to weather modification consistent with the bill, in coordination with the Department of State, and that both Departments shall assure representation at international meetings and conferences. Under these provisions the Department of Commerce will continue its leadership in international meteorological affairs. The Administrator of ESSA is the permanent U.S. representative to the World Meteorological Organization and an elected member of its Executive Committee. In such capacity he already represents the Nation in meteorological matters, including exchanges of information on weather modification. The excellent cooperation now existing within the world meteorological community will provide the background for the extensive further international cooperation envisaged by the bill.

Of particular importance, in our judgment, are the provisions of the bill which direct that the studies of the legal, socioeconomic, and ecological and biological consequences of weather modification shall be carried out by the Secretary of Commerce in coordination with other agencies. We feel that the value of such a joint approach cannot be overemphasized. Preliminary studies of these problems have indi-

cated that they are extremely complex and may be more difficult to solve even than the technological aspects of weather modification. Such studies must be carefully planned and coordinated to keep the overall costs within bounds, and to take advantage of the limited manpower resources available. The joint effort specified in S. 373 is, in our opinion, a most valuable step in assuring an efficient approach to the solution of these profound problems.

I would now like to discuss very briefly the present ESSA program in weather modification and the more specific approaches to be taken in the future in accomplishing the objectives of S. 373. The six major areas of weather modification are:

- (1) Modification of precipitation characteristics.
- (2) Moderation of tropical disturbances and hurricanes.
- (3) Modification of severe local storms, such as thunderstorms and tornadoes.
- (4) Mitigation of hail and lightning.
- (5) Modification of climate, both intentional and inadvertent.
- (6) Exploration of the socioeconomic, legal, and ecological consequences of the various forms of weather modification.

The possibilities for increasing, decreasing, redistributing, or altering the timing of rain and snowfall represent the foremost problems in weather modification, and are still far from being firmly established. The utterly conflicting results of many well-executed experiments, both in our own country and abroad, suggest that cloud and precipitation processes are complex and highly variable. A prime objective of the ESSA program will be to resolve these conflicting findings and to establish a firm physical foundation for future tests and applications.

Our current activities include further tests of the successful experiments on semitropical convective clouds previously carried out near Puerto Rico. Again with support from the U.S. Navy and Air Force, we are conducting more extensive experiments in the southern Florida area where better control will be possible.

Another current project is an attempt to bring relief to the Great Lakes area from the severe snowstorms which often paralyze the communities along the southern shores of Lake Erie and Lake Ontario. Intensive exploration of these storms over the past several years has suggested that modification of the precipitation patterns should be possible. Preliminary seeding tests are scheduled for the coming fall and winter seasons.

As the weather modification program develops it will be necessary to conduct experiments over all representative regions of the Nation. The program of the Bureau of Reclamation constitutes an excellent attack on the problems in the Western States. We are supporting a design study for a major project in the Northeast. In association with the Department of the Interior we hope to extend the scope of the national effort to the many areas at present unexplored.

The eventual moderation of hurricanes and lesser tropical storms continues to be a major objective of our program. Project Stormfury carried out jointly with the U.S. Navy, with assistance from the U.S. Air Force, involves preliminary seeding experiments to determine if the thermal structure of these storms can be modified so as to reduce their intensity. Paralleling these experiments is a major effort to

gather further data on the structure and dynamics of these storms through continued aircraft reconnaissance, and to develop much more realistic computer models of the storms to permit a fully logical approach to their modification.

Study of the possibilities for modification of thunderstorms, tornadoes, and other severe windstorms, and the attendant hail and lightning, represents a significant part of the ESSA program. Many suggestions for modification of these storms have been made, and have been investigated, but as yet none has proved feasible. Our major approach at present is focused on establishing more fully the structure and dynamics of these storms as a forerunner to developing a rationale for modification. Much of this work is carried out at our National Severe Storms Laboratory at Norman, Okla., and in the upper Great Plains area, in both instances in cooperation with other agencies.

Turning now to a much different time and space scale, changes in climate, natural, or deliberately or inadvertently caused by man, seem much less spectacular than other types of weather modification. However, in the longrun such changes could have a much greater impact on our civilization. The causes of the natural variations of the past which, if repeated, could have catastrophic effects, are not fully understood. Studies of these changes are being pursued by paleoclimatologists, and these will provide a framework for further research. Our major effort, however, is on the development of mathematical models of the entire earth's atmosphere which will permit simulation of the world's climate on giant computers. Much progress along this line has been made over the past decade, and, as mentioned, further expansion of the program will be an important aspect of the world weather program. Man's pollution of the atmosphere may be already causing climatic changes on various scales, and these may become serious in the future. ESSA has undertaken a program for monitoring the pollution load in the "clean air" representative of large-scale conditions. Observatories have been in operation at the top of Mauna Loa in Hawaii, and at the South Pole, for a number of years. Additional sites will be added to the network. In association with the Public Health Service pollution is also monitored at many points throughout the Nation. Trends in contaminants are being analyzed, and their effects on climate will be determined through the computer models already mentioned.

The importance of studies in depth of the socioeconomic, legal, and ecologic and biological consequences of weather modification has been stressed earlier. In accordance with the provisions of S. 373, we intend to fully explore these questions. Several studies of the effects of natural weather variations on commerce, industry, and agriculture are underway, and these will provide a background for assessing artificial changes.

A program such as described will of necessity require a wide variety of supporting research. In the interest of brevity I will simply enumerate some of the main aspects to be included:

- (1) Studies of the physics and chemistry of precipitation.
- (2) Studies of cloud nucleation technology.
- (3) Computer modeling on all scales.
- (4) Development of measuring technology.
- (5) Advancement of experimental design and evaluation.

(6) Determination of the water and energy budgets of storms and cloud systems.

Turning now to the other bill before your committee, S. 2058, this measure provides for both an operational project and associated research and development efforts. The operational project would be conducted in the Upper Colorado River Basin, and would be designed to obtain maximum increases in precipitation. The research and development would be aimed at (1) determining the effectiveness of the operations, (2) development of new and improved modification techniques, (3) studying the effect of the operations on the ecology of the basin, and (4) evaluating the practicability and efficacy of the operations. While we support the objectives of this bill generally, we believe it to be unnecessary if S. 373 is enacted. The research objectives of S. 2058 can be more appropriately and effectively carried out under S. 373. We would defer to the Department of the Interior with respect to the operational objectives of the bill, in view of their ongoing program in the Western United States.

Senator DOMINICK. Could I interrupt you and ask you some questions?

Senator CANNON. Yes.

Senator DOMINICK. This is quite interesting, because in your statement here you point out specifically the four things which the bill asks for: (1) the effectiveness, (2) the development of new techniques, (3) the studying of operations on the ecology, and (4) evaluating the practicability and efficacy of the operation.

The Secretary of the Interior doesn't apparently go that far. He says that it only takes care of cloud seeding and evaluation. So I don't think he has read it very carefully, as I said before. You say that you defer the operational stuff to the Department of Interior. But the Department of Interior in turn says, "Well, what we need is more ability to do research." So, once again, you have the same proposition of the Department of Interior and the Department of Commerce locking hands over who is going to do what.

Dr. BAUM. Well, I'm not quite sure, Senator, that that is the situation. I want to emphasize again that we support the general objectives of this bill. We feel that the research aspects that are envisioned under the bill can be more effectively and appropriately carried out within the general framework of S. 373.

Senator DOMINICK. That would be fine.

Dr. BAUM. And that does not necessarily say which department would be doing it under S. 373. As a matter of fact, I suspect Interior would be doing it because of the specific provision in S. 373, charging them with rain augmentation activities.

With regard to the potential operations, we simply felt that we could take no position at all and would have to defer to Interior since they are now in the business in the Western United States and we are not, and we deferred to their judgment. And, of course, I cannot indicate how they came to the judgment that they did.

Senator CANNON. In other words, you're just saying simply that on the first part you don't believe it's necessary if S. 373 is enacted, that all of these things could be done under S. 373? Is that in effect what you're saying?

Dr. BAUM. I believe that all of the research objectives in Senator Dominick's bill could be met under S. 373.

Senator DOMINICK. That would be great. We would cut \$3 million off the bill right away.

Dr. BAUM. I don't know about the operational objectives, and on this I defer.

Well, in closing, let me simply say that we in the Department of Commerce must press forward immediately in seeking the advantages of weather modification. The potential benefits, both to our own Nation and to the world, are almost without limit. We must organize the vast technological and other required resources to attack the remaining problems with an intensive and fully organized program of research and development. We believe that S. 373 and its companion bill in the House of Representatives, H.R. 9212, will provide the basis for this much-needed effort, and again we recommend their enactment. Thank you very much.

Senator CANNON. Thank you for your very fine statement.

Senator, do you have any questions?

Senator DOMINICK. Just a couple of questions, Doctor.

I am a cosponsor of S. 373 and I am delighted that you are supporting it. I think it's great. The whole statement that you gave has emphasized the research effort which you are conducting. There was not a single statement in here on application of techniques that have already been discovered to be effective.

Now, is the Commerce Department or ESSA determining that there should or should not be operational techniques? I don't care whether it's hail suppression, fog dispersement, or augmentation of precipitation.

Dr. BAUM. I believe the Commerce Department's position is that as soon as any technique is clearly effective, demonstrably so, it then becomes a matter of policy determination as to whether or not it should be carried out.

Let me give you an example of a problem we're working on—which I suspect Dr. Benton will discuss in some detail—which is in a different geographical area, but which serves to illustrate the principle very well.

We have an experiment shaping up in the Northeastern United States, specifically in the Buffalo general area, on the lee side of Lake Erie. We have very good reason to believe that it may be possible to ameliorate the very heavy snowstorms which occur on the lee side of Lake Erie, especially in November and December of each year. You're probably aware of the fact that they get mammoth snowfalls there at the time of year when the water is still warm and the air is already cold. Now, we have a reasonable hypothesis about the possibility that we could spread that snow over a wider area, and therefore, eliminate these tremendous snowfalls. We intend to test that hypothesis in practice this coming year on an experimental R. & D. basis.

Now, let us suppose, on the basis of the R. & D. experiment, we come to the conclusion that we really can do it. Then there is the operational question as to should we do it on a continuing basis? I don't think that's a question that should be decided by a group of individuals, or for that matter, a group of scientists sitting in isolation somewhere. I think it becomes a public policy question. I think the people of the

area effected have an important role to play in this. It's not as clear cut as the problem out in the West, where I suppose everybody will agree we need more water. Some people around Lake Erie might decide that they like to have a foot or 2 feet of snow at one time. So I don't think that going operational then is in a different category than simply R. & D. And I think the decisionmaking process on operation needs to be a different kind of a process than the decisionmaking process in R. & D.

We, as of this time, within the areas in which we are engaging, are not prepared to propose any operational programs. Therefore, in the activities in which we would engage, we would be essentially in R. & D. work, at least for the first few years. Certainly, we would hope that operational projects would come out of this.

If the legislation, as it now stands, is enacted, it would probably be necessary to get specific approval from the Congress, as a matter of fact, before we could proceed with operation.

So, to answer your question specifically, we don't foresee any commercial operational activities over the short run. We expect R. & D., which would lead to operational projects, and then the policy decisions will have to be made as to whether those operational programs should be carried out.

Senator CANNON. Thank you very much, Dr. Baum. I appreciate your appearing here and presenting your very fine testimony.

The next witness is Dr. Archie M. Kahan, Chief of the Water Resources Office of the Bureau of Reclamation. Dr. Kahan, are you about to say that most of your testimony has already been given by Senator Dominick?

STATEMENT BY DR. ARCHIE M. KAHAN, CHIEF, OFFICE OF ATMOSPHERIC WATER RESOURCES

Dr. KAHAN. Not really.

Senator DOMINICK. No, he has a lot more.

Dr. KAHAN. My name is Archie M. Kahan. I am a meteorologist employed by the Bureau of Reclamation in Denver, Colo.

I very much appreciate your invitation to participate in these hearings on S. 2058 and S. 373 and the opportunity you have provided me to bring to your attention some of the progress that has been made since the 1966 hearings on similar legislation.

Secretary Udall has reported to Senator Magnuson the views of the Department of the Interior on S. 373 and S. 2058. Copies of these reports are available for the record. Briefly, the reports convey (1) that the Department of the Interior has no objection to enactment of S. 373 if it is amended to allow greater flexibility in the discharge of functions covered by the bill, and (2) that passage of S. 2058 is not necessary at this time. The Bureau of Reclamation's ongoing atmospheric water resources program includes planning for orderly transition from experimentation to application in the Colorado River Basin. We consider that the best way to progress toward applying what is known now for increasing the water supply of the Colorado River Basin is to set up one or more carefully planned pilot operational projects. These projects should combine many aspects of the best available commercial cloud seeding practice with activities designed to pin down

just what is being accomplished in each link of the complex chain of events that occur between the starting of a cloud seeding generator and the observation of the characteristics of subsequent precipitation. The Bureau of Reclamation has the authority to do what is necessary in this regard. Appropriation of adequate financial support and allowance of reasonable time are the principal additional requirements. We are moving toward the creation of such pilot projects as rapidly as circumstances permit.

As you may be aware, we have focused a good portion of our attention and available funding on the Colorado River Basin. A contract with Colorado State University has already been let which calls for designs of a pilot operational project in the Colorado River Basin. In addition, the University of Wyoming has started field instrumentation work for a pilot project in the Wind River Mountains of Wyoming.

Let us turn our attention now to consideration of what progress is being made. Important progress has come to light in the 2 years that have elapsed since the 1966 Senate hearings on weather modification. It should be remembered that many of the efforts which paid off in the past 2 years began more than 2 years ago. It is early to expect results from research started during the past 2 years. Knowledge is being gained from research which is providing an improving foundation upon which to base operational programs.

Perhaps the progress most pertinent to the purpose of these hearings is found in recently published results of a number of randomized cloud seeding experiments which have run for periods up to 5 years. Evidence of important positive effects characterizes experiments conducted in Israel, South Dakota, California, and Colorado. An important aspect of the results published in this country is the fact that the positive effects are ascribable to cloud seeding of only a portion of the storms which were seeded as a part of the experiments reported. In the South Dakota experiments, precipitation increases appear to have occurred in storms characterized by southwesterly flow, but not in those in which the flow is from the northwest. In the Lake Almanor, Calif., experiment, Pacific Gas & Electric Co. has reported positive effects in westerly storms, but no apparent effect on southerly storms. In the Climax, Colo., experiment, Professors Grant and Mielke of Colorado State University found that cloud seeding apparently produces increases of 54.5 percent when temperatures at the 500 millibar level were between -12° C. and -23° C., and decreases of 14.8 percent when temperatures were between -24° C. and -39° C. And it's an important fact that something like half of the cases that occurred in this area would fall in that category.

Senator CANNON. When you say "half of the cases in this area," what do you mean?

Dr. KAHAN. In the Colorado River Basin—and this is a very important thing, because I think it's pretty clear that seeding has gone on in circumstances that would fall into these categories.

These results indicate the need for local definition of cloud and storm characteristics as an important prerequisite to well-designed cloud seeding operations.

Advances have been made in several important areas by investigators who are part of the Bureau of Reclamation's atmospheric water

resources program as well as by investigators whose support comes from other agencies. In evaluating the following illustrative listing of categories of recent progress, it will be well to recognize that many agencies have contributed support to the progress that has occurred. Further, the order of appearance in the listing should not be considered a ranking based on importance.

As a calibration of the progress listed, keep in mind the fact that expenditures for the national effort in weather modification was \$9,-516,000 in fiscal year 1967 and will total approximately \$10,700,000 in fiscal year 1968. In fiscal year 1967 the Bureau of Reclamation expended \$3,743,532 in support of the efforts of 22 contractors. And that was spread over the entire program. The obligation of funds for fiscal year 1968 total \$4,524,801, covering efforts by 30 contractors, 16 of which are universities, six are private research groups, two are State agencies, and six are other Federal agencies.

Senator CANNON. How often do you require reporting now to the Bureau?

Dr. KAHAN. It depends on the contract, Senator. If the contractor wishes to be paid monthly, then he must submit a letter report that provides the basis for payment. If he is willing to be paid quarterly, then the quarterly reports are sufficient for this purpose. In addition, there are annual technical reports from which we can get a full statement of the progress that the contractor has made.

Senator CANNON. Do you evaluate those as each report is made at the conclusion of each project?

Dr. KAHAN. We evaluate any report as we receive it. We don't wait until the conclusion to evaluate it.

Senator CANNON. You have an ongoing evaluation then or monitoring of each project as it goes ahead and you evaluate it as it goes on?

Dr. KAHAN. To the extent that we are able to do so; yes, sir.

PROGRAM ADVANCES

1. Improved experimental design leading toward better field research programs that will enable sound statistical analysis of seeding effects and permit stratification of data and results by storm type. The successful climax experiment by Colorado State University for the National Science Foundation has emphasized the importance of careful design. The same group at Colorado State University is now preparing a design for pilot project in the Upper Colorado River Basin.

2. Increased definition of precipitation and storm climatology at field sites. For example:

(a) Summer convective clouds that occur over the northern Great Plains have different glaciation characteristics than those over southwest Missouri or over northern Arizona.

(b) The presence of cold arctic air at the surface in the Bozeman, Mont., area significantly reduces the orographic lift, which tends to reduce the amount of precipitation in the area and furnishes a less opportune seeding situation. This cold air, often extending 4,000 feet above the surface, is a common winter feature.

(c) The primary source of moisture for the southern portion of the Sierra Nevada during periods of high precipitation potential in the summer is the Gulf of Mexico.

(d) The ESSA Weather Bureau has completed investigation of the importance of upper atmospheric lows in producing winter precipitation in the intermountain West. This study, made for the Bureau of Reclamation, will be particularly useful for experiments in the Upper Colorado River Basin.

3. Development of techniques for the operational use of neutron activation in the analysis of silver in precipitation. The University of Nevada's Desert Research Institute has devised procedures for analyzing large numbers of precipitation samples from weather modification experiments using silver iodide. The amount of silver in a precipitation sample, plus the total of precipitation, from seeded and from unseeded areas gives additional insight into the effectiveness of the seeding experiment.

As an aside, I might mention that where we have taken some of the samples in projects that are being conducted, sometimes as fairly operational projects, there are cases where some of the cleanest snow that you can find, from the standpoint of lack of silver, can be found in some of the target areas of seeding projects. So that we are not yet to the point where simply because we can designate a target area that we can assure that precipitation is high in silver and presumably effected by the silver, possibly effected by the silver as actually reaching the target.

4. Development of a real-time system for the acquisition, display, and utilization of data from ground and airborne instrument platforms. Developed jointly by the University of Nevada, Meteorology Research, Inc., South Dakota School of Mines and Technology, and Pennsylvania State University, the system was used operationally in Flagstaff, Ariz., during the summer of 1966. Further development is continuing, incorporating more instruments and greater precision and reliability.

5. Evidence of statistically significant precipitation increases from seeded convective clouds. South Dakota School of Mines and Technology found when southwesterly flow exists, the seeded target area received at least between 5 and 10 percent more precipitation than the unseeded area. Fresno State College found that when one of a pair of summer convective clouds was seeded in the southern Sierras, the seeded cloud produced more precipitation than the unseeded cloud. Often the unseeded cloud did not precipitate at all.

6. Instrumentation and equipment development. The University of Wyoming has developed a hard line telemetry system and an aircraft data-gathering system with digital readout capability. An ice nuclei counter invented at the National Center for Atmospheric Research has been further developed as a useful field tool by E. Bollay Associates. Meteorology Research, Inc., has developed a rapid-response ice nuclei counter, a foil precipitation sampler, and an airborne metaldehyde generator. The University of Nevada has developed and refined particle samplers. Colorado State University has developed a prototype of a variable-output silver iodide generator.

7. Pyrotechnic seeding devices. The Naval Weapons Center has led in the development of a number of pyrotechnic seeding devices. Some are meant to be dropped from aircraft; others are ground-release devices. The total amount and rate of release can be varied.

These devices are becoming increasingly important in all types of weather modification field experimentation.

One of the big areas of progress has been in the area of numerical modeling. There has been marked improvement in the past 2 years in demonstration of the efficacy of mathematical models, some of which are still quite crude in predicting what should happen to a cloud when it is seeded, whether it is seeded or not seeded.

There has been improved definition of the diffusion characteristics, with some evidence that diffusion from the ground doesn't always get as high as it is sometimes hoped. And there are times when, under circumstances, where the material is confined to the first 450 meters above the ground, it would be of too little rise to get into the roots of growing clouds.

In the interest of saving time, I refer to the statement. We had some studies that improve our recognition of the problems and of what we can hope to accomplish. We are trying to move aggressively toward operations. We have preliminary studies which identify very favorable areas in the Colorado Rockies for pilot projects. These areas are characterized by ease of streamflow, increase of evaluation, relatively infrequent areas of low precipitation. We believe that we can develop a well-designed full-scale operational program capable of producing nearly 2 million acre-feet of streamflow augmentation by 1975, given suitable support.

Senator CANNON. Now, what do you mean by "given suitable support?"

Dr. KAHAN. The necessary funding to carry out the studies.

Senator CANNON. I know that. But let's be a little more specific. What are you talking about now in terms of support?

Dr. KAHAN. I think that figure, if you're looking at the Colorado River Basin, the ability to expend \$3 million a year for the next 5 to 8 years, depending on natural events, would accomplish this.

Senator CANNON. In other words, you're saying that if you were permitted to spend \$3 million a year—with a pro rata breakdown, I presume, that Senator Dominick referred to earlier—that then in the time frame that you have defined you think you could increase the flow, the Colorado River Basin flow, by 2 million acre-feet; is that right?

Dr. KAHAN. I am assuming that we would also continue with our other programs and studies which, while not focused on the Colorado River Basin, would presumably contribute to this learning. I would like to not agree wholeheartedly on too rigid adherence to the ratio that is defined in S. 2058. There is a danger in this regard in that the cost of operating in any year should be at least partially determined by what happens in that year. In other words, it would seem to be an improper use of the taxpayers' money to simply guarantee to an operator that regardless of what storms developed or were seeded that he got a blanket sum of money. This could result in a research effort that was tied to the actual seeding operations if too rigid an interpretation were given to the words in S. 2058, while an average expense of a million dollars for operation and \$2 or \$3 million for research might be a very desirable thing.

Senator CANNON. You would feel then that as a general guideline that is probably over the long run a good ratio; is that what you're saying?

Dr. KAHAN. Depending on the definitions that are applied to the terms, yes. But it does concern me a little that you could find yourself in a situation where, because of the weather events, because of the expenditures for operation were not being made, that you were therefore not authorized to make required research expenditures. That, as I say, might or might not develop, and it would depend on interpretations that are placed on the wording in the bill.

Senator DOMINICK. All I can say, Mr. Chairman, is that I have no intention of trying to bind anybody on this. We are simply trying to follow out Dr. Kahan's suggestions. And I'll be happy to change the wording any way you want to. I think it's very interesting to me that Dr. Kahan once again says that by 1975, continuing with the necessary support, they can produce 2 million acre-feet of water additional in the Colorado River Basin, which, heaven knows, we need so badly we can practically wet our lips with it right now. And I don't see why, if we get this bill through, we haven't given them the support they need.

Senator CANNON. We could just about meet that and prorate the cost.

Senator DOMINICK. It would be tremendous.

Dr. KAHAN. The disparity that you pointed out, Senator, between my testimony and the Department's position proves that the Department of Interior is not a one-man organization.

I think perhaps I can clarify some of the position that will re-establish your faith in Assistant Secretary Holum's ability to read.

Senator DOMINICK. It's going to take a little work.

Dr. KAHAN. There are some key words in the statement, I think. In regard to the statement the word "emphasize" is an important word. I don't think there is any feeling that other things aren't mentioned. But, apparently, the feeling that it emphasizes was on operation and evaluation. The aims of S. 2058 are, I think, near and dear to the hearts of people in the Department of Interior. It is the position of the Department that the real need is for money, not authority. And while the bill authorizes the appropriation of the money, there is a distinction drawn in this analysis, the distinction between authorizing an appropriation and the actual appropriation. Even in the event that the bill were to pass, as I understand the position, there would still be need for actual appropriation. And if the Congress in its wisdom desires to appropriate that money, we have, as we see it, the authority to do just what the bill calls for in a reasonable and orderly way.

Senator DOMINICK. Well, I appreciate your summary. I'm happy to hear that your position on a good number of occasions may differ from some of the people in Washington, I appreciate that.

My recollection is that when we had testimony before, Doctor, that you indicated that just from cap clouds alone, in the Colorado River area, by proper seeding techniques which are presently available, we could produce 2 million acre-feet of water in the Colorado Basin area.

Dr. KAHAN. That was a qualified estimate based on indications that we were getting at that time from the studies at Elk Mountain which consisted of a sizable extrapolation from fairly small-scale experiments. It may still be a valid statement. But the 2 years that have elapsed since those studies have indicated that the problem is a good deal more complex than the early indications of what we gave.

The work by the University of Wyoming group in pinning down just how the material gets from the ground to the cap clouds has brought to light the fact that now we can get up on the mountain and actually count the nuclei; that indications that were previously taken as being effective seeding are now not so clearly that way. This is characterized by a great deal of work. You can start with an indication of effectiveness which, when you sharpen your ability to trace the steps, turns out to be effective under some circumstances and not effective under others.

Senator DOMINICK. Well, my concern—and I have said over and over again—and I'm sure that you share at least part of this concern—is that we are going to spend our entire time and our entire patrimony on research and never get around to putting into effect any of the techniques that are now developed. And we have been doing this now, as far as the governmental pattern is concerned, ever since 1953. And we really haven't started applying this to a really useful purpose, even the cold-fog dispersal had to be done by private operators, United Airlines, to be specific, in order to really put this into effect. And, granted that a lot of research has been done, but can't we go forward with a program of some kind to put it to a useful purpose?

Dr. KAHAN. We feel that we have outlined such a plan and program. We are not interested in doing research for the sake of research. But we are interested in the proper stewardship of the taxpayers' money and not in spending money that isn't going to produce a useful result.

In this connection I think there is a difference that has to be recognized between the circumstances of private support for cloud seeding and the use of public funds. A great deal of cloud seeding has been supported by private funds. The field was essentially kept alive by such efforts. And there have been some long-term projects that have been supported for a long time by people who were committing private funds, who were in a position to make that decision to evaluate what risks they were taking and who were also in a position to benefit from a desirable result. The public situation is somewhat different. There is the use of tax money being committed by people other than the ones whose money it is.

Senator DOMINICK. Well, Doctor, of course, I know all that. And so does Senator Cannon. We are already in the effort of trying to save the taxpayers some funds if we can. What we are trying to do here is simply say that if we get a project authorized by Congress which will provide 2 million acre-feet of Colorado water for the Colorado River Basin, we have solved an awful lot of problems, national problems. And if we have the techniques to do it, I personally think we ought to go ahead and do it. But, apparently, Mr. Holum at least doesn't think it's necessary.

I don't have any more questions. I think Dr. Kahan gave a very good statement and I think the work which they are doing is great, and I just hope they can do some more.

Senator CANNON. Did you want to complete your statement there or have you substantially completed it?

Dr. KAHAN. I have completed it.

Senator CANNON. Now, in section 303 of this bill, the proposal there is that before any agency conducts a weather modification activity designed to effect the atmosphere more than 150 miles from the source

of the activity, the President shall transmit notification to the Congress, and so on. On page 8 of your statement, you there indicated, I think, that frequently the effects are carried out at distances of 100 miles or more downwind. In light of that, do you think that section 303 is a good provision in the bill?

Dr. KAHAN. I think it's a little restrictive at the present time, in that I don't see that there is any basis for choosing 150 miles or any other particular distance in the light of our present knowledge. The key word may be "designed to create an effect." Now, in none of the studies that we have made where the operations that were studied were designed to create an effect 150 miles away, and yet, there is some evidence that they may have done so. This study is important evidence. It hardly constitutes proof of an effect. There appears to be the possibility that in seeding for a local target area you may set off a wave type of dynamic effect that extends downwind and produces perhaps increases and decreases alternately. The evidence for this is quite crude and it needs to be studied a good deal more.

And I want to mention that we do have from a study of past commercial efforts, compared with storms taken from years when there was no seeding, evidenced that there may have been increases much farther downwind than the project was designed to cause.

Dr. BAUM. May I comment on section 303, since you brought it up?

Senator CANNON. Yes, sir.

Dr. BAUM. From the Commerce's point of view, we also feel that the legislation would be better if that were deleted for the reasons which Dr. Kahan decided. On the other hand, I want to make it clear that we consider the legislation of such fundamental importance that it is better to have the legislation with that provision in it than it would be to have no legislation at all.

Senator CANNON. Thank you.

I think what is intended there is to make sure that there isn't arbitrarily some activity taken that might detrimentally effect some area a long distance away without giving the Congress the chance to step into the picture if they want to make a policy determination as to whether or not that should be done. I think you pointed out a moment ago that a lot of times, if you're using your own funds, you may want to gamble on something and take a chance; but where you're using taxpayers' funds, that you might injure those taxpayers at some great distance. And this is something that should have a good close look.

Dr. Kahan, in your statement, where you point out those interesting temperature levels, the decrease of 14.8 percent when temperatures were between -24° and -39° C., is that a fairly definitive study? Are you able to come out with some pretty strong conclusions now, or is this just sort of a preliminary shot at it?

Dr. KAHAN. Well, I think that the study in which these results were published was one of the best experiments that has been conducted anywhere in terms of its attention to what is going on each step of the way. I think it would be a mistake to overgeneralize the results of any single experiment. These are circumstances that prevailed at Climax, Colo. I think there is some good basis for explaining a decrease in terms of the availability of natural nuclei at the colder temperatures. It is a well-observed fact that such materials as clay and mineral dust are effective nucleans providing the temperature is sufficiently cold.

So the decrease observed may have resulted from adding nuclei to an already well-supplied situation, so that the nuclei were competing with each other for the available water molecules and ended up producing ice crystals too small to fall out. Whether that would happen in another basin under another set of circumstances I really don't know. I think such things as this need to be looked at in a variety of circumstances.

One of the things that is quite apparent is that results of apparent successes or apparent failures should not be generalized too widely. Local topography, local circumstances need to be understood and fitted to the operational plan. And it is this feeling that perhaps gives the false impression of a reluctance to plunge into large-scale operations on principle.

What we are trying to do is to insure that when operations begin that they are soundly based and designed for the locality involved. It is true that there have been successful cloud seeding efforts. Some of these have gone for a long time. But if you look at the record you'll see that, according to one knowledgeable individual, less than 95 percent of the programs that have been undertaken have been carried on on a long-term basis. Now, there are many reasons for stopping a seeding program, one of which would be an end to the need for the water. But at least in a good many of these cases it was stopped because the effects that were desired were not being produced.

Senator CANNON. Thank you very much, Dr. Kahan, for your fine testimony.

The next witness is Bernard A. Power, Weather Engineering Corp. of America, president. We are happy to have you here, Mr. Power. You may proceed.

**STATEMENT BY BERNARD A. POWER, PRESIDENT, WEATHER
ENGINEERING CORP. OF AMERICA**

Mr. POWER. Thank you, Mr. Chairman. I have already submitted a prepared statement, and with your permission perhaps I could just give a quick ad lib summary of what is contained in it.

Senator CANNON. Very well. Your statement will be made a part of the record and you may summarize from it if you wish.

Mr. POWER. My name is Bernard A. Power. I am a meteorologist I am president of Weather Engineering Corp. of America. We are a commercial cloud-seeding company and have been engaged in seeding for water production principally for the past 14 years. The principal fields have been for increased reservoir supply, for hydroelectric power production and for forest fire prevention.

We have already at the previous Senate hearings in 1966 and 1967 given evidence on the conventional seeding techniques that we have carried out over the past 14 years and the results achieved.

Just briefly I might say that they agree in general with the results found by the National Academy of Science's committee in their report published in January 1966; namely, increases ranging from 20 percent up to slightly over 33 percent from continuous ground-based operations and continuous generator-type airborne seeding type operations.

What I would like to talk about this morning is not conventional seeding techniques with continuous burner-type operations, but a new

seeding device which has been produced by a research and development program that we have carried out since 1959.

In 1959 we were interested in developing a very high-yield type of cloud-seeding device for possible hail suppression operations. Hail suppression theory indicates that the chances for success are greatest if the whole supercooled portion of the cloud can be converted to ice. Consequently, this pointed out the need for a very high-output seeding device. So we began experimenting with an explosive technique for generating or vaporizing large quantities of silver iodide. As a result of this, there has been produced a product which we have called Weathercord. It incorporates the silver iodide in a ropelike cord. The silver iodide is mixed with the detonating chemical and then sealed into the rope. The detonating velocity of the explosive is extremely high. Some 25,000 feet of cord can be detonated in 1 second. Consequently, a typical loading of 1 gram of silver iodide per foot of Weathercord, 25,000 grams of silver iodide in a single strand can be detonated in 1 second, either at a single point in space or over a linear or other geometrical path. Now, this technical capability in generating silver iodide is enormously greater in output than any of the conventional seeding generators that have been developed. A typical conventional ground-based seeding generator will vaporize between a few grams up to about 100 or 200 grams of silver iodide per hour. As I've mentioned, we can detonate, if required, as much as 25,000 grams in a single second.

Senator CANNON. What is the largest size that you have detonated so far?

Mr. POWER. 500 feet at the present time. In operations we have actually found it convenient to use 25 feet of cord in a single package. This would be 25 grams of silver iodide. The detonation takes place at about a thousandth of a second. One of these is usually found sufficient to accomplish the release of precipitation from a single cumulus cloud. It can be dropped either from an aircraft to detonate within the cloud at any given level or it can be detonated on the ground from a ground-firing battery, and the silver iodide is then carried up in the normal method of seeding from the ground.

Well, this Weathercord device was sent for testing in 1964 to the National Center for Atmospheric Research here in Colorado. Laboratory tests confirmed the nuclei output found in our developmental work. Field tests and firings were made by NCAR on Old Faithful Geyser in Yellowstone National Park during the winter months and on natural nonraining winter cumulus clouds over the Sierra Nevada Range in central California.

The results of these NCAR tests have been described in a scientific report "The Laboratory and Field Evaluation of Weathercord, a High-Output Cloud Seeding Device" by Goyer, Grant, and Henderson, *Journal of Applied Meteorology*, April 1966. The NCAR tests on the supercooled clouds in California pointed up a rather new and rather remarkable effect; namely, the rapid growth of the cloud top following the detonation of the silver iodide in the Weathercord package. Rapid glaciation and precipitation within 20 to 30 minutes occurred.

Now, the same type clouds have been seeded by standard conventional seeding methods from aircraft with burners for many years,

and no observable effects were found to occur from this type of small cumulus cloud of limited development. So that we had here a rather remarkable effect, and it seems to promise to us the possibility for the first time of a device which would actually make rain from a cloud by seeding rather than increasing rain as heretofore has been the case.

So we continued with tests on a redesigned package with the aim of developing a fail-safe ejection and firing method which would achieve the approval of the aviation authorities for operational use.

This was done in tests that were run out of Harmon Air Force Base in Newfoundland in the fall of 1966. Well, last summer, in July 1967, we put this new designed Weathercord package into operational use for the first time. In July there was a period of severe drought through the Newfoundland area. It's a wilderness area, mostly spruce forest with a rather limited soil retention of moisture and it dries out very quickly. They had a drought. The forests were dry. And a dry cold front came through the area with lightning, dry lightning, and some 90-odd fires were set off in a very long arc of about 400 miles. This was a very difficult area to operate in for forest fire prevention, and we were called in to seed with this new technique.

In 5 days of seeding the same effects occurred as were found in the NCAR tests in California. There was rapid growth of the cloud tops that were seeded. We could detect immediately increased internal turbulence in the clouds at the drop point and heavy precipitation usually resulted within 20 to 30 minutes. All fires were under control over this large area within 5 days and the whole area was thoroughly soaked within 10 days although the general drought pattern continued elsewhere. This was the general weather pattern. Everyone, all operating personnel, were then removed from the area. The fire danger was over.

But on a second occasion some 10 days later, another dry front set another large number of fires, 25 more major fires in the same area. On this occasion we were the only personnel who were called back in just for cloud seeding, the aircraft with the crew. And on this occasion 3 days of seeding had extinguished all of these major fires and then the area was again generally soaked.

To retrace a moment, this Weathercord technique was first exhibited in Washington at the International Water for Peace Conference last May. And as a result of that, subsequent to this meeting, a contract was negotiated in August of last year with the Government of Iran for a major 3-year cloud seeding project in using Weathercord on three major watersheds in the Elburz Mountains in northern Iran just north of the capital city. These watersheds furnish water for hydroelectric power production, storage for irrigation and municipal water supply to the capital city. A 6-year general drought had persisted in that area and the reservoirs were low. The Weathercord seedings began in November, late November, and were completed on April 30, 1968. This ended the first phase of the 3-year contract which had been resumed in November of this year. At the close of the operations, although the precipitation, based on the preliminary analysis that we have made to date, was still below normal in the general surrounding area of northern Iran, all of the three reservoirs were filled or spilling and the desert agriculture closely surrounding this target area is green and flourishing. It is expected that they will have bumper crop and

the municipal water supply is assured and the problem of possible shortages of hydroelectric power have been solved, at least for this season.

Here again, the reaction of these middle eastern weather systems to the Weathercord seeding has been startling—intensification of the cloud systems, increased cloud turbulence following the seeding, and then followed within 20 to 30 minutes by precipitation. We feel at this time that we can say that the Weathercord type of seeding is apparently 100 percent effective in the sense that every time that the device is used on supercooled clouds, precipitation results. This, of course, is not the case with conventional seeding. In conventional seeding techniques I think it is generally agreed that you get an increase in precipitation from an already raining cloud but not an initiation of the precipitation.

Senator CANNON. At what altitude were you making your drops in Iran?

Mr. POWER. Well, these are determined by the temperature levels that prevailed in the clouds. But in the winter cloud systems there, most of the drops were made between 17,000 to 22,000 feet, with a time-delay fuse that would allow a 2,500-foot drop of the package into the clouds. So that most of the detonations would take place between 13,000 and 19,000 or 20,000 feet.

Senator CANNON. Has our own Department of Agriculture indicated any interest in this system?

Mr. POWER. No, they haven't, Senator. As a matter of fact, I doubt if they know of the operation, since we have just returned from the first phase.

Senator CANNON. We have here in the bill where the Secretary is authorized to carry out a program in such aspects of weather modification that would relate to the control of lightning and hail and the protection of vegetation from the effect of other weather phenomena. That might come within that.

Mr. POWER. Well, as I mentioned, we originally had the intention of developing this seed technique for hail suppression. It has the technical capabilities of doing, I think, an outstanding job in completely glaciating the clouds into which it is introduced. But the effects on increasing precipitation have been so startling that we have simply concentrated on that.

Senator CANNON. Do you have any estimate as to the amount of precipitation, let's say, that occurred in these reservoir areas or the runoff that you got in Iran after your seeding started?

Mr. POWER. Well, we are working on the evaluation. The data is coming in. I think we can say at this time that it seems to be considerably in excess of the increases that can be obtained with the standard cloud-seeding techniques either from ground or cloud operation or burner operation. We can see the effect visually. There is no difficulty in seeing the effects; that is, a glaciation which takes place almost immediately and then you have the precipitation followed in 15 to 30 minutes. This we can observe. We cannot observe it with the standard cloud-seeding techniques. So we know there is a greatly increased effect and we feel that the eventual increases will be considerable in comparison to those established with other techniques.

Senator CANNON. Are you willing to tell us what we are talking about in terms of the cost factor, or is that something that you would

rather not disclose as your company business? I'm talking about the Iran operation.

Mr. POWER. Well, I could describe what is involved in it. You need a heavy-duty, all-weather twin engine aircraft or multiengine aircraft. It has to operate under extremely severe weather conditions day or night, often without very adequate navigational aides. So you need a powerful aircraft. You need a crew that is operating most of the time on oxygen, or they would need a pressurized aircraft. So the aircraft expenses are much in excess of those that are required with standard conventional seeding. We have a figure which we have used which perhaps would give you some idea of the cost. We feel that the maximum cost for the water with this technique is less than 1 cent per thousand gallons for the minimum sized project area, and that this cost goes down very rapidly with a larger sized area to a fraction of a cent, something in the order of a tenth of a cent for a thousand gallons.

Senator DOMINICK. Can you put that in terms of acre feet?

Mr. POWER. Yes. I think that on a large-scale operation, say, 10,000 square miles or larger, that the acre cost for an acre-foot should be something not more than 30 cents per acre-foot.

Senator CANNON. When you complete your evaluation on this Iran study, would you furnish the committee a copy of that?

Mr. POWER. Yes, we would be delighted to. I expect that this will be a matter of 2 to 3 months from now, but we will be glad to furnish it.

Senator DOMINICK. I think this is really great information that Mr. Power has given to us and I want to thank him for coming out all the way to Colorado to testify here.

You mentioned the altitude at which drops occurred or where the Weathercord explosion took place as between about 13 to 15,000 feet, if I recall what you said.

Mr. POWER. The detonation is at 13 to 19,000 feet.

Senator DOMINICK. Did you have any estimate of the temperature of the clouds at that level before you dropped?

Mr. POWER. We have the temperatures. They haven't been analyzed as yet on an operational basis. We have the temperatures though. I would say that the general weather patterns and the general atmospheric structure, the temperature and cloud structure is not similar to the cloud structure that you would have over the upper Colorado in the winter season. The two areas are fairly similar. They are at about the same latitude. Iran is about the same latitude as Denver. It's on the eastern edge of about a thousand miles of mountains, high mountain ranges through Turkey, and it's about a thousand miles from a major source of water, the Mediterranean, as opposed to the Pacific here. So there is a fair comparison. The target areas are in high mountain ranges. The average height of the ranges is about 12 to 15,000 feet, with a few peaks higher.

Senator DOMINICK. Was your project conducted for the purpose of getting snow or water?

Mr. POWER. Eventually water. Of course, in the winter the precipitation is initiated as snow. But the eventual aim is water.

Senator DOMINICK. So your actual result in the Iran mountains then was to develop additional snowfall as opposed to water?

Mr. POWER. Snowfall and water rainfall. In March and April the precipitation reaches the ground as rain, although there is heavy snow on the mountain peaks.

I might mention that in regard to the temperatures in detonation, the effect of this on the clouds, we do know, of course, that the temperature of the cloud exercises a very important effect on the result of the seeding. But you can look at the thing either on the basis of an individual seeding of clouds or on the basis of the overall seasonal effect. If you find that your seeding technique is getting you over a whole season a net increase and this exceeds the cost of the operation, you have a net benefit from the operation. Now, if you can sharpen your operations to the point that you can select the clouds that are going to yield the maximum increase and avoid any decreases, if they should occur, then you could increase your efficiency. But I think we have been through this, of course, with the standard seeding technique over the last 20 years, that standard seeding produces a net increase. Now, that net increase could be increased if you could select your seeding occasions. But it's still a paying proposition and yields an excellent benefit-to-cost ratio without this selection. I think that is for the future.

Senator DOMINICK. Thank you very much, Mr. Power.

Senator CANNON. Do you let that primacord reel out? Do you reel it out back of the airplane so that you get distance?

Mr. POWER. No. The research test used a method of allowing it to unreel. This was so there would be no possible coagulation in the initial burst. There is a very high concentration of particles and coagulation that would take place in a matter of seconds. But we found that this was not a matter of concern. So we now use a coiled package incorporating 25 feet up to, say, 50 feet of primacord. This is a dummy package. There are 25 feet of cord here. This is a simulated cord simply coiled around, and in the interior is the firing mechanism. This is the firing ring. In here is contained an igniter fuse, delay cord and plastic caps. So when the ring is pulled there is sufficient time that elapses to allow this to clear the aircraft by 2,500 feet.

Senator CANNON. That goes out as a package?

Mr. POWER. Yes, and completely disintegrates.

Senator CANNON. Then in going through this, you drop quite a series of these?

Mr. POWER. Well, we found that in a single cumulus buildup, a single cumulus head, that one or two of these is sufficient; in other words, 25 to 50 grams is sufficient. If we are seeding in a layer-type cloud system on instruments, then we would be seeding in a geometrical path with drops being made at different time intervals.

Senator CANNON. That's very interesting. Thank you very much.

We will have a 5-minute recess.

(Mr. Power's prepared statement follows:)

STATEMENT BY BERNARD A. POWER, PRESIDENT, WEATHER ENGINEERING CORPORATION OF AMERICA

INTRODUCTION

Weather Engineering Corporation of America (WECO) is a professional cloud seeding organization with principal offices in Washington, D.C., Manchester, Vt., Montreal, Canada, and Tehran, Iran.

We have been engaged in cloud seeding for water production for the past fourteen years. The principal fields of operation have been for hydro-electric power production, and for forest fire prevention. In both of these fields clients have been both private concerns and public bodies.

In this statement I will deal only very briefly with the conventional cloud seeding techniques and will concentrate on a description of a new cloud seeding device which we have developed and put into operational use in the past year with remarkable results, namely the actual "making" of rain as opposed to increasing it as is done with conventional seeding methods.

TECHNICAL METHODS

From 1955 to 1966 we have used conventional silver iodide generators, both ground-based and air-borne. Such generators dispense a continuous stream of silver iodide nuclei of moderate concentrations.

The results of our conventional seeding operations have been detailed in our previous testimony to Senate Hearings on S. 23, S. 2916, and S. 2875 in March and April of 1966. In summary, these conventional operations which we have carried out show increases in the precipitation of up to 33% caused by the seeding. The Gatineau River operation, one of the largest and longest contractual operations yet carried out anywhere in the world, shows a 29.5% to 33.3% gain at a statistical confidence well over 99.9%.

Since 1967, as a result of eight years of research and development work, a completely new seeding technique has been put into use by WECO with remarkable results. This technique generates silver iodide seeding nuclei by means of an explosive; the 9000° F. blast vaporizes the seeding chemical almost instantaneously. The explosive and the silver iodide are in a rope-like form called WEATHERCORD.

The device was developed jointly by our Canadian affiliate, Weather Engineering Corporation of Canada, Ltd. in conjunction with an explosives firm, the Canadian Safety Fuse Company Limited, Brownsburg, Quebec.

WEATHERCORD is, by a wide margin, the most powerful seeding device yet developed. It is capable of emitting a million times the concentration of silver iodide that is possible using conventional devices. The linear detonation velocity of WEATHERCORD is about 25,000 feet per second. Thus, at a typical loading of one gram of silver iodide per foot of WEATHERCORD 25,000 grams of silver iodide in a single strand can be detonated in one second, either at a single point in space, or over a linear or other geometrical path.

By comparison, typical conventional generators are capable of putting out from a few grams to about a hundred grams of silver iodide per hour.

The WEATHERCORD detonator can be dropped from an aircraft to detonate within a cloud at any desired level, or it can be detonated on the ground in a ground firing battery.

The device was sent for testing in 1964 to the National Center for Atmospheric Research (NCAR) here in Colorado. Laboratory tests confirmed the nuclei outputs found in our developmental work. Field tests and firings were made by NCAR on Old Faithful Geyser in Yellowstone National Park during the winter months, and on natural non-raining winter cumulus clouds over the Sierra Nevada range in Central California.

The results of the NCAR tests have been described in a Scientific report "The Laboratory and Field Evaluation of Weathercord, a High Output Cloud Seeding Device" by Goyer, Grant, and Henderson, Journal of Applied Meteorology, April 1966, pages 211 to 216.

In the words of the NCAR report "Weathercord provides in unit time and unit volume the highest concentration of nuclei available from any known source." And again describing the Old Faithful seedings "These experiments left no doubt in the minds of the observers concerning the high efficiency of Weathercord." On the operations in California on non-raining winter cumuli the reports state, "In all cases relative small charges of Weathercord appeared to convert large volumes of supercooled water clouds to ice crystals and * * * shower activity followed." The results of the tests described establish Weathercord as a silver iodide generator of unique characteristics."

The California Seeding tests showed a remarkable effect, namely, rapid growth of the seeded cloud top in about ten minutes followed by heavy precipitation within twenty to thirty minutes. Thus, on clouds which normally never produce measurable precipitation at the ground, WEATHERCORD seeding produced sizable quantities of precipitation within a thirty minute period.

Our next step was to develop an operational delivery technique which would permit safe and acceptable use of this explosive seeding device, which appeared to us to promise for the first time "rainmaking" rather than as heretofore "rain increasing".

Tests on a designed package, and on a fail-safe ejection and firing device were run out of Harmon Air Force Base, Stephenville, Newfoundland, in the fall of 1966. Observing were USAF, USN, Newfoundland Forest Protective personnel, personnel from Canadian Safety Fuse, Canadian Industries Limited, and WECOA. The design has now won approval of the Federal Aviation Authority, and the Canadian Air Services Branch.

The first operational use of WEATHERCORD took place in the following summer (July 1967) in Labrador on major forest fires. Summoned by the Newfoundland Forest Service and using a Lockheed-18 (Lodestar), we operated out of the Goose Bay USAF Base. Some 93 major forest fires, the worst on record in this wilderness area, were spread over a 400 mile long front, and were extinguished in five days of seeding operations. The whole area was heavily soaked by the time operations were discontinued. The cloud reaction to WEATHERCORD seeding was the same as that found in the NCAR tests in California, namely, rapid building of the cloud tops, increased internal cloud turbulence, and heavy precipitation within thirty minutes.

On the second occasion, July 22nd to 24th, another dry front with lightning set some 25 more major fires again in Labrador. These fires were doused by WEATHERCORD operations in only three days. The first fires employed some 1000 fire fighting troops and up to 50 supplementary water bombing and support aircraft and helicopters before our seeding aircraft was brought in. On this second occasion only the seeding aircraft was needed to extinguish them.

Once again the same cloud reaction was observed, growth, increased internal cloud turbulence, followed by heavy rainfall.

The WEATHERCORD process was exhibited in Washington at the First International Water for Peace Conference, May 1967, by WECOA, which was the only professional cloud organization at the Conference. President Johnson announced his support of weather modification operations as a proper field for foreign aid in his opening address to the Conference. Intense interest in WEATHERCORD was expressed by water resource experts from all parts of the world.

Subsequent to this meeting, a contract was negotiated in August, 1967 with the Imperial Government of Iran, for a major three year seeding project on the three major watersheds in the Elburz Mountains in northern Iran. These watersheds furnish hydro-electric power to industry in northern Iran, as well as water for irrigation, and for municipal water supply to Tehran itself.

The WEATHERCORD seedings in Iran were completed on April 30th, for the first Phase of the three year contract, and will be resumed in November, 1968. Although at the beginning of the operation the water levels were low in all reservoirs (a six year drought was still in progress); on April 30th all three reservoirs were full or spilling, the water supplies on hand insure a record harvest, and even the desert agriculture surrounding the target area is green and flourishing. Detailed evaluation of the results is continuing.

Here again, the reaction of these middle eastern weather systems to the WEATHERCORD seeding has been startling—intensification of the cloud systems, increased cloud turbulence followed by heavy precipitation. It can be stated at this time that the WEATHERCORD seeding technique is apparently 100% effective. That is to say, every time the device is used on suitable super-cooled clouds, precipitation results.

The percentages increases to be realized with this technique over a whole season are being studied. Indications are that it is greatly in excess of the percentage increases already established by conventional type seeding and mentioned earlier.

The aircraft used in the Iran operation is a DC-3 with heavy engines, and high altitude capability. The aircraft operated well in the extreme turbulence and heavy icing encountered during the operations which were frequently carried out over very high mountains.

The outstanding success of these winter operations in a semi-arid region in Iran leaves no doubt in our minds as to the suitability of WEATHERCORD type operations for the upper Colorado for the purpose of increasing water supplies there, and we are pleased to present this testimony to the hearings on S. 2058 and S. 373. Thank you.

Senator CANNON. The hearing will come to order.

The next witness will be Dr. A. R. Chamberlain, executive vice president of Colorado State University. Doctor, we are happy to have you here.

**STATEMENT BY DR. A. R. CHAMBERLAIN, EXECUTIVE VICE
PRESIDENT OF COLORADO STATE UNIVERSITY**

Dr. CHAMBERLAIN. Thank you, sir.

Senator CANNON. You may proceed.

Dr. CHAMBERLAIN. Senator Cannon, my name is A. R. Chamberlain. I am executive vice president of Colorado State University in Fort Collins Colo. I am privileged to speak to you on the relationship of university research and field operations in weather modification as related to S. 2058 and S. 373. Efforts at beneficial modification of the atmosphere by man are still in an early state of development. Frequent inaccuracies in weather forecasting attest to the lack of definition for the varied and complex processes in the actions in the atmosphere. Large-scale air circulation and modification over the globe serves as a dominant role in the distribution and transport of atmospheric water resources. Despite the dominant role of the large-scale air moisture circulation, its modification is essentially not considered in contemporaneous weather modification attempts. The inability to incorporate this large-scale dominant factor places a severe restriction on local scale attempts at cloud modification; and local in the scale context of the atmosphere includes areas as large as whole river basins, such as the drainage of the upper Colorado River.

There are also many smaller scale restrictions on successful precipitation modification. These are the ones, frequently on the scale of an individual cloud, that have received primary attention during the past quarter century when concentrated efforts have been made to exert some control on precipitation. One of the basic achievements arising from studies of individual clouds during the past couple decades has been the confirmation that the smaller scale processes do play a role in determining the precipitation efficiency of a cloud system. It must always be emphasized, however, that the large-scale control of the atmosphere still provides the dominant control. This is one way of saying "we can't induce additional precipitation from a clear sky"; and the clear sky is controlled by the large-scale atmospheric circulation. This could just as well be stated: "We can't induce additional precipitation from clear skies or from many types of clouds." It is obvious that some clouds are too shallow or too short lived to form precipitation. There are many other less obvious reasons why some clouds are not suitable for beneficial precipitation modification. One of these, of course, is that some clouds will precipitate naturally at near optimum physical efficiency. We are still far short of being able to understand or describe nature's needs for modification assistance to enhance precipitation. This includes having the ability to specify when clouds can beneficially be altered and to distinguish these from situations when seeding efforts would be detrimental. The university can certainly play a role in this developing technology.

Cloud modification, and the formation of precipitation, has been clearly demonstrated in laboratories and under specialized field condi-

tions. This has established the basis for weather modification efforts in the field, but does not in itself provide the know-how for consistent and beneficial modification under the diverse weather situations experienced in the atmosphere.

As might be expected, and has been dramatically demonstrated by the Colorado State University research program near Climax, Colo., modification of cloud systems can have diverse effects ranging all the way from large precipitation increases of the order of 100 percent, through situations with no effect, to cases with substantial reductions in precipitation. The approach to field operations of weather modification, as is amply demonstrated in the logs of seeding operators, has been to seed essentially all natural cloud and precipitation situations and hope that there is more benefit than harm.

Evaluation evidence suggests that fortunately in a few projects this has been the case. Judging from the large number of commercial projects that have not been continued once started, one would conclude that results in many cases have not been promising enough for continuation.

The establishment of adequate criteria for planning and implementation of reasonably financially and operationally efficient weather modification operational programs requires some additional basic research studies, but primarily involves technological developments. It is a long way from demonstrating cloud modification in the laboratory, or in a certain natural cloud, to being able to constantly achieve beneficial modification in the atmosphere over large river basins.

Progress has been rapid, and almost spectacular, during the last few years. This has been possible because of the increased governmental support, largely to universities, primarily by the National Science Foundation and the Bureau of Reclamation. Other agencies participating include the Department of Agriculture, Department of Defense, Department of Commerce, and others.

Unresolved scientific areas still exist. Many of these are important to full understanding of the processes involved and an ultimate development of the potential; but are not critical to early, routine implementation of efforts for operational weather modification. Some unresolved problem areas are vital to adequate field operations and it is my understanding that these are receiving expanding attention at the present time. These critical areas include:

1. The development of an adequate model of natural cloud processes and the effects of seeding specifically defined clouds are necessary to be able to delineate weather situations that should or should not be seeded. These models should also provide at least basic information as to the seeding procedures that should then be followed for the differing situations. The development and verification of such models are well along at CSU in connection with the research underway in the upper Colorado River at Climax. These developing models describe the weather situations that should be seeded and provide at least basic information as to how seeding procedures should vary from one subbasin to another.

2. A second area critical to development of routine field operational programs is improved knowledge of the movement of the seeding materials into the cloud systems. This has been a very deficient aspect of operational programs in which substantial progress is now

being made. Some of this progress is being made at the universities, such as the work at our university, and the fine work being done at the University of Wyoming, as two specific examples. Important work concerned with the transport of seeding materials is also being carried out by private companies, such as E.G.G., North American Weather Consultants, Atmospheric, Inc., and others.

Senator DOMINICK. Mr. Chairman, I wonder if I could interrupt for just a moment. I know very well that Dr. Chamberlain is doing a very great job up at Colorado State University and I congratulate him. I have no intention in any bill to ever cut down on the research that we are going to need for a long period of time. However, unfortunately, I have to leave right now and I wish I could stay. But I have here a statement from the chairman of the board of directors of the Federation of Rocky Mountain States; namely, Governor Hathaway of the State of Wyoming, that I would like to have included in the record.

Senator CANNON. Fine. It will be incorporated.¹

Senator DOMINICK. And I hope that you will give my apologies to Dr. Krick, whom I see is now coming into the room. I have got to leave right now. I appreciate your coming and taking care of this hearing for us. I hope it will do some good.

Senator CANNON. Thank you.

Dr. CHAMBERLAIN. No. 3, a third critical area involves the design of operational field programs that can—

(a) Provide adequate control for the operations to permit maximum incorporation of contemporary scientific knowledge to maximize return and to minimize undesirable effects to other areas;

(b) Provide for monitoring all field results, good and bad; and

(c) Allow for further learning as the field operation continues.

This requires careful coordination of the operational program with additional necessary research that must be carried out in the field. It requires close cooperation between the university, private firm, and governmental personnel, all of whom need to be involved.

As mentioned earlier, it appears that resolution of these critical areas is advancing rapidly and specifically for the region of the Upper Colorado River Basin that provides water supplies for much of the Southwestern United States. At least some of the indicated solutions are probably unique to this area. They consequently represent a return for the effort specific to this basin. The results do not seem fully transferable to other regions of the Nation.

University groups have played a definite role in the developing fields of cloud physics and weather modification. This is true of the universities in the Rocky Mountain area and includes work at Colorado State University. The universities in the Rocky Mountain area are also playing an important role in investigations that are directly concerned with the local aspects of cloud systems and seeding problem in this area.

There is considerable pressure on the part of governmental agencies and from public opinion to obtain a solution to the increasing need for additional water. The developing technology, to an extent probably even greater than in many other fields, requires the coordinated

¹The letter referred to appears on p. 118.

efforts of theoreticians in the fields of chemistry and physics, field mechanics, mathematics, engineering, and so forth, as well as in meteorology.

The university offers unique opportunities in that experts in these many contributing fields are available for assistance. For example, in addition to atmospheric science department staff at CSU, we have professional people from the civil engineering, mechanical engineering, mathematics, physics, chemistry, economics, and watershed management programs directing their primary research activities to problems of weather modification. This even extends to the administration level since I have personally become actively involved in problems relating to weather modification. At some universities, Colorado State University being an example, there are experts available in the diverse fields of atmospheric science itself. These areas include dynamics of the atmosphere, hemispheric circulation, radiation, climatology, et cetera, of which all relate to the specific problems of cloud and weather modification. The talents of such diverse specialists could hardly be collected and their efforts directed to a specific problem in any other group except an extensive and very expensive task force effort. Most of the specialists at the university are already available and only the direction of their efforts to the specific problem set forth by the public policy bodies such as the Congress is required.

Some specialized researchers are, of course, necessary to coordinate and direct the overall effort to the critical problems. Much of the current progress now being made is possible as a result of problem orientation that has been provided by these individuals in the past. Our efforts at CSU include research on such basic topics as the microchemistry and physics of nucleation and such applied topics as generator development.

To this point I have primarily emphasized what I believe to be the vital role of the university in developing weather modification technology. I would like to state just as clearly the partnership role that I see for the private industry sector in weather modification, particularly now that some operational field programs appear to be more feasible.

Operational field programs of weather modification clearly are not in the realm of interest of the university, and in my opinion properly belong with the private industry sector of our economy. This should extend not only to operational programs to systematically attempt to beneficially modify clouds, but to the actual mechanics of carrying out large field research programs as are necessary. Field research problems and programs can in most cases clearly be defined and designed by university researchers, frequently in coordination with other specialists. The university is generally not the most satisfactory organizational framework for conducting the field operational work. In the CSU project at Climax, for example, private contractors are used to conduct the operations and all field activities except specialized research studies. This frees university staff to concentrate on basic scientific and engineering problems and the analysis of data; clearly a better utilization of their efforts. May I emphasize—much of the work in weather modification requires the partnership of private industry and university personnel, working under a framework of governmental public policy.

Private industry also has a role in research and development. The private groups must have competent staff to properly carry out operational programs, with sufficient scientific knowledge to make good decisions when problems arise on short notice in the field. These competent individuals will certainly be motivated to feed their field experience back into developing research programs, pointing the way for further university research that is needed by field personnel. In most cases they will want to also relate this to the broader research programs that are underway at the universities. The university as its part should have as one of its basic objectives the training of competent people interested in going into private industry.

In summary, we appear to be rapidly reaching the point where operational field programs of weather modification can be consistently feasible in some regions of our country. There are still several important unresolved problems in vital problem areas that restrict present operational efforts. Early solution to some of the critical problems appears probable as a result of the expanding efforts, primarily at the universities. Many vital basic problems will still remain for consistent improvement in the technology.

Let me now summarize, the most efficient, economic and rapid development of weather modification for the direct benefit of society can come from the circle of effort that includes:

- (1) Research, primarily by university faculty
- (2) Development, primarily by university, Government and private industry staff
- (3) Field operations, primarily by private industry
- (4) Evaluation, primarily by university and governmental personnel
- (5) New research needs uncovered by the above.

The university provides unique opportunities for conducting research, development, and design of field programs in a manner that will also permit effective evaluation. The field programs should be conducted by private groups. Such a circle of effort can provide for the most rapid development of our atmospheric water resources. It will provide means to get the most return for the tax dollars invested.

Success in the early and efficient development of weather modification for fulfillment of public policy goals requires a close partnership of—

- (1) Government—to delineate critical areas of public need and to encourage progress through financial support not available on the local level;
- (2) The university—to lend intellectual guidance to the solution of the physical and technological problems; and
- (3) Private enterprise—to get the field operations job done in an efficient and economic manner.

At this point, with your permission, I would like to insert some specific points regarding the two bills in question as to relatively minor modifications that perhaps would enhance the effectiveness of the legislation.

Senator CANNON. Fine.

Dr. CHAMBERLAIN. In regard to S. 2058, there is a section referring to the membership of a Council and calling for four members. I would like to suggest that (a) though perhaps minor but very significant

modification, the membership of this Council would be to include one or more users of water. The present membership does not provide for representation such as that drawn from some of the major conservancy districts or the major agricultural organizations or the municipal organizations that might be the beneficiary of the water; (b) I would like to suggest that the specific ratio of research to operational dollars be deleted and let that be a matter of Executive decision under the guidance of the Council that the bill calls for establishing. I would like, not in the context of the language itself, but in terms of the significance of the legislation under S. 2058 and also under S. 373 to express concern that we design field programs very carefully for selected areas rather than just a general seeding over large areas, and that the actual operation be carefully monitored and operated in order that we not seed when it might be detrimental to the interest involved.

To illustrate, it would be very detrimental to the tourist industry of Colorado, as an example, to seed continuously and find that you had actually been seeding cloud situations that resulted in decreased snow at the crucial time when the ski resorts are in operation.

In broader context, the last winter problem for the Indians in the Utah, New Mexico, Arizona, and Colorado areas certainly indicates that some of the work in regard to redistribution of precipitation could be crucially important.

So there are problems other than those solely of trying to increase precipitation in the Upper Colorado River Basin that are of importance to us.

In regard to the language in S. 373, you have already heard this morning's testimony regarding the dropping of the authority of the National Science Foundation to call for reports from private operators. I expressed grave concern that there be a specific provision designating some agency of the Federal Government to have the authority to continue to call for such reporting to be made. I further would ask that that authority specify that in addition to receiving the reports that a job of analysis be completed, which as I understand it, has not been adequately done up to this time by the agency presently responsible. But the most important point is that some agency of the Federal Government really should have the authority to continue to call for the reporting of any contemplated field operations.

I would like in regard to the bills to tie back to some early work in which I participated on behalf of the National Science Foundation Commission on Weather Modification.

That Commission report made a substantial point of wanting to see a much enhanced program on the legal, ecological, social, and economical aspects of weather modification. I notice that S. 373 particularly, and to a lesser extent, S. 2058 makes note of this particular need. I feel, however—and it is corroborated by the testimony this morning—that there is still inadequate national attention being given to the buildup of intellectual capability and program effort in this area of legal, ecological, social, and economical aspects of weather modification. On the other side of the coin, however, I do feel that the progress during the last 2 years is very encouraging. The number of intellectual investigations underway, both within Government organizations such as ESSA, Interior and certain university efforts in these areas are encouraging and do portend that given emphasis in

the legislation and emphasis by the executive departments we can see a better measure in the areas ahead to the level of need for this legal, ecological, social, and economic research.

Within our own State there is a related program underway, recently authorized, that is the grasslands ecological study to take place in northeastern Colorado. This is being sponsored under the auspices of the international biological program, and specifically the U.S. portion of it. We feel particularly pleased that Colorado State University is going to have the responsibility for the regional leadership of this grasslands ecological study and expect to coordinate it quite closely with the intensive weather modification research that is underway in the same area.

To illustrate the values of coordination of effort, I have mentioned this particular major ecological study, but also I would like to draw your attention to the efforts in this region by the universities and particularly my own, Colorado State University, as typical of the interest of the State as well as the Federal Government in broad program effort. We want work to be done in weather modification. Our program supplementing all of our graduate education research, of course, in weather modification now totals some \$975,000, very modest when weighed up against the dollar figures mentioned by some of the prior testimony this morning. But so far as university programs in weather modification are concerned, it is quite substantial. But this \$975,000 program includes some \$100,000 of State of Colorado money. It is a measure of the interest of the State of Colorado in university research in support of weather modification development. The program also includes some \$275,000 of Department of Interior money, and it includes some \$600,000 of National Science Foundation money. These efforts then called for, as far as we see it, pluralistic financial support by the Congress to the several agencies of the Federal Government. And we want you to rest assured that the State of Colorado is extremely appreciative of the effort of the Congress in making money available.

What kind of work is done with this kind of money within the university setting that perhaps is of direct value to such programs as those envisioned in S. 2058 and S. 373? Let me just illustrate some topics:

1. Physical and statistical study of Rocky Mountain clouds and precipitation in their modification;
2. Surface properties of heterogeneous nuclei;
3. Joint hail suppression research program in northeastern Colorado.

And I believe you are aware that northeastern Colorado has probably the highest incidence of hail of any area in the United States.

4. The design of descriptive and theoretical cloud models and associated hail suppression experiments on the high plains;
5. Design for operational adaptation programs for the Colorado River Basin. This is supported by the Bureau of Reclamation and ties very specifically to background work necessary to apply research results to field operations of weather modification for precipitation augmentation in the Upper Colorado River Basin.

6. Diffusion and transport of seeding material, a subject referred to by several of your people presenting testimony this morning;

7. The design and evaluation of ice nuclei generation devices. Here our effort has a somewhat unique nearby national laboratory so far as the significance is concerned for the evaluation of nuclei generation devices.

8. The evaluation of ice nuclei dispersion systems related to our previous one;

9. The determination of atmospheric silver by atomic spectroscopy on the hydrologic aspects of weather modification.

Senator CANNON, the testimony which I have presented, I hope, emphasizes two things:

1. That progress in weather modification is sufficiently far advanced that the research efforts can well be coordinated effectively with specific planning for field operational work, at least under the atmospheric circumstances that seem to prevail in the Upper Colorado River Basin; and

2. That the best progress for the future requires public policy and public support, such that we can have an intensive partnership program of governmental, university, and private industrial enterprise for the years ahead.

Senator CANNON. Thank you very much for your very fine statement. The committee will consider your recommendations as to the proposed amendments of the bill.

The next witness is Dr. Irving Krick, president of Irving Krick Associates. Dr. Krick.

STATEMENT BY DR. IRVING P. KRICK, PRESIDENT, IRVING KRICK ASSOCIATES

Dr. KRICK. Senator Cannon, ladies and gentlemen, we have entered on behalf of our companies a written report, and rather than read that full report, I would like to read a summary statement which I will also enter for the record, if I may.

Senator CANNON. Your full statement will be made a part of the record, and if you will summarize, that will be very fine.

Dr. KRICK. Yes, sir. I will simply make a summary statement as follows:

We began our investigations in weather modification at the California Institute of Technology in 1946, following the General Electric discovery that certain nucleans could be dispersed into the atmosphere to stimulate precipitation. By 1949 we had conducted fieldwork combining research and actual operations for the Salt River Valley River Users' Association in Arizona, and we found substantial evidence that precipitation and resultant streamflow could be increased through these operations. That gave us our first interest in broadening the scope of our operations, so that ultimately we might engage in work on the Colorado River, which was so important to our own State of California and to the other upper and lower basin States.

We were invited by the Denver Water Board in 1950 to begin experimentation in this area of Colorado, to see what could be done to augment snowpack in the Colorado Rockies. We have continued now for 18 consecutive years to operate winter programs for snowpack in portions of the Rocky Mountains in Colorado.

Following our early research in 1947 and 1948 we withdrew from the California Institute of Technology to broaden the scope of our operation. We formed a nonprofit research foundation to conduct the research aspects of our work called the American Institute of Aerological Research, in which the quality of nucleans, their reaction in the atmosphere, dispersion and diffusion patterns, were studied. Proper concentrations of materials were used for use under various storm conditions, and basically the type of thing that is still being investigated by those that have recently entered the field.

In addition to our research organization, we formed a number of corporations in the United States and abroad to carry on field operations, and my summary statement will simply be a review of our actual field operations to give you an idea of the scope of the work in the past 18 years in the full spectrum of climatic areas throughout the world. Gentlemen, consider the following:

1. Our group has been engaged in actual weather modification research and program servicing since 1946, over 20 years of time;
2. We were convinced man could increase the streamflow of the Colorado River Basin as early as 1949;
3. We have operated programs of weather modification in 30 States of the United States, seven Provinces of Canada, Mexico, Central America, the West Indies, Spain, France, the French Alps, Italy, Sardinia, Israel, Syria, Algeria, and the Congo;
4. We have conducted actual projects designed to increase streamflow and resultant storage into catchments within the following areas:

In the United States: California, Oregon, Washington, Idaho, Montana, Arizona, Texas, Colorado, Wyoming, Nebraska, Kansas, Oklahoma, Louisiana, Arkansas, Missouri, Michigan, and North Carolina; in foreign areas: Canadian Provinces of British Columbia, Ontario, Quebec; Spain, France, the Alps, Italy, Sardinia, and the Congo.

Some projects covered river basins ranging from a minor size to and including the 32-million-acre drainage basin of the Columbia River. We have experience of 18 years in snowpack operations within the Colorado Rockies;

5. Our group has operated the longest consecutively sustained weather modification operations for agriculture in the States of Washington and Oregon. If you would consolidate the time sequence of our four projects in these areas, with a commencement date of 1950 to now, it would amount to a timespan covering 50 years. It is important to note that all four projects are in a very similar, a homogenous climatic structure;

6. Based upon our background of experience and actual operations of generators, which now exceeds 2 million hours of generator time, it is our opinion:

(a) That estimates of increasing the streamflow in the Colorado River Basin by 10 and 20 percent are conservative estimates;

(b) That no further time be lost in implementing such a program;

(c) That the program be established for at least 10 years;

(d) That the program be operative within the framework of a long-range weather/streamflow forecast. I refer to ex-

planation relative to this statement contained in our detailed report. We believe that all weather modification operations of any duration should be conducted and planned within the framework of ultra-long-range weather prediction, which we now have been able to establish on a routine basis commercially for power interests up to periods of 5 years;

(e) That current and continuing evaluation of results be maintained and progress reports issued at intermittent periods;

(f) That the so-called private operator be given a part in the performance of such contemplated programs.

7. It is our basic opinion that the results achieved in a program of weather modification are directly related to:

(a) The financing of the project;

(b) The skill of the operator;

(c) The generating equipment and potency of particles dispersed;

(d) The individual characteristics of the weather regime being influenced.

I wish to thank Senator Cannon for the opportunity to present our portion of the information, and we appreciate the depth of interest expressed by these Senate committee members in attempting to apply all scientific means available to augment the flow of the Colorado River.

I have one other short statement which is not directly related to the Colorado River problem, but which we feel is interesting and perhaps important. And this is a summary review comparing the results in Russia as published by the Russians on hail reduction as compared to those that we have achieved over a 12-year span in the areas of Alberta, east of Calgary, which are reputed to be probably the worst in the world, even more extreme than here in eastern Colorado, where we conducted early research on hail suppression back in the 1951 and 1952 intervals. It is interesting to note that the Russians have achieved essentially the same results over a 2-year period, which they feel was a realistic period, of appraisal of operations. We've gone on, however, for 12 years, and the results are rather interesting. I'll just read the summary of comparisons.

The project area in Canada comprises 2,400,000 acres; in Russia, 1,200,000 acres. Hail incidence prior to hail suppression in Canada, one of the three worst in the world; in Russia, a less severe area than the Alberta target. This is an opinion based upon a study of the report. The experimental period, in other words, the one used for refining techniques for hail suppression, our period covered 1956 to 1959. In other words, we were in the process of developing effective operating techniques during that period. In Russia their period was 1956 to 1963, 8 years. The operational period in our case was 1960 through 1967, 8 years; in Russia, 1964-65, a 2-year period.

The agent used in our case was silver iodide for dispersal of the hail-producing clouds; in Russia it was lead iodide.

The delivery system in our case was ground-based equipment and aircraft. The Russians used antiaircraft artillery guns. The amount of seeding agent used for severe hail threats: We used over a thousand grams per hour from ground generators and aircraft (average drain 6- to 9-hour interval). In Russia, their early tests, they used 500 grams

which they thought necessary to seed one cubic kilometer of hail cell centers.

Further tests proved that the desired modification could be accomplished with 20 grams, which amounts to about 450 to a thousand grams per hour, which is similar to our release.

Seeding principles: We seeded the total air mass before entering the protected area to decrease the degree of supercold moisture. Aircraft line seeding is used to introduce high concentrations of silver iodide in the cloud-breeding area prior to any cloud development, continuing line and cell seeding on approach to target as well as seeding across protected area.

In Russia, after hail is detected over target on radar, 80 grams of lead iodide is fired into the hail center of the cloud. They must reach this point in the cloud in 2 or 3 minutes after first detection on radar.

Protected area of reduction and hail damage: During the last 2 years in Canada, to make it comparable to Russia—and this is the meat of the coconut—the hail reduction in 1966 and 1967 is 80 percent in Canada; 83 percent in 1964 and 1965 in Russia.

Unprotected area hail damage change in the last 2 years; in other words, outside the target area: The hail has been somewhat more intense in Canada than normal, based on a 40-year record. And in Russia it was also more intense than normal, based on a 5-year record.

Now, protected area of long period reduction. In other words, if we take a 7-year running mean in our project in Canada, from 1961 through 1967, the hail reduction averaged 71 percent. Our 88 percent during the last 2 years of operation showed that we had increased our efficiency. In Russia, only the 1964–65 results were available, which I read a moment ago, 83 percent.

Now, the method of evaluation is interesting, because we both used the same method. In Canada we used hail and insurance data, hail reports from farmers which are collected by the Albert Hail Research Organization, which is Government sponsored, and physical and meteorological data. In Russia they used hail insurance; in other words, hail loss data inside and outside the target areas, both before and after any protection was given. They also used physical and meteorological data and an inspection of areas by hail-control groups. In other words, their method of assessment is about the same as ours. And they received reports of our method which we introduced in 1960, and we suspect that they felt it of enough value so that their method of evaluation for 1964–65 more or less paralleled what we had developed in Canada by 1960.

Now, the historical hail insurance data record is interesting. Before hail suppression operational programs in Canada, we had 40 years of this loss to risk data; whereas in Russia they only had 5 years. Although it's not definite as to the length of time of the record used, 4 or 5 years were used.

Now, evaluation results: Great reduction in hail damage insurance payments on protected cropland in comparison to unprotected cropland. And in Russia it was the same as it was in Alberta. So this means that one of the most violent products of nature, severe hail—and in Alberta these hailstones are of cantaloup and basketball size on occasion, which kill cattle—have now been suppressed to a point where insurance data shows a significant reduction. And we are enter-

ing a whole new era in hail insurance. Insurance companies are becoming interested in the possibility of reducing premiums in areas that are protected by a program that has shown such demonstrable results.

We find that we have been able to develop in our cloud-seeding programs for streamflow and for filling reservoirs and in agricultural areas, due to the evaluation techniques that have been developed over the years, that we are now in a position to make guarantees of certain results which might be achieved. And I have had correspondence with Senator Dominick in connection with the Colorado River based on our studies and those of others which are contained in the overall report, indicating that we can guarantee over a 10-year period an average increase in streamflow, say, measured at a place like Lee's Ferry, of a million and a half acre-feet per annum. Now, that means that it might be less in dry years and more in wet years, and we feel that this is a conservative estimate, that's why we feel that it's a thing that could be guaranteed. We also feel that it is possible to operate a program effectively within the framework of 5-year forecasts of the streamflow within the river. And there is an example given in our report of a 5-year streamflow forecast verification in a very anomalous period for a number of river basins, including the Columbia, subscribed to by a power group in the Pacific Northwest to verify the validity of this sort of work.

Now, we have made a cost estimate indicating that on the basis of an increase of a million and a half acre-feet of water a year, operating primarily in the Upper Colorado River Basin, we could produce such a program at approximately 50 cents per acre-foot, which would mean something under a million dollars a year, including the evaluation effort and also the forecast of streamflow to be anticipated so that management decisions on the operation of a river basin of this kind, from all the economic aspects, flood control, and so on, could be anticipated.

I believe that summarizes basically what I wanted to state. I know you are running late and I don't want to hang over too long, but if there are any questions that the Senator would care to ask, I would be very happy to try to answer them.

Senator CANNON. Thank you, Doctor, for your very fine statement and summary. I will look forward to going through your statement in detail. It was quite interesting to hear those comparisons that you gave. I appreciate very much your appearing here. You are the concluding witness. So with that, the hearing will be adjourned at this time. The hearing will resume at 10 a.m. Monday morning in Reno, Nev., our next series of hearings.

(The hearing was recessed at 12:35.)

(Dr. Krick's prepared statement follows:)

THE COMBINED STATEMENT OF AMERICAN INSTITUTE OF AEROLOGICAL RESEARCH, WATER RESOURCES DEVELOPMENT CORPORATION, IRVING P. KRICK ASSOCIATES, INC., IRVING P. KRICK, INC., OF TEXAS; PRESENTED BY IRVING P. KRICK, PH. D., PRESIDENT

INTRODUCTION

Mr. Chairman and members of this Senate Committee, it is with deep gratitude that I accepted your invitation to appear and provide information relative to the vital subject of increasing the streamflow of the Colorado River Basin.

I don't intend to enter into a long dissertation nor elaborate fully on the benefits to be derived from the application of weather modification within this region

of the United States. But I should like to review briefly the position our group has maintained, since 1949, on this subject directly related to the Colorado River Basin.

It was our opinion, as early as 1949, that precipitation could be materially increased within this basin. Some of our very early field operational programs pointed out the potential. In January 1949 we announced that our weather modification program conducted to increase streamflow in the Salt and Verde River watersheds in central Arizona reflected an increase of 11,990 acre feet over what would have been anticipated. (I mention this only to get on record that our interest in cloud seeding the Colorado River area was sparked at that time).

HISTORY

We commenced our research and development in weather modification in 1946 and by 1949 were conducting field operational programs in various areas, establishing our first "so-called" commercial operations in 1950 in the wheat growing areas of the State of Washington. Such programs are even now in operation and represent the longest continuous weather modification programs for agriculture—now in the 18th year of operation.

On December 6, 1951, I addressed the Eighth Annual Meeting, Colorado River Water Users Association, stating:

"Based on our experience in increasing water supply to meet the needs of a variety of water users ranging from consumers of drinking water to vast hydro-electric installations, I can confidently state that it is possible for a program of artificial nucleation to increase the water supply of the Colorado River Basin. (This presentation, with slides, reported upon the scientific and technical aspects of how such a program should be designed and operated). It also covered another point of importance: A final factor for study grows out of the newness of cloud seeding and the amount of misunderstanding still existent concerning its potentialities and limitations. No cloud seeding operation can hope to be truly successful if there is not a conviction on the part of most of the people in the area being seeded that they benefit from cloud seeding operations. Co-ordination with local interests and proper public relations have proven to be a very important part of planning operations. In cases where the area to be seeded is not the area which will eventually receive the benefits as in the case of a snow-pack operation designed to increase streamflow that will be used a considerable distance downstream, it becomes increasingly important to have the people in the snowpack area understand that the operation will not be carried on to the point of causing damage to them. Our experience has proven that intelligent men working together in cooperation can reconcile conflicting interests and permit the attainment of maximum benefits for all."

Our interest in the Colorado River Basin did not subside, even though only a small group seemed to have an interest in such a program. In 1956 we again presented a proposal to interested citizens as follows:

"On January 12, 1956 one of the first official government endorsements of weather modification to increase precipitation was made by Senator Case of South Dakota. In the Congressional Record of that date, his statement included the following:

"The Advisory Committee of President Eisenhower on Weather Control has produced a series of statistical evaluations showing that cloud seeding does produce ascertainable and economically important results in certain circumstances, but this does not at all mean that cloud seeding will not produce important results in other circumstances . . . these results are quite important historically. They mean that the Nation has crossed an important ridge and now must consider the entire subject in a new light provided by this positive information."

The proof supplied Senator Case by the Advisory Committee on Weather Control will go a long way to convince those who have required assurance, "that the benefit of more water through weather modification operations are real and obtainable". Between 1917 and 1933 average annual runoff for the Colorado River Drainage Basin measured at Lee's Ferry was 14,800,000 acre feet. Between 1934 and 1951 it was 11,800,000 acre feet. This means a reduction of 3,000,000 acre feet per annum over a relatively short period of years. To quote from "Economic Implications of Weather Modification report on Project Two of Work Program of President Eisenhower's Advisory Committee on Weather Control:

"This would indicate that if the present weather regime continues, the potential deficit could reach as much as nine or ten million acre feet including

the million and one-half acre feet which is required to be furnished to Mexico under the Mexican treaty. It can be seen therefore that there is not enough water in the Colorado River to meet present plus future expected demand, and that additional water will have to be secured in some manner if these potential demands are to be met."

The following figures, text, and tables are quoted from a report by Consultants to the National Advisory Committee on Weather Control, Agricultural Economics, Pamphlet 60, December 1954 under title "Economic Implications of Weather Modifications":

Benefits of weather modification to power production in the Colorado River Basin by means of the rainfall-runoff relationship established between precipitation values for 83 stations in the Drainage Basin and streamflow measured at Lee's Ferry, developed by this group, increases in precipitation of 10% and 20%, would result in the following increases in flow:

"INDICATED RUNOFF AT LEES FERRY, PERCENT OF NATURAL PRECIPITATION (ACRE-FEET)

"Season	100	110	120
Dry season 1933-34.....	4,377,000	5,600,000	7,100,000
Average season 1944-45.....	11,530,000	13,800,000	16,000,000
Wet season 1951-52.....	17,300,000	20,200,000	23,000,000

The indicated increases in runoff of the Colorado River at Lee's Ferry under the assumed 10% and 20% increase in precipitation are:

Season	10-percent increase in precipitation, resultant seasonal increases		20-percent increase in precipitation, resultant seasonal increases	
	Acre-feet	Percent	Acre-feet	Percent
Dry season 1933-34.....	1,600,000	40	3,100,000	78
Average season 1944-45.....	2,270,000	20	4,570,000	40
Wet season 1951-52.....	2,900,000	17	5,700,000	33

The above tabulation indicates that in an average season, 10 and 20% increases in precipitation would apparently result in increases in seasonal runoff of the Colorado River of 20 and 40% respectively. In a dry season the apparent increases in seasonal runoff would be 40 and 78% respectively, and in a wet season 17 and 33% respectively. It will be noted that the percentage increase in runoff is greatest in the dry season.

Benefits of weather modification to agriculture in the Colorado River Drainage Basin could be sizeable. The yields of all existing and proposed water conservation works would be increased as a result of increased runoff. The amount of the increase yield of these facilities would depend upon the quantity and occurrence of the additional runoff and upon the relation of the size of the conservational facility to runoff. In the case of Lake Mead, with a useable storage capacity of over 29 million acre feet, some 240% of the average seasonal runoff at this point, the additional firm seasonal yield of water due to 10 and 20% increases in precipitation is assumed to be equal to the increase in runoff at Lee's Ferry, or 2,270,000 acre feet and 4,570,000 acre feet, respectively. In addition to producing hydroelectric power at Boulder, Davis and Parker Dams, this water is available for diversion to agricultural, urban or industrial uses.

There is little dry land farming in the Upper Colorado River Basin; however, livestock and livestock products accounted for about 50% of the total value of agricultural production in the Basin in 1940, indicating the importance of the vast areas of grazing land. Census figures for the Upper Basin indicate that in 1940 there were approximately 2,000,000 head of livestock. There are also about 50,000,000 acres of grazing land in the Upper Basin. If as a highly simplified assumption, it can be assumed that, during a six month grazing season,

this grazing land therefore has an annual carrying capacity of one-quarter animal unit per month, the total increase in grazing land yield due to increase in precipitation can be estimated.

One animal unit month is equivalent to about four-tenths ton of alfalfa hay, and if hay is valued at \$25 a ton, the one quarter animal unit month is equivalent to \$2.50 per acre in feed value. It is believed that the carrying capacity of this grazing land would be increased proportionately to an increase in precipitation. Therefore, the total annual increase in grazing land yield would amount to \$12,500,000 and \$25,000,000 per year for increases in precipitation of 10 and 20% respectively. Total annual costs of a weather modification program to increase precipitation upon the Colorado River Basin above Lee's Ferry are estimated at \$1,000,000 annually.

(Note the foregoing information was presented in December 1954, we included this in a proposal to cloud seed the entire Basin in February 1956). At that time we were presenting not speculative thoughts but data based upon concluded weather modification operations of practical field experience exceeding 500,000 hours of generator operations within 24 states and 10 foreign countries. It included specific operations directly for runoff and streamflow for all but one of the tributaries to the Columbia River above Grand Coulee, Rio Alberche River in Spain, the upper watershed of the Isere River in France and several other U.S. and Canadian private power interests.

Early in the development of this new science we realized the importance of integrating long range weather forecasts into the operational program of weather modification. It is our opinion that all future long term projects of weather modification will require such long range weather forecasts. This is especially so where one is concerned with operations within major drainage areas such as the Colorado River Basin. It is highly important to have advance knowledge of weather events prior to influencing by exerting weather modification techniques.

There is also another reason why long range weather forecasts become important. The large variations observed in seasonal and monthly distribution of the annual runoff in most river basins poses a major problem in the operation of hydroelectric power systems, flood control and irrigation. On December 4, 1958 I presented a paper "A Physical Basis for Dependable Annual Streamflow Forecasts" to the Colorado River Water Users Association on this particular subject. We have been and are currently preparing *5 years in advance* weather/streamflow forecasts for major water basins in the Pacific Northwest, including the Columbia River. An unsolicited verification of such a forecast prepared *in 1961* for the water year *1 October 1966 through 31 March 1967* is as follows:

1,000 acre-feet	Actual	Krick estimate	Difference, actual estimate (percent)	Median	Difference, actual media (percent)
Lewis River, Ariel.....	2,339	2,343	-0.3	1,956	+16.4
Umpqua River, Elkton.....	4,005	4,159	-3.8	3,381	+15.6
Rogue River, Raygold.....	1,273	1,262	+0.8	996	+21.8
Klamath Lake inflow.....	785	785	+3.5	639	+20.2
Columbia River, Grand Coulee.	17,349	16,895	+2.6	14,699	+15.3

This client needed to know if they would encounter critical low water levels. This weather/streamflow prediction was of particular significance to the client because flows had been depleted from dry weather in the spring and summer of 1966 and they were facing a critical power shortage in the fall of 1966 had not the above median flows anticipated from the forecast occurred on schedule.

It is most important to note this long range, 5 year in advance forecast, was reflecting major departures from the Median—and that such departures did actually occur.

An examination of some streamflow figures for the Colorado River Basin will point out the wide fluctuations that do occur and help evaluate the usage of 5 year in advance weather/streamflow forecasts:

Station: Lee's Ferry, Arizona

	Acre-feet
15-year average-----	12, 657, 000
Lowest (1934)-----	4, 377, 000
Highest (1917)-----	21, 860, 000
Water year flows of previous years :	
1956-57 -----	17, 326, 000
1955-56 -----	8, 740, 000
1954-55 -----	7, 590, 000
1953-54 -----	6, 101, 000
1952-53 -----	8, 787, 000
1951-52 -----	17, 960, 000
1950-51 -----	9, 817, 000

It is quite simple to perceive how a reasonably accurate long range weather/streamflow forecast could aid in the management of the overall complexities of this variable water basin.

To focus attention upon the importance of considering the part of long range weather forecasting within future major water basin projects, I testified before the Subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives 85th Congress, Second Session on Bill S. 86, March 18 and 19, 1958 as follows :

"THE USE OF HIGH-SPEED ELECTRONIC COMPUTERS FOR LONG-RANGE WEATHER
FORECASTING AND CLOUD-SEEDING EVALUATION"

"Weather Problems for Electronic Computers"

"Two items of continuing interest, both in scientific journals and to the public during the past several years, are the development of electronic computers and advances in weather knowledge, both from the standpoint of forecasting and modification. Many of the weather problems being solved today by electronic computers were well beyond the scope of human undertaking just a few years ago.

"Meteorology deals with the atmosphere. The atmosphere is constantly in motion; it is compressible; it is made up of many gases, of which one at least, water vapor, is continually varying both in amount and change of state. The atmosphere is constantly subjected to differential heating on both large and small scales. Thus its behavior pattern is a complex thing.

"Practically all human activities are dependent on the weather. So despite its complexity, we try to solve the problem of forecasting events which are taking place in the atmosphere. The human mind is incapable of unraveling its mysteries without the aid of devices such as these new electronic computers.

"In addition, we are finding ways to exploit the rainfall potential of the atmosphere and to otherwise modify the weather. Electronic computers are aiding in the assessments of results.

"The preparation of weather forecasts for extended periods"

"What is an expert weather forecaster? He is a man who has vast experience in determining common, or infrequent, weather developments in the atmosphere. He does this from his background in watching previous but similar developments.

"Unlike many finds in the field of astronomy, the forecast was not arrived at by computations. He can draw conclusions from previous similar developments because weather tends to repeat itself. This, of course, is stating the situation in the simplest of terms.

"The atmosphere is affected by many complex wave-length movements similar to the waves and tides of the ocean. The disturbances travel around the earth from west to east in rhythmic patterns and obey natural laws. Many of these wave streams were set in motion millions of years ago. Some are being set in motion in a systematic fashion even today. Since they follow an ordered behavior pattern somewhat like the tides, although much more complex, they must be predictable.

"As early as the thirties it was apparent to our group working at Cal-Tech that these atmospheric waves produced specific patterns of weather in relation to the distribution of the continents and oceans and certain broad-scale features of the atmospheric wind systems.

"Our weather today is a function of the weather that has gone before, and of the current forces acting on the atmosphere, so that given sufficient past data and a method of determining any systematic recurrences in the pressure waves in the atmosphere, forecasts for days, years, or even centuries, are feasible.

"In the work at Cal-Tech in the thirties, 6-day sequential patterns of pressure-wave systems and their associated weather were discovered and carefully defined. Frequently, and sometimes for several months, these patterns would follow in a systematic progression so that reliable forecasts could be made from 6 days up to sometimes several months in advance.

"The real limitation to further development, however, came about as the result of drastic transitions between weather patterns caused by complex wave systems which could not be foreseen.

"Methods of forecasting these transitions from one weather pattern to another have been studied during the past 20 years. Now, at last, we have sufficient data punched onto cards for use by the electronic computer so that we can process it rapidly enough to produce dependable predictions before the weather outruns the calendar.

"We now have 20 years of appropriate data on cards. The Remington Rand Univac is used in processing these data. This unit is capable of producing day-by-day forecasts for periods several times the length of the data record.

"Weather-modification evaluation

"Along with new developments in long-range forecasting, the most significant advances in meteorology in the past decade are being made in the field of weather modification.

"Langmuir and Schaefer in 1946 discovered that supercooled clouds could be crystallized by introducing artificial nuclei composed of substances which stimulate the process more effectively than natural nuclei. Since that time, developments in cloud physics have progressed rapidly and the science of weather modification has evolved to a completely practical stage.

"A discussion of weather modification, along with long-range forecasting, may seem to be covering a diversity of subjects in such a short paper. However, they are closely related.

"The primary problem in long-range forecasting is to know what the pattern of weather will be so that human affairs can be related to it.

"Perhaps the major problem in the field of weather modification has been evaluation of results. This is basically a function of what the weather would have been without cloud seeding so that variations caused by weather modification can be determined.

"In the final analysis, if one can accurately determine upcoming weather and superimpose changes possible through weather modification, activities involving agriculture, hydroelectric operations, the impact of drought, can all be planned realistically and effectively.

"Regardless of the technique used, the essential consideration in evaluation of weather modification involves an estimate of what the precipitation would have been had weather modification activities not been carried out as a basis for comparison with measured precipitation.

"Until the beginning of 1956, the public could have been forgiven for being completely confused concerning the whole issue of cloud-seeding evaluation. Findings published in cautious terms by university investigators were often misconstrued and often times given unjustifiable headlines in the press and were frequently guilty of gross oversimplification.

"Statisticians have devoted extremely large amounts of time and money on statistical evaluations. It was relatively easily determined from statistical means that overall average increases from weather-modification operations were of the order from 9 to 30 percent in the direction of an increase.

"The determination of increases from individual storms or a refinement on the average increase in various projects proved much more difficult.

"The problem was one of looking for, say, a 20-percent increase in a sample of precipitation data when natural variations from a conglomerate of weather patterns were of the order to 200 to 300 percent. The ultimate in refinement to date in this purely statistical approach has been the excellent piece of work achieved by the President's Advisory Committee on Weather Control.

"For the first time, following intensive study in the use of a statistical method that cannot be held too much in question, a quantitative measure of cloud-seeding effects was arrived at by that group for rain-increase programs conducted in

orographic conditions on the west side of continents. Average increases of 9 to 17 percent were established for a series of Pacific coast projects.

"The concentration on these west coast projects results from a consideration of the seasonal character of the precipitation patterns in that area, and that these projects have been in operation for a number of years—many since the early 1950's. Even these refined statistical techniques have been inadequate in the assessment of flatbed projects in the Central-Eastern United States.

"To overcome the inadequacies of purely statistical methods of cloud-seeding evaluation, a consideration of the elements of storms being seeded must be included. Both purely statistical and physical techniques have considerable independent value. This value, however, increases greatly when broad-scale meteorological, as well as physical, information can be integrated and treated statistically.

"The use of weather patterns as employed in the preparation of long-range forecasts when adapted to weather modification evaluation efforts, provides one of the best means of accomplishing this objective.

"As early as 1948, when our group was conducting its first studies in the field of cloud seeding, such comparisons were made. This involved determinations of the frequencies of various weather patterns and their related precipitations in a specific area.

"By studying a large number of cases for each weather pattern, various probabilities of precipitation expectancy for any case of the individual pattern were established.

"Consequently, for each weather type as it occurred a probability could be established for the occurrence of the measured amounts of precipitation. By studying these probabilities for a large number of seeded weather patterns, the deviation of the actual precipitation during cloud seeding from that which would have been expected under natural conditions over an extended period of time, was established.

"These investigations were very laborious and limited in scope due to the large amount of data analysis necessary. Now that all weather-pattern data are being placed on punched cards so that it is susceptible to analysis by electronic computers, this technique which takes full advantage of meteorological and physical considerations in a manner that can be realistically treated statistically makes possible detailed and objective evaluations of individual seeding projects.

"The following example, based on a preliminary analysis, illustrates this approach. The Water Resources Development Corporation has operated for the United States portion of the Columbia River Basin above Grand Coulee for several years. In a report of the cloudseeding potential of this area prepared before the project was undertaken, values of precipitation expected in the basin for each weather pattern were calculated. Subsequently, in the report covering operations carried out in the fall of 1951, it was determined on the basis of weather types occurring during cloudseeding, that the basin average should have been 1.34 inches between September 21 and October 1. This was nearly double the longtime average of 0.68 inches for this period.

"The longtime average, of course, is established from the precipitation from all-weather types. The actual precipitation was 1.49 inches. It can readily be seen that a consideration of the weather patterns present confirmed that precipitation should have been well above normal for the period, but still less than the actual amount recorded. Crediting the extra rainfall above that expected from the prevailing weather patterns must be considered with reservation, for a single case. Refinements, of course, can be made. To start with, many cases can be accumulated. In addition, target and control relationships can be developed, based on rainfall data for the various weather patterns.

"For the winter season, 1954-55 and 1955-56, when weather-modification operations were carried out for this same basin, the variation of actual precipitation from type expectancies has been made. This has also been done for the same period for control stations, along the Pacific coast, unaffected by cloud-seeding operations. The use of control areas can also point up trends in climatic change resulting from persistencies in the occurrence of certain weather patterns during any particular period.

"During the 1954-55, 1955-56 seasons, the United States part of the Columbia Basin received 142 percent, as much precipitation as might have been expected from the weather patterns which actually occurred during the operational periods.

"During the same interval, a group of control stations immediately along the Pacific coast which should not have been directly affected by weather modification, received 124 percent, as much precipitation as might have been expected from the patterns which did occur. There was thus an 18-percent differential in favor of the seeded area based on the normal distribution of rainfall in both target and control area for this same group of storm types. Excesses over normal expectancies in the control areas imply a climatic trend toward wetter conditions in recent years in this section of the United States.

"A similar study is underway in the Midwest. It involves a period from June 20 to October 28, 1956, during which cloud seeding was in progress in eastern Nebraska, Iowa, and Missouri. Precipitation data from North Platte, Nebraska, a station not in any weather modification project during the summer of 1956, has been reviewed in some detail. During the interval investigated, North Platte and that area of Nebraska, were affected by the following North American weather types:

	<i>Cases</i>
"Type A-----	2
Type AB-----	4
Type B-----	5
Type BA-----	2
Type B-D _n -----	2
Type BN-----	7

"From this distribution of weather patterns, North Platte could have expected 5.80 inches of rain from June 20 through October 28. This is well below the historical average of 8.17 inches of rain for this period at North Platte. However, the actual amount of 6.09 inches was not far different than the 5.80 inches which would have been expected from the weather which occurred. At Kansas City, however, the picture is much more complex. With the extreme drought through the Southwest from which airstreams reach Kansas City, the precipitation was considerably less than that which the prevailing weather patterns would have produced. The weather patterns for this period which, of course, are the same as the ones indicated above for North Platte, should have produced 14.18 inches of rain at Kansas City—again an amount less than the normal of 15.36; 10.03 inches actually occurred.

"Once again, to further focus attention upon this vital subject of weather modification, particularly for the Colorado River Basin, I appeared before the Committee on Commerce, United States Senate, 89th Congress, Second Session March 31 and April 1, 1966 and presented considerable testimony, including the following.

"Our own work during this era was probably at a maximum in the United States, because of the era of drought over the Midwest, and we had individual projects ranging from a few hundred square miles in size to one 32 million acres in size. In the 1950's we conducted weather modification over major portions of the Columbia River Basin under contract to both a U.S. Government agency and a combine of utility companies. Our operational analysis noted significant increases in precipitation and streamflow. One member of an independent U.S. Government evaluation committee stated that in his presentation our findings were conservative. We mention this to stress that in our opinion significant positive economic benefits were available from operational activities of this type, as early as 1953, for major river complexes. We believe this opinion was also shared at that time by other commercial operators. We still believe it practical and urge such programs be initiated without further time loss.

"Also our foreign operations began to take shape during this area. By 1952 and 1953 and 1954 we were operating for the Governments of Spain, France, and Israel. Their engineers had studied our reports, has visited our projects, were convinced that there was validity to what was being done, and launched on projects for agriculture and for hydroelectric.

"In France, an Alpine project for snowpack or increasing water production for hydroelectric power development was initiated. In Israel, a small country, there were agricultural projects in the semiarid areas.

"In Spain both hydroelectric and agricultural projects were pursued.

"We operated these programs under contract to the government departments involved. In Spain it was the Department of Agriculture. There were also private hydroelectric companies that contracted for operations in France. The work was

conducted for Electricité de France, which is the Government's hydroelectric activity. In Israel it was for the Government of Israel under the sponsorship of funding from the United States.

"By 1957 the Eisenhower Committee on Weather Control chaired by Howard Orville, who had been in charge of the Naval Weather Service during the war and a very competent meteorologist, released findings indicating that their studies showed an average increase in precipitation from all of these varying operations throughout the world ranging between 9 and 17 percent.

"Therefore, at that time, practical applications were recommended on a broad-scale under Government sponsorship.

"By this time we had several hundred projects completed, many of them having operated in consecutive years since 1950, and our analyses showed that benefit-to-cost ratios were ranging from 10 to 1 in the hydroelectric field to around 100 to 1 at times in the agricultural field.

"These figures for hydroelectric were supported by independent studies conducted by the French Government on the project operated for Electricité de France from 1954 to 1958.

"By 1957 France also commissioned us to operate large agricultural projects in North Africa, in Algeria.

"We suffered, I suppose, as many others did, by 1961 when President de Gaulle came into power. He decided that any work of this type in the future would be conducted by Frenchmen within the national organization, so our operations were terminated not only by the independence of Algeria but by these developments in 1961.

"After the war, upon my return to Cal Tech, we read in 1946 of the General Electric discoveries to stimulate the precipitation process in clouds composed of supercooled water droplet. We became impressed with their ideas, and we began aircraft seeding with dry ice, simulating experiments of the type that General Electric had been conducting.

"We continued this work, and by 1948 we felt that we were in a position to conduct broad-scale field tests. We were fortunate in arranging for such tests with the Salt River Valley Water Users of Arizona in the watershed of Roosevelt Dam.

"These tests continued in 1948 and 1949 and permitted us to develop evaluation techniques using statistical methods somewhat similar to those which Mr. Lang has reported.

"We used aircraft to dispense dry ice. By 1949 we were using ground generators to dispense silver iodide smoke under controlled conditions based on the varying meteorological development.

"We felt we had attained sufficient knowledge so that by 1950 we were able to enter broad-scale commercial work. By this time we had, with our group, moved out of the university in order to add to the flexibility of our operation and to enlarge on the commercial implications both here and on an international scale.

"By 1950 there were numerous projects in operation for snowpack, for increasing precipitation, for farming operations, and for municipal water supply. It was in 1950 that we gave consideration to the location of our control point in Colorado because we were entering a drought era and we felt there would be a great deal of call for our type of work in the Great Plains area. We also wanted to learn more about cloud seeding in mountainous areas to increase snowpack because of the importance in our minds of the Colorado River as it supplied water to the upper and lower basin States.

"We knew of this importance, having been in California for many years and relying there in southern California upon Colorado River water.

"Now, it became clear in 1951 and 1952, that although our programs were carefully planned, all operations carefully logged and evaluated by the control target techniques, our results as announced were not impressive to the scientific community outside our own group of scientists.

"It was at this time that the Senate of the United States became interested in the possibilities of Government regulation and Government participation in these projects, and it was during this era that we were under contract to one of the Government departments for a rather broad operation in the Columbia River Basin.

"We had also started work in the Upper Colorado River Basin for the Denver Water Board which had interests in that area.

"This led to the development of hearings, which in turn resulted in the formation in 1953 of President Eisenhower's Advisory Committee on Weather Control.

"This Committee was given the responsibility of gathering data from all of the commercial operators and everyone that was interested in cloud seeding to attempt to assess independently the results of such operations.

"However, we gained a great deal from these experiments overseas because of the tremendous mass of data that was accumulated. And also during this era we had developed techniques for processing weather data by computer for improving our long-range forecasting techniques.

"It is our view that weather modification on a large scale or for long periods can be better conducted within the framework of even generalized long-range projections of natural weather conditions so that large sums will not be expended on feasibility studies in an area where the precipitation need not be increased in a particular year or in an area where there will be so little opportunity to increase natural precipitation that a program would be invalidated for that reason.

"By 1966, on the basis of all of these various operations throughout the world, we had amassed 2 million hours of generator operations in the field. A generator-hour is an hour's operation of a single unit.

"Now, obviously, in the early stages of this program we recognized that we would require a long time if we were going to get valid statistical analyses on the basis of evaluation techniques that were in vogue at that time as each one seemed feasible and in that way accumulated this tremendous mass of carefully logged data which will remain valid as an evaluation tool as new evaluation techniques emerge.

"So anything that we have found to date can be reassessed in the future on the basis of any new techniques that anyone may come up with, and these records are carefully cataloged and accessible.

"I think I am making a fair statement when I say that 2 million operational hours is probably a greater accumulation of operational data at this state in the evolution of weather modification than any other single group or perhaps many combined have attained.

"Now, these data are available from mountainous areas, from flatlands areas, from arctic climates to semiarid climates. They represent the full spectrum of climatic changes throughout the world. So that we have in these data a very valuable resource for the future.

"Also, the forecasting phase is very important if one is to detect any operations conducted by an unfriendly nation which might be detrimental to the national security of our country. By knowing in advance in detail what the pressure patterns in the atmosphere will be even in a general way, any modification which appears in these patterns must be studied to ascertain whether or not they are real.

"Senator DOMINICK. When you talk about long-range forecasts, how long are you talking about?

"Dr. KRICK. Well, I am talking about forecasts now that are valid up to periods of several years. We have forecasts prepared for power interests in the Pacific Northwest which have been translated into streamflows on the Columbia River and on the tributaries which now extend into the future for 5 years, and they are brought forward and extended a year every year so that they are always aware at least of our judgments on what these river basins are going to do based on the natural precipitation regimes.

"Now, if you introduce cloud seeding, that might not be discernible within the ranges of cloud seeding capabilities now and the observational error that is introduced in the forecast. In other words, we cannot forecast to a 10-percent accuracy. But we can certainly forecast whether it is going to be a wet year or a dry year and give some indication of the timing of the basic outflow from snow-melt and so on. In other words, the result of streamflow.

"Senator DOMINICK. You are not just talking about major areas of weather disturbance? You are talking about actual streamflow and things of this sort?

"Dr. KRICK. Exactly. I believe, as others have stated it, that we will never have all the answers. Research will go on forever. I mean that is the purpose of research. So that there will be things that we will want to know forever. But in the meantime we must apply known knowledge, and I think we have advanced far enough in this field now to apply known knowledge.

"We asked that private enterprise, the so-called commercial operators, receive recognition and become an important part of the future Government-sponsored work in this field. Between the work of President Eisenhower's Committee on Weather Control starting in 1953 and the U.S. Senate hearings in 1957, it is our

firm opinion that 10 years of time have been lost recognizing that commercial operators have indeed increased natural precipitation by cloud seeding in the range of 9 to 17 percent. In this 1966 Report of the Panel on Weather Modification of the National Academy of Sciences, very similar positive increases from 10 to 20 percent were reported.

"Now, again, unless positive action is taken, another 10 years could be lost debating the relative merits of such programs.

"We have perhaps more experience in the Colorado Rockies and plains areas than other groups. There has not been a year since 1950 that we have not had at least one operational program in this area. We have performed considerable research in this region, including potentials of hail suppression. We today have engineering competence and special operational skills that are most important to this particular area.

"We see no reason for any further delay in activating operational programs here to augment national precipitation.

"We believe that the several economic studies on the record based upon a 5- to 10-percent increase in natural precipitation within the watershed area of the Colorado River reflect extremely important potential economic benefits ranging from \$14 to \$150 million annually.

"In connection with our program for augmenting river flows, I would like to mention one more aspect of it. We have conducted programs in Texas and Michigan for increasing streamflow to reduce stream pollution so that plants could operate at maximum capacity and still be within the legal limits of pollution permitted on these streams.

"Now, this has been a successful operation, and it has been conducted only in those years when the long-range forecasts indicated that it would be necessary.

"Now, this is a valid thing on the Colorado River as well, because by increasing flows in the Colorado River, decreases in salinity would be achieved that could help resolve our problems with Mexico where there is considerable agitation because of the high salinity of the water which reaches the arable lands in Mexico which are irrigated by the Colorado River waters.

"Senator DOMINICK. To have meaningful increase in the Colorado River, how large a program would have to be instituted and for how long a period of time do you figure that it would have to be carried on in order to make it a meaningful applied research experiment?

"Dr. KRICK. Well, we have made a number of feasibility studies of this basin, and we think that a minimum program of 10 years over the snowpack areas of the upper basin and in the areas which receive summer precipitation would be a valid operation and would augment flows sufficiently to give the economic values with which our group and others have come up with.

"Senator DOMINICK. Is there any way of translating this increase into geography as to how many miles or acres would be involved in seeding experiments?

"Dr. KRICK. It could be done. I do not have that at the tip of my fingers. But certainly all of the source regions in Colorado, and certainly parts of Wyoming and possibly Utah would be valid areas of operation.

"Senator DOMINICK. How much increase in terms of acre-feet would this amount to? Do you have any idea?

"Dr. KRICK. Well, in studies that we conducted putting a priority on specific areas that contribute maximum flow to the Colorado River, we felt that a reasonable estimate in an average year would be an increase of 2 million acre-feet. In a low-water year that would be less. In a high-water year it might be much more, because in high-water years the increments of increase that you gain from cloud seeding result in greater increments of streamflow.

"Senator DOMINICK. So you think it is presently feasible with existing techniques on an average over a 10-year period to increase the river flow in the Colorado River by 2 million acre-feet per year?

"Dr. KRICK. I believe that is a fair statement. And the point of measurement would be Lee's Ferry. That is the point we used in this consideration in our studies.

"Senator DOMINICK. Do you have any idea of the yearly cost of such an operation?

"Dr. KRICK. Well, I would judge that it would be less than a million dollars. In the neighborhood of a million dollars.

"Senator DOMINICK. Certainly if we could get going and the results should prove this, this would be far more beneficial from a cost-benefit ratio than would importation of water, would it not?

"Dr. KRICK. In our view it would. And if we could maintain the benefit-to-cost ratios which have been achieved in other projects of even greater magnitude than this, that would be a valid statement. Because I think the lowest return that has been computed on a 10 percent increase is around \$14 million a year in an average year.

"Since 1953 we have advocated the establishment of an operational weather modification program over the Colorado River Basin. Feasibility studies have shown that such a program at sound costs would alleviate greatly the recurrent water shortages and the problems of the upper and lower basin State water users and our neighbors across the border in Mexico. Again, in our opinion, 15 years have elapsed without action to implement a vital and sound project.

"Gentlemen, the record clearly shows that whenever the validity of cloud seeding is put to the test, first by President Eisenhower's Advisory Committee on Weather Control and recently by the National Academy of Sciences, it has required an examination of long-term operational records of qualified commercial operators. In both instances findings have shown positive increases in precipitation. Both times the findings have been in the similar order of magnitude.

"Therefore, what is now being said in 1966 was also self-evident in 1957—this represents quite a timelag to recognize almost identical findings.

"Why should we wait longer? The commercial operators have shown they are achieving economically important results. The world has no time to lose in acquiring additional water and increasing food production to meet the population demands. An operational program to add precipitation and streamflow within the Colorado River Basin is practical now. We are ready, have been since 1950, are established in this area, have completed numerous feasibility studies, have intensively studied the daily weather of the area and have other knowledge applicable to this specific task. We have not argued or sought the restriction of research funds expended since 1957 within this field. We do, now, urge that serious consideration be given to the practical capabilities of the commercial operator. Why shouldn't he be a constructive member of this over all effort? Let's use available talents. We, as a group, have prepared over many years to take part in such an effort.

"There are sufficient data and analyses available to validate the merits of commencing an operational weather modification program, without delay, within the Colorado River Basin. In chapter VI, 'Economic Effect of Increased Precipitation on the Colorado River Basin,' Dean A. M. Eberle, Vice Chairman of President Eisenhower's Advisory Committee on Weather Control, reports:

"If we assume that precipitation is increased by only 10 percent as a result of weather modification the estimated value of the additional water is as follows for the Colorado River Basin at Lee's Ferry:

"This yields the following dollar values on an average year basis:

"(a) Hydroelectric power value \$1,135,000 (additional runoff was valued at 50 cents per acre-foot).

"(b) For diversion to agricultural, urban, and industrial uses, assuming a value of 50 cents per acre-foot, \$1,135,000.

"(c) Grazing land yield annual increase, \$12,500,000.

"(d) Total dollar value of increase, \$14,770,000.'

"The above figures do not include the effect upon the general economy of the West. The additional water would help to offset part of the potential water deficit in the basin. The total annual cost of a weather modification program to increase precipitation upon the Colorado River Basin above Lee's Ferry would be a small fraction of the potential estimated value of the additional water. It is extremely important to note that the value of only a 10 percent increase is in line with estimates included in a final report of the Panel on Weather and Climate Modification to the Committee on Atmospheric Sciences, National Academy of Sciences, National Research Council as reported in 1966. Such an increase is also in agreement with the findings of President Eisenhower's Advisory Committee on Weather Control as reported in 1957.

"It should be noted that a very conservative value of 50 cents per acre foot was used to determine the value of additional runoff. A recent American Meteorological Society Bulletin article, 'Summary Report on Weather Modification' quotes as follows:

"The costs of water in the United States have been variously estimated to be in a range from \$1 to \$75 per acre-foot, depending primarily upon uses to which it is put.'

"There are other authoritative estimates of additional water values from weather modification within this basin reported upon ranging from \$10 million to \$150 million."

Summary

I don't believe it is necessary to belabor or discuss in small detail the true and urgent need for additional water within the Colorado River Basin. I believe we are all familiar with the problem and are truly interested in seeking a solution.

But I should like to point out that it is almost 20 years from the time we announced streamflow could be economically increased by weather modification. Today most competent scientists, deeply involved in weather modification, will agree what we stated in 1949 is feasible. We have lost many precious years of time, so let's not permit more years to pass before initiation of this Colorado River Basin project.

We propose the following for your consideration :

1. That no time be lost in implementing the project.
 2. That a broad-scale weather modification program be commenced to augment the flows of the Colorado River. (A major portion of the runoff originates within the State of Colorado so concentrated efforts should be placed upon snowpack increases within this State).
 3. That the program have at least a 10 year life.
 4. That current and continuing evaluation of results be maintained.
 5. That operations be conducted within the framework of a long range weather/streamflow forecast.
 6. Since 1950 our company has accumulated 18 years of operational experience in the Colorado Rockies—right in the heart of snowpack areas for runoff.
- Gentlemen, I do appreciate this opportunity to meet with you and discuss this urgent program and look forward to the time when it becomes a reality.

RELATING TO WEATHER MODIFICATION

MONDAY, JUNE 17, 1968

U.S. SENATE,
COMMITTEE ON COMMERCE,
Reno, Nev.

The committee met at 10 a.m., in room 4040, Bankruptcy Courtroom, Federal Building, Reno, Nev., Hon. Howard W. Cannon presiding.

Present: Senator Cannon.

Senator CANNON. The hearing will come to order.

This is a hearing on two bills to advance weather modification.

One bill is S. 373, of particular interest to my home State of Nevada, the University of Nevada, and its very fine Desert Research Institute. Several eminent scientists of the institute will be witnesses at this hearing.

The bill, S. 373, is to provide what would be in effect a coordinated national program in weather modification in which four departments and two agencies would participate.

The other bill, S. 2058, is to provide a practicable weather modification program for the Upper Colorado River Basin, which is defined in the measure as Colorado, New Mexico, Utah, and Wyoming.

S. 373 is similar to S. 2916 of the 89th Congress, which passed the Senate late in the second session, too late for action in the House of Representatives. In November 1965 I conducted hearings on S. 2916 at Las Vegas and Elko, Nev., and several witnesses appearing here today gave important testimony also at those hearings.

Hearings on proposed legislation similar to S. 373, but with a number of largely technical changes, have been held by the Subcommittee on Communications and Power of the Committee on Interstate and Foreign Commerce of the House of Representatives, and that bill, H.R. 9212, is pending before the standing committee.

S. 373 is cosponsored by four members of the Committee on Commerce, which has jurisdiction over legislative matters relating to weather. They are Senators Warren G. Magnuson, of Washington, chairman of the committee; Hugh Scott, of Pennsylvania; Peter Dominick, of Colorado, and myself. Senator Dominick introduced S. 2058.

Weather modification has many aspects, among them:

Producing moisture in the form of rain or snow where or when the normal precipitation is insufficient; hail suppression; lightning suppression; fog dissipation, particularly in airport areas;

Moderating or preventing tornadoes, hurricanes and other violent storms; and frost prevention.

There are others, but perhaps the earliest goal of mankind has been to produce precipitation in areas that are arid or semiarid, or in areas

where there are deficiencies in rainfall during certain seasons of the year.

In more recent times this has been expanded to encouraging snowfall in upstream areas so that there will be increased runoffs for irrigation and for reservoirs.

A start toward attaining these objectives has been made, as I believe the witnesses here today will confirm, but there is still much to be done and a long ways to go.

And I might add that a very interesting matter appeared at our hearing in Denver a few days ago, where the statement was made that one firm was willing to enter into a contract based upon performance, where they would guarantee that they could increase the flow of the Colorado from the Upper Colorado Basin to the extent of 2 million acre-feet a year.

Congress has been alert to the need to increase precipitation, particularly in the West, for nearly three-quarters of a century. In 1890 it provided limited funds for experiments in producing rainfall by exploding balloons in the clouds.

In mid-Texas, where these experiments were made, the tests were discouraging, although light spatters of rain for 20 or 30 seconds were known. The tests were abandoned in 1893.

Today, in Soviet Russia, antiaircraft guns are battering threatening hail storms with projectiles charged with silver iodide, and the U.S.S.R. claims that in one area last year 15 "hail focuses" were destroyed by antiaircraft shells. We may perhaps take this report with a grain of salt, but in any event S. 373 does not contemplate the use of antiaircraft guns.

We are fortunate today in having as our first witness Dr. Patrick Squires, director of the Laboratory of Atmospheric Physics, Desert Research Institute of Nevada.

Dr. Squires is one of the real pioneers in weather modification. He participated in conducting the first cloud seeding experiment that produced rain on the ground in Australia. That was in 1947, only a few months after the first cloud seeding experiments anywhere were undertaken here in the United States by Dr. Vincent Schaefer, and the late Dr. Langmuir.

Dr. Squires has a further distinction. He was the first scientist to artificially stimulate convection to build a quiescent cumulus cloud into a towering storm cloud.

Nevada is fortunate to have him. His coming to the university here in Reno, I am told, was responsible for it being designated as a "center of excellence" for "Project Themis" of the Department of Defense, in which our Navy has a particular interest. And perhaps Dr. Squires will tell us about that today.

The Desert Research Institute has many other eminent scientists in weather modification or related fields. I have asked Dr. Squires to bring some of them with him, and the committee extends to them a warm welcome.

Before we proceed with Dr. Squires' testimony, I would appreciate it if Dr. Squires would introduce the people who are accompanying him, and state briefly the activity that they are primarily engaged in. If time permits, at the conclusion of the testimony today, we may have these gentlemen elaborate some on their work.

I am particularly interested for one in electronic and radar applications in the trace analysis methods that have been developed here, and in the work that the laboratory is doing for the Atomic Energy Commission.

Other witnesses here today who will testify are Mr. J. Robert Stinson, Associate Chief, Office of Atmospheric Resources, Bureau of Reclamation.

Dr. George S. Benton, Director, Environmental Science Services Administration, at Boulder, Colo.

Mr. Robert Elliott, president of North American Weather Consultants, a private meteorological concern that has wide and long experience in western cloud-seeding operations.

Mr. Elmer DeRicco, director of the State department of conservation and natural resources, is unable to be here, and has Mr. Norman Hall appearing for him.

And I understand that Dr. Williams from the Department of Atmospheric Science of Fresno State College, of Fresno, is here, and also Mr. Thomas Henderson of Atmospherics, Inc., of Fresno, Calif.

So with that, you may proceed, Doctor.

Dr. SQUIRES. I would like to add a little to what I have given in written testimony, touching the high points only.

Senator CANNON. I may say that the typed statement will be made a part of the record in full. So if you, or any of the other witnesses, desire to summarize or add to it, feel free to do so, and the printed copy will be made a part of the record.

STATEMENT OF DR. PATRICK SQUIRES, DIRECTOR, LABORATORY OF ATMOSPHERIC PHYSICS, DESERT RESEARCH INSTITUTE, RENO, NEV.; ACCOMPANIED BY JOHN CHISHOLM, WILLIAM BUTCHER, AND DR. JOSEPH WARBURTON, DESERT RESEARCH INSTITUTE, RENO, NEV.

Dr. SQUIRES. The bill S. 373 represents a great diversity of interests involved in any modification of the atmosphere, and in this respect it is a very long step toward realism.

There is no doubt whatever that there are some places and some seasons where it is possible and in fact it is achieved that weather modification techniques increase precipitation, particularly in the form of snowfall.

The situation we now face is that we are somewhere within sight of small-scale operational experiments, pilot projects. And two questions naturally arise.

One has to do with how do we regulate for the national interest the activities of people who are undertaking the practical modification of the weather. And in what areas are research and development needed which will extend the application of these techniques and make them more efficient.

With respect to the first question, the regulation, licensing, it seems clear to us in the Desert Research Institute that the matters that we are dealing with here are not really suitable for State regulation. It is true that water law is a State function. Water, however, runs downhill in a predictable manner. The water vapor in the air, with which we are

dealing here, flows uphill and downhill, whichever way the wind is blowing. There is no way of predicting what area will be affected, predicting for all time, by a weather modification attempt in one State.

It appears to us that the possible clashes of interest between States are so real that, because of the fact that the water vapor can flow with the wind, that only Federal regulation can cope with this.

We also feel that the proposal in S. 373 to accomplish this regulation through an operating agency leaves a great deal to be desired. And we don't really feel that any operating agency, particularly one which is interested in the field of weather modification, is in a position to carry out regulations when interests on the State level are liable to be involved. And we believe that the more appropriate form, more appropriate structure, would be one something like suggested in the bill S. 2058, where it is proposed that the President appoint a council or commission to control the weather modification operations.

On the national scale, as distinct from the regional scale of the upper Colorado, it would seem that such a commission would primarily have a judicial function, being advised by both the users and the people who are capable of delivering the services which are required.

Turning next to the question of what research and development seems to be needed at this point to most rapidly advance the possibilities of weather modification, the first point to note is that existing techniques apply to only one kind of cloud; namely, those clouds which are so deep that they reach above the freezing level. There are many clouds, particularly in the warm parts of the country, which do not reach the freezing level, some of which rain naturally, and it would be very desirable indeed to extend our understanding of the processes that are going on in clouds to the point where we could modify those clouds in a desirable way. It's true indeed that we do understand reasonably well what goes on in the warm clouds, but the indications at the moment are that, while it may be possible to modify these processes, it will take a great deal of research and development before we know for certain whether that is true or not.

Coming then to the cold clouds, to which the existing techniques apply, there is little doubt that in our present state of relative ignorance of what we are doing with the clouds we sometimes increase the precipitation and sometimes decrease it. And it may well be that the rather modest figures of increment of precipitation which are commonly equated are in fact only a net increase. If we were sufficiently well informed about what is going on in the clouds so that we could choose to seed only on those occasions when we were going to prove a positive result, and avoid those occasions when the result would be adverse, it may well be that the total increment in precipitation would be considerably more than it is now, than it appears to be at this point.

In order to achieve this, we would need to carry on, press on, with the basic research leading to an understanding of the physical processes going on, and we would also need to give a lot of attention to the development of technology which was adequate to collect quickly the information that you need to have to make a decision. You obviously can't collect the data and analyze it, and know the answer 6 months later. You have to collect it in real time, analyze it in real time, and

make a decision in real time before the clouds that you are looking at have dissipated.

Another area in present technology which appears to be one where significant development is needed is in the matter of placing the seeding agent in the clouds. Our understanding of how materials are diffused in the atmosphere is only moderate. There have been some occasions when the hopes of experimenters have been denied, they have placed generators, silver iodide generators in certain positions in the hope that the silver iodide would be carried by the wind that would be diffused up into the clouds and produce precipitation in a certain area. If, as is always the case in this point in development of weather modification, if one needs to know where the precipitation is going to fall, this presents a great problem. The reason why one needs to know where the precipitation is going to fall as a result of seeding, if indeed there is an increment of precipitation, is because it is impractical economically to put a dense network of precipitation gages over a very large area. It is necessary to concentrate in a target area.

And there are other reasons why one needs to identify the area in which the increment of precipitation is attempted. The basic reason, of course, is that in any experimental undertaking, or even a pilot project, one wants to be sure that there are useful effects being produced, and one can only do this if you know where to look for the effects.

Thus, the problem of putting the material in the clouds to produce the desired result in a known place is a serious one, and one which is going to require the development and extension of a great deal of technology: on the one hand, the devices for doing this; and also a very considerable development of our understanding, basic understanding, of diffusion processes in the atmosphere.

I believe that is all I need to say, Senator.

(Dr. Squires prepared statement follows:)

PREPARED STATEMENT BY DR. PATRICK SQUIRES, DIRECTOR,
LABORATORY OF ATMOSPHERIC PHYSICS

The recognition in S. 373 of the diversity of interests involved in any modification of the atmosphere is a long step forward. Here, just as in the utilization of the oceans, many governmental agencies are vitally concerned. Pursuing that analogy, it would be appropriate if the Bill took more account of the interests and contributions of private individuals and organizations.

The weight of the evidence leaves no doubt that, in certain regions and in certain seasons, precipitation can be, and is being, artificially increased. Two questions naturally arise from that situation: (1) What research and development is needed to broaden the possibilities and improve the efficiency of modification techniques and (2) how will current projects be controlled and coordinated in the best interests of the nation?

With regard to the first question, it is well known that the techniques now in use are applicable to only one class of clouds—those which reach above the freezing level—"cold clouds". Our understanding of the formation of precipitation in "warm clouds"—those which lie wholly below the freezing level—has been steadily increasing, but while it seems quite possible that the processes occurring would lend themselves to practical modification procedures, a very substantial research effort will be needed to find out whether or not this is so.

Considering only the "cold cloud" techniques, a wide range of possibilities is immediately apparent. There is little doubt that seeding clouds sometimes results in a decrease in precipitation. The modest increases which have been reported as a resulting from modification attempts may represent only the net increase. Very much more significant effects might be achieved if we understood the clouds well enough to seed only on the right occasions. To reach the desirable position

of being able to choose these, it will be necessary to encourage basic research in all phases of cloud physics. Another large improvement will probably be available when delivery methods are developed to the point at which it will be possible to introduce seeding agents into the clouds economically and controllably. This again will depend on the encouragement of broad-scale basic research on atmospheric diffusion and convection.

The overall charge given in S. 373 to the National Science Foundation to advance the state of knowledge is entirely appropriate. However, while some of the underlying scientific problems are general, some are identified with particular regions and purposes. Since the various agencies with various charges and interests will often be concerned with different regions, it would be entirely appropriate that each agency should be authorized to concern itself with relevant basic and applied research aspects. The language of S. 373 does not appear to clearly specify that agencies other than NSF and Commerce would have this essential authorization.

Turning to the second question, the control of projects and pilot projects, the proposal to place the regulatory and licensing responsibility in the hands of the Secretary of Commerce is not suitable. These powers are all-pervasive. They potentially affect all states, as well as interested agencies in the Federal government and private individuals and organizations. An intra-state dispute about the down-wind effects of seeding operations, for example, would present a very difficult problem to the body vested with licensing and regulatory authority. A more appropriate kind of solution is that proposed in S. 2058—the formation of a Council or Commission appointed by the President. On the national level (as distinct from the regional emphasis of S. 2058) this body may well exercise a more of a judicial role, seeking advice and support from agencies, user groups, institutions of higher education, private individuals and organizations. As operational use spreads, the need for such a body, analogous to the Federal Power Commission, for example, will become more and more apparent.

It is inevitable that operational projects will sometimes adversely conflict with research projects. Since the Commission would have to have access to the best possible scientific advice in order to discharge its regulatory functions, it seems possible that the overall determination of related research and development, policy and emphasis should also be its responsibility. Title III of S. 373 authorizes the President to direct the planning, supervision and coordination of the various agency programs without describing the means to be used for this purpose. It would be most unfortunate if these responsibilities were delegated to one of the operating agencies, since this would make the maintenance of a proper balance of agency and private interests virtually impossible.

Senator CANNON. Thank you, Doctor, for your very fine comments. I have read your statement and it is a very interesting one on the subject.

You then believe that if we are to have regulation that it must be on the Federal level, for the reasons that you have stated? In other words, that State regulation, perhaps by cooperative agreements, would not necessarily solve the problem from a regulation standpoint; is that correct?

Dr. SQUIRES. I feel that it would be very difficult, indeed. For instance, if you think of water that falls on the Sierra Nevada, some of it flows east, some west. And this is determined by the topography once and for all. But if you are talking about the water vapor in the atmosphere, this is a very different matter. It comes in from the Pacific and flows up the mountain and down the mountain on this side.

Now, no one knows, scientific knowledge is not good enough to tell us what are the results in Nevada of seeding in California on the western slope of the Sierra Nevada. Perhaps a naive guess at this would be that the Californians are removing water vapor from the atmosphere before it reaches Nevada. However, the matter is not necessarily as simple as that. It's equally likely that the net result of those activities is to redistribute the water vapor in the atmosphere in such a way as to improve the chances of precipitation in Nevada.

We just don't know what the answer to that is. But you can just well see that one day this could give rise to intrastate problems.

Senator CANNON. Now, you indicated that you thought a commission, on the order of that provided in S. 2058, which was suggested for the Upper Colorado River Basin, would be the preferable type of thing. Are you thinking of something on the order of, for example, the CAB or the Federal Power Commission, or something of that sort?

Dr. SQUIRES. I believe that is really more what I'm thinking of, yes, on the national scale. I believe this commission would be essentially largely a judicial body.

Senator CANNON. And would actually be more of a regulatory and a licensing body, and certainly not an operating agency?

Dr. SQUIRES. Certainly not an operating agency.

I think, since they would need to be very well informed scientifically and technically in order to carry out their regulating and licensing functions, I think it's very possible they should have a role in the determination of policy with regard to the overall development of research and development, if it's advising the President in this direction.

Senator CANNON. Do you see any need in the near future for international cooperation in the field of weather modification?

Dr. SQUIRES. I don't believe that this is very close at hand. But, on the other hand, I'm sure that eventually this problem will arise, just as the efforts at seeding the clouds in one State are liable to give rise to afterthoughts in a downwind State. People would wonder what's happening. So we must look forward to the time when nations will begin to be concerned about each other in the weather modification field.

There have already been some indications, for example, in a slightly different area, that the pollution of the atmosphere, which is a worldwide phenomenon these days, is on the scale of the whole hemisphere. It isn't merely just a local effect. The pollution is produced in one part of the hemisphere and is experienced in another part, and of course in a much diluted form. But no one knows for certain what the effects of this pollution are. We have yet to find that out.

To take a very clear example, some unrelated but still perfectly clear, the carbon dioxide content of the atmosphere is steadily increasing year by year as a result of the combustion of fossil fuels. We don't know very well yet what the effects of this will be. It's not at the point where it's going to poison us all within a few generations, but it might well begin to have some effects upon plant growth, upon climate, upon we don't know what. One could imagine this needing an international agreement to regulate the combustion of fossil fuels. They may well give rise to a pressure on the international level for the elimination of fossil fuels as a source of energy, and their replacement, for example, by nuclear energy in order to avoid a further increase in the carbon dioxide content of the air.

Senator CANNON. Here at DRI you have assembled a very outstanding research group in cloud physics, and I'm wondering whether or not this group has made any notable contributions toward the realization of weather modification possibilities.

Dr. SQUIRES. Yes, sir; I believe that we have made some contributions which are of some significance.

I mentioned earlier that one of the outstanding needs that we can foresee in weather modification procedures is the ability to rapidly collect information concerning clouds upon which one proposes to operate, and rapidly analyze this information to determine what action should be taken or should not be taken in order to maximize the benefits to be achieved from seeding procedures.

Mr. Chisholm has been working in this area. He is a pioneer of the development of techniques directed toward this end. Would you like Mr. Chisholm to speak on the subject?

Senator CANNON. Yes, I would be very happy to have you, Mr. Chisholm.

Mr. CHISHOLM. Senator Cannon, gentlemen: About 3 years ago in Elko, Nev., I testified before your committee, and in testimony today I would like to elaborate on that a bit and show the progress we have made from that date to the present time.

First of all, I would like to cover two specific points I made in that testimony, and then sort of elaborate on the general testimony that I gave.

The two specific points I made were: (1) that the airplane we were using was not adequate. This was in connection with the need for better facilities. And, (2) the other point was that in my opinion any weather modification experiment on a small or large scale should have very adequate radar coverage. Otherwise, you have a very difficult time in determining what you are doing.

Well, we conducted an experiment subsequent to that time, about a year later, in the Elko, Nev., area, which pretty dramatically illustrated the two specific points I would like to make.

Could I use the board up here and draw a little sketch?

Senator CANNON. Yes; sure.

Mr. CHISHOLM. The point I'm trying to make here is coverage that is required, this is the State of Nevada here drawn very crudely, and in the winter of 1966-67 we conducted the following experiment:

We were quite confident, as many other people are, that you can modify clouds and make it snow. In fact, we were so confident that we did the following thing on a particular day. One of our staff stated, I forget the exact date, that conditions over Elko, Nev., were very suitable for cloud seeding, in the sense that there was no natural precipitation, but that it should be capable of introducing artificial precipitation. So we dispatched our airplane, and Joe Warbuton was in the airplane, and he is part of the story, we dispatched it from Reno, Nev., toward the Elko area. At the same time we called up the Salt Lake City Weather Bureau, and told them that we would soon be producing artificial precipitation in the Elko, Nev., area, and would they observe the resulting patterns.

Now, how they were going to do it, there was an FAA radar here at Battle Mountain that covers this area, and this then would be remoted to the FAA Center in Salt Lake City, and the weather bureau would be using this radar network because there are many other radars netted into there from all over west here. They were using this to study experimental weather patterns, on an experimental basis.

I really don't think they believed us, that we were able to produce snow at the time and place we said, but in any event, these people went and watched the FAA radarscopes from the Battle Mountain

area, and at the designated time and places echoes were produced on the radar screen, and they were observed in Salt Lake City. And we, some 500 miles away from Salt Lake City, were telling what would happen, and it did happen.

Well, this thing proved a couple of points. It proved, first, that the FAA radar was very adequate for wide-area coverage. It proved our airplane was unsafe. Joe Warbuton was in the airplane; the airplane iced up very heavily, and with the general icing conditions over this place, with no place to go essentially and get out of them, you are in trouble.

So we decided at that point; we regrouped and decided essentially our airplane was indeed unsafe to fly in these wintertime storms, except in conditions where there were broken clouds. And we sort of knocked that off until we could get a better airplane. As of about a week ago, the Fleischmann Foundation has given us the money to get a good airplane. We are now in a position to again fly in these storms.

Secondly, it shows that our computations on the FAA radar network were indeed true, that you could produce precipitation of sufficient magnitude that they could be observed 100 miles or so from the radar, which meant that we had essentially complete coverage over the West.

It also pointed out to us, however, the difficulty in using a radar that only would give you a planned position indication; it doesn't give you altitude. The difficulty in using such a radar for pinpointing precipitation is that we had aimed our seeding trajectory so that the snow would fall in our rain gages in Elko. Indeed, it turned out that the echo went some other way, completely contrary to what we were predicting.

As a result of this, two things happened: We backed off on the airplane, and we backed off on the radar, using the FAA radar and other radar, and started a program from which we essentially tried to develop technology that would permit us to attach a digital computer to the radar, and end up with a three-dimensional picture of what this snowfall trajectory that we were creating was doing. So then we could seed in one place, and predict where that snowfall was going to fall.

Now, the significance of that is quite important in terms of wintertime precipitation augmentation.

Let me repeat. We backed off using radars and entered into a 2-year program sponsored by the National Science Foundation to permit us to attach a digital computer to a radar, so that that computer could show in three dimensions where the snowfall was going to go, so that we wouldn't have to run all over the ground with buckets, but we could seed in a certain place and know that the snow was going to go into another place that we could predict. The importance of that is as follows:

If this is a mountain [drawing] and you look where the snowfall that falls is of most economic benefit; it's right up in this area here [indicating]. In fact, if you just look out the window, the water that's flowing from the Truckee now is coming from isolated mountain spots where the snow packs in at high altitudes. In order to get the snow to go into this pocket here where it is stored, you've got to know what the trajectory of the snow particles is doing. And you need to

know that because then you have to seed at a certain place in order to get the snow to follow this trajectory to get into that area.

So we backed off, and are now in a position where we believe that in about a year from now we will be in a position, with other contractors, to seed airborne seed and dump the snow where it is supposed to go.

And as a continuing step in this, we hope this winter to cooperate with a group in Steamboat Springs, in which we will supply a radar and our data processor and our airplane, and they will supply their airplane and their other radars that are in this area, and we will get exact data on this snowfall trajectory. We believe that after this winter's work is done, we will be in a position, with other Bureau contractors, to conduct a fairly significant experiment in the upper regions of the Colorado.

Specifically, if you look at this map—I only have one map, but this is the upper region of the Colorado, and here is our own Ruby Mountains in Elko. If you station an airplane in Salt Lake City, such as the one we have, the B-26, it can reach any of these areas of interest in approximately 30 minutes.

The radar coverage from Rock Springs, Wyo., goes to Salt Lake City, has coverage over the Wind River Range, the Uintas, and the eastern side of the Wasatch. The radars in the Salt Lake City area cover the eastern slopes. Battle Mountain covers our experiments in Elko, Nev. So you can station a crew here at the FAA Center and conduct a very large cooperative program with various Bureau contractors in this general area.

To repeat myself, we hope this winter to engage with people in Steamboat Springs in a definitive program, using our radar technology and their theoretical models, so that we can tie down this trajectory once and for all. Using our trajectory knowledge and the technology of the radars, both the single radars and the three-dimensional radars, and the large-scale FAA radar for control of a large experiment, we feel confident that the DRI can participate in the forthcoming pilot experiments which I believe will start to yield very specific results.

Senator CANNON. Thank you very much. That's a very interesting statement.

What about your funding? Where do you acquire your funds to carry on this program, Doctor?

Dr. SQUIRES. The funds of the DRI for this, and related programs, come from the Department of the Interior. They have Project Skywater in the Bureau of Reclamation; from the Department of Defense, under Project Themis, which you mentioned earlier, Senator; and from a number of smaller individual programs which are supported by the National Science Foundation.

These National Science Foundation supported programs continue to be of the more basic nature, which is, of course, consonant with the function of the National Science Foundation. They also have a very useful function for the Desert Research Institute, which I would like to recognize at this point. They introduce into our institute an element of community scientific leadership, because these grants that are given in this manner are given to the individual, and not to the institute or to a part of the institute. The individual himself is respon-

sible to the National Science Foundation for the proper use of the grant moneys he is given.

Senator CANNON. Well, does the DRI exercise any management control over the project, then?

Dr. SQUIRES. Only in an accounting sense. And only in an extreme situation would there be any interference by the DRI management with the scientific aspects of the man's work. He has obtained this grant because he has been evaluated by the agency through its regular method of proposal review throughout the national scientific community.

This is a very valuable part of our funding for this specific reason: We get their broad scale appreciation and help in leadership in the scientific area.

I mentioned Project Themis, which is a new project of the Department of Defense. And this is a very interesting departure, in response to a direction from the President in 1965 that agencies funding research should consider in what way they can use research to assist the process of higher education. The Department of Defense has devised this project, which puts a heavy emphasis upon the involvement of graduate students in its research work, and provides a very desirable element of stability, because it has one of these step-funding schemes which ESSA, I think, was the first to introduce, where at any given time we have enough money committed to us to complete the education of graduate students who may be now involved; even if the project should terminate tomorrow the money goes on in decreasing amounts for 3 years.

Other work of a related kind is carried on by the Water Resources Research Center of the Desert Research Institute. And I would like to ask Mr. Butcher, who is the acting director of the center, to speak on this work, briefly, if I might.

Senator CANNON. Certainly.

Mr. BUTCHER. Senator, I would like to explain the center's part in the Desert Research Institute. We are the center in the State of Nevada which is one of a chain of 51 supported by the Office of Water Resources Research, which is within the Department of the Interior. The Center for Water Resources Research is partly supported by the Office of Water Resources Research, and as well seeks contracts for research and service work, service which supports the research from other funding agencies.

At the present time Interior is supporting us to approximately 50 percent. For them we carry out contract research, some of it especially allocated to us as a base grant, which we know will give us continuity.

Senator CANNON. Well, is all of your work in the field of basic research, or do you have any practical experiments that you are carrying out?

Mr. BUTCHER. Our research is by the pure and applied. We seek to keep a balanced program in both areas. In some cases our applied research will support going activities of the Federal Government. For instance, we have a contract with the Atomic Energy Commission. In this capacity we are a part of the hydrologic task force which is working in connection with the supplemental test site in central Nevada. Our function in this task group is to look to the regional hydrology in the test site area.

We are working in concert with two other organizations, a branch of the U.S. Geological Survey, and a private company called Isotypes, Inc. We formed with these two companies the hydrologic task force, and a portion of this is to look to the regional hydrology, the large-scale operations. And we feel this has important experience both for our staff and for the students, many of whom are supported on research incidental to this general activity.

In addition to AEC and Interior, we also receive support from State and local organizations for whom we do contract research, and the university also gives us a measure of support.

To give you some general idea of our operation, our total funding for this fiscal year now concluding is in the order of half a million dollars, of which AEC would be giving us something in the order of 30 percent, and Interior approximately double that, the balance being made up from the miscellaneous local and private sources.

Senator CANNON. That's very, very good. Thank you.

Dr. SQUIRES. Senator, before I leave the table, I would like to mention that Mr. Warbuton, also of the Desert Research Institute, came along. And if you feel there is time, he would be willing to describe briefly his trace analysis work, which is vitally important in connection with determining the success or failure of attempts to seed a particular area.

Senator CANNON. I think we could hear from him briefly on it at this point, without throwing us too much behind schedule.

Mr. WARBUTON. Senator, since coming to the United States I have been engaged in research aimed at detecting the seeding materials which are used for weather modification purposes in the cold precipitation process. The reasons for doing this are to try to obtain knowledge on whether or not the seeding material has in fact entered the precipitation-producing area, and possibly by various modifications of these techniques determine whether or not the seeding material has in fact taken part in the precipitation mechanism.

We have developed these techniques at the Desert Research Institute during the last 2 years, and these techniques are now used throughout the West in most of the weather modification programs being conducted.

The techniques so far have been able to show us that only on some occasions does the seeding material enter the target area where the precipitation is to be effected. Whether or not the material has taken part in the process is not very well known. It is expected that it does, since it does in the laboratory. And so one can infer that if the seeding material appears in the precipitation that it probably took part in the mechanism.

However, if it does not appear in the precipitation, it throws considerable doubt on the efficiency with which one dispenses this material. And some of our results have shown that we do not have a very clear understanding of what happens to seeding material released in mountainous terrain.

As a result of these measurements, I am of the opinion that considerably more work needs to be done on devising better methods of delivery of cloud seeding materials into cloud systems. We should continue to improve our analysis techniques so that we can assess the results of weather modification work. I think we are not very well off

with regard to assessing the final result of weather modification. Just to measure the precipitation on the ground is not enough. The local winds that occur in a mountainous region over a targetal pilot project area may be sufficiently great to redistribute precipitation which has fallen on previous occasions in such a manner that it completely confuses whether or not you have changed the precipitation on a particular seeding day.

And I think that a great deal more work needs to be done in devising better methods of assessment of the amounts of precipitation falling, and this may be supplemented to some degree by further chemical and physical measurements on the precipitation itself.

Senator CANNON. By the way, we had in the Denver hearings a very interesting statement from one of the witnesses concerning a new method they are using of getting the precipitant in the proper place. And they have the silver iodide carried in a primacord sort of thing. It can reel out and then be exploded with explosive force in the cloud formation that it is desired to impregnate with.

And it sounded like they had had some very good results, from the testimony that we received.

Mr. WARBUTON. Would you like me to comment on that, Senator?

Senator CANNON. Yes.

Mr. WARBUTON. I think that the use of primacord is probably rather limited. It delivers a very large amount of the seeding material in a very short space of time. And, say, in a hurricane-type situation, where you may be trying to produce a very drastic effect upon the cloud, I think this sort of thing may be extremely useful. However, I would rely on the development of pyrotechnic devices, which is being done by the people principally at China Lake Naval Test Station, as being one of the most significant advances in recent years in the means of dispensing in a controlled manner the seeding material into the atmosphere.

Senator CANNON. Thank you very much.

Doctor, does that complete your group here?

Dr. SQUIRES. I believe so, sir. Thank you.

Senator CANNON. Thank you very much. We certainly appreciate your appearing and giving us the benefit of your views today.

The next witness is Dr. J. Robert Stinson of the Office of Atmospheric Water Resources of the Bureau of Reclamation, Department of the Interior.

Doctor?

STATEMENT OF DR. J. ROBERT STINSON, ASSOCIATE CHIEF, OFFICE OF ATMOSPHERIC WATER RESOURCES, BUREAU OF RECLAMATION, DEPARTMENT OF THE INTERIOR

Dr. STINSON. It appears appropriate to comment first on S. 373, cited as the Weather Modification Act of 1967, Senator.

The main purpose of this legislation appears to be the establishment of a major role for the Department of Commerce in weather modification. Secretary Udall's letter to Senator Magnuson stated that we have no objection to the enactment of this bill if it is amended in accordance with specific suggestions. Those suggestions are in the record, and will not be repeated here.

No specific research program is specified in S. 373. However, the Secretary of Commerce is authorized to carry out a comprehensive program in the field of weather modification and furnish technical assistance and information in the field of weather modification to any other Federal agency requesting such assistance or information.

The second bill, S. 2058, cited as the Upper Colorado River Basin Weather Modification Act, proposed a major operational weather modification program for that region and provides funds for operations and research. In a second letter from Secretary Udall to Senator Magnuson it was stated in part, "We recommend that the bill not be enacted * * *." This document is in the record and will not be repeated here. This bill proposes direct action to provide an early operational program for the Upper Colorado River Basin for the purpose of augmenting water supplies.

Senator Magnuson also asked me to comment upon the statement of the American Meteorological Society with regards to weather modification. And this request says:

In a statement preceding the Proceedings, AMS states in part that there is still somewhat ambiguous statistical evidence that precipitation from some types of cloud and storm systems can be modestly increased or redistributed by seeding techniques, and then adds:

"It is essential that research in this area be expanded. Many crucial aspects need additional study: for example, the downwind effects of cloud seeding must be clarified; the immediate effects of seeding individual storms need specifically to be identified as opposed to their being subjected to statistical averaging; and, it is essential to develop a better understanding of the specific physical conditions under which seeding produces an increase or decrease of precipitation or has no effect at all. To this end, a vigorous program of research on precipitation mechanisms must be continued. This will involve considerable theoretical work in conjunction with laboratory and field experiments.

He further stated that it would be helpful for the committee to have my views on the above expression, and also whether the program proposed in S. 373 would expand research in a manner that would be beneficial.

In my opinion, the American Meteorological Society's "Statement on Weather Modification" is valid. However, it appears to be strongly flavored by the National Academy of Science's 1966 statement. And it is important to remember that research on weather modification is not standing still. Vigorous programs do exist in the United States and in certain other countries. Of particular importance is the increasing accumulation of physical evidence in support of the basic concept that meaningful cloud modifications are possible through the introduction of appropriate treating materials.

Important research programs are underway. The technology required for conducting experiments and operations in precipitation management is developing rapidly, but more rapid progress is possible.

Some of this technology has been talked about here through the University of Nevada, the two technologies developed at the University of Nevada which are of general application in other areas. One is the rapid response, readout systems which have been developed there, and the silver trace analysis system, which has also been developed at the University of Nevada.

Programs in weather modification now exist in the various agencies authorized to do research in S. 373. For example, the Bureau of

Reclamation has been conducting a major precipitation management research program for several years.

Some of the programs sponsored by the Bureau of Reclamation or other agencies which have a direct bearing on the program proposed in S. 2058 include: (1) The Park Range in Colorado conducted by E. Bollay Associates, Inc.; (2) at Elk Mountain in Wyoming conducted by the University of Wyoming; and (3) at San Francisco Peaks in Arizona conducted by Meteorology Research, Inc. In addition to these programs, the Climax, Colo., experiments conducted by Colorado State University continue to contribute heavily toward learning how to conduct meaningful operations in the Upper Colorado River Basin.

This research is sponsored by the National Science Foundation.

In addition to these programs, the Bureau of Reclamation has a contract with Colorado State University for design of an operational adaptation program for atmospheric water resources development in the Colorado River Basin with a completion date of March 31, 1971. Other support programs include hydrological and physical modeling studies at Colorado State University and design and evaluation studies at Denver University.

In addition to these programs, there are many technologies being developed for a variety of agencies, in both Government and private, which do lead to the eventual and hopefully soon major operational programs.

One of these is the treating materials, which was just referred to, primarily being developed at the Naval Weapons Center at China Lake. These are the pyrotechnics which are easily dispensable from either the ground or the air in controlled amounts.

We also have the production of nucleating materials going on at Colorado State University, the Naval Weapons Center, and so forth.

In addition to these, once these materials are produced, we have the problem of delivery of these materials.

And we have to understand the cloud response to the nucleation problem.

Also, the precipitation targeting problem is very important.

The trace analysis program previously referred to is becoming an important part of most research programs, and also of any operational program that should be undertaken. I think it will play a very major role there.

We have the problem of airborne nuclei detection. This allows us to take an airplane and nuclear counter to trace the plumes of the material, even after they have gone through the clouds, to pick up the residue on the other side of the experiment and determine what goes out the other side, to some degree.

In addition to this, we have many types of new cloud physics instrumentation which allows us better looks at the individual clouds.

We also have the increasing understanding of how the precipitation is read out on the ground.

Senator CANNON. What procedure does the Bureau follow in selecting the private concerns to participate in these programs that you have just been describing?

Dr. STINSON. These are primarily in response to the planning documents of the Bureau of Reclamation, which are circulated to all agen-

cies, private concerns, on request if they weren't active in the field. If they are active in the field, they get these, anyway, to which we have received many proposals. And the proposals are the primary basis of the action.

Senator CANNON. What reporting is required by the Bureau?

Dr. STINSON. The report that is required by the Bureau is in part determined by the contractor, based upon how he chooses to be paid. If he chooses to be paid by the month, then there is a monthly report. These reports go all the way from a letter to an extensive document.

If the contractor wishes to be paid on different intervals, he can have a different contracting option, or reporting option.

At the most recent Skywater Conference conducted by the Bureau of Reclamation, in Denver, the consensus of opinion appears to be that it was now time to begin prototype operations, that this was considered to be the next logical step in the orderly development of operational weather modification.

It was further discussed and generally agreed that one of the important places to begin such an operation is in the Colorado Rockies. And it was the general consensus from this conference that large-scale operations be based upon the consensus of what was learned from these pilot programs.

Senator CANNON. Have the results of that conference been published, or been made available?

Dr. STINSON. The conference results are in the process of being prepared. The timelag between when the conference is held and the report is made is some place between 3 and 5 months. This will become available to the general public.

Senator CANNON. Were other agencies participating in that conference, as well?

Dr. STINSON. This conference included representatives, from all of the agencies participating in weather modification, to our knowledge. There were representatives of all of the Bureau of Reclamation contractors, a number of specific scientists, who are not necessarily involved in weather modification, some engineers not involved in weather modification, representatives of private industry not involved in the Bureau of Reclamation program, some universities not involved in the Bureau of Reclamation program, and some Government agencies which have their own program.

Senator CANNON. Now, are there any plans to expand that pilot program to other arid areas?

Dr. STINSON. The general consensus was that if this was the logical step, two areas were primarily ripe for this type of pilot program. That was the Sierra Nevada of California, and the Colorado Rockies, particularly in the upper reaches of the Colorado River Basin.

Limiting clauses in S. 373 under section 303 (a) and (b) would, in my opinion, severely restrict the performance of pilot programs of the type urged by the recent Skywater Conference.

Under section (a) the 150-mile limit seems arbitrary and overly restrictive at a time when learning about the causes of such effects is becoming increasingly important.

It should also be pointed out that secondary effects can also be the source of useful water in the case of precipitation augmentation. Section (b) seems unduly restrictive in that it requires congressional

approval before a Federal agency conducts weather modification operational activities which, from the definition given on page 3 of operations given in section 102, could possibly be interpreted to include experiments as well as operations designed to achieve a planned and continuing substantial result of social, economic, commercial, biological, or medical significance. Large-scale continuing experiments or pilot operational programs would appear to be controlled by this proposed legislation.

This might cause some delay long beyond our scientific and operational capability to conduct such experiments.

S. 2058 would clearly authorize a large-scale operation in the Upper Colorado River Basin and would meet the requirement of section 303 (b) requiring congressional approval before a Federal agency conducts weather modification operation activities, but might cause some confusion in light of the procedures under section 303 (b).

My particular response to Senator Magnuson's suggestion that it would be helpful to have my views on the AMS statement on weather modification is that, while S. 373 would establish definitive rules for the various Federal agencies' roles in weather modification and authorizes funds for the programs, the restrictive clauses may cause delay in the conduct of the critical experiments which provide the basis for early large-scale operational weather modification programs such as the one described in S. 2058.

It is my opinion that weather modification can and should play an important role in augmenting ground water supplies and the alleviation of weather disasters. Further, I believe that adequately funded, well planned and soundly directed problem-oriented programs should give the earliest possible operational programs.

I think this concludes my statement.

Senator CANNON. Thank you, Doctor.

What do you consider would be adequate funding there, where you say "an adequately funded program"?

Dr. STINSON. Adequately funded, in this definition, includes the ability of the scientific and industrial community to do meaningful work. This would include the number of scientific proposals, the number of students developed by the various universities, it would include the urgency of the program. The more urgent the problem, the more rapid the funding would have to be.

It is my opinion that we are now lagging behind what is the optimum amount of funding to develop this program. We now have a situation in which the personnel does not seem to be the restrictive requirement it was before. We have many applications from scientists and engineers who would like to put their talents into these programs, and the funds are inadequate for this.

We have many useful proposals which can't be funded at the present time. And we are probably delaying the eventual operational weather modification programs where we actually know exactly what we are doing for some years by our present policy, present funding.

Senator CANNON. I take it from that, that you don't have a specific dollar tag that you could give us?

Dr. STINSON. I think that in my opinion this amount currently, as far as the Bureau of Reclamation program, would be in the order of \$10 to \$12 million, which would be an optimum number, considering

the talent. And I think if you look to the whole community in general, a number at least double this for the next fiscal year would not be out of order.

Senator CANNON. Thank you very much, Doctor, for your very fine testimony.

I think we will take a 10-minute break now, and then we will resume with the witnesses.

(Short recess taken, proceedings continuing thereafter as follows:)

Senator CANNON. The hearing will come to order.

I have received a telegram from Mr. Ivan P. Head, manager of the Las Vegas Valley Water District. He says:

Regret I am unable to appear before you this morning in support of S. 373 and S. 2058. Referring to my testimony in Las Vegas on S. 23, November 5, 1965. Urge that every means of augmentation of Colorado River flow be fully explored. Weather modification I believe at top of list priority.

(Signed) IVAN P. HEAD,
General Manager, Las Vegas Valley Water District.

The next witness will be Dr. George S. Benton, Director of ESSA Research Laboratories, Boulder, Colo.

Doctor, we are happy to have you here today. You may proceed.

Dr. BENTON. Thank you, Senator Cannon. With your permission, I would like to expand and briefly summarize my prepared testimony.

Senator CANNON. All right.

**STATEMENT OF DR. GEORGE S. BENTON, DIRECTOR, ESSA
RESEARCH LABORATORIES, BOULDER, COLO.**

Dr. BENTON. My name is George S. Benton. I am Director of the Research Laboratories of the Environmental Science Services Administration.

These 14 research laboratories, and their supporting research flight facility, exist across the United States, but are headquartered in Boulder, Colo. Several of our laboratories are engaged in programs which relate to weather modification.

At the meeting of this committee in Denver on June 14, the Deputy Administrator of ESSA, Dr. Werner Baum, presented the views of the Department of Commerce with respect to bills S. 373 and S. 2058. As Dr. Baum indicated, my testimony will be directed toward the ESSA technical program.

ESSA endeavors to conduct a comprehensive program in weather modification. Our efforts are primarily directed toward four areas of modification: (1) precipitation characteristics, (2) tropical storms and hurricanes, (3) severe local storms, and (4) large-scale and climate modification.

Major activities in weather modification in this and other countries are presently concerned with the exploitation of the basic cloud seeding capability to improve our water resources. Numerous field projects, supported by private sources and by Government agencies, are underway throughout the world not only to produce rain or snow in specific locations, but to gain a better understanding of the physical, statistical, and quantitative aspects of the precipitation mechanism. ESSA has concentrated on certain important concepts which, if fully developed, may lead to major breakthroughs in a comprehensive national

weather modification program as contemplated by S. 373. I would like to describe here two of our field projects concerned with the modification of precipitation.

Under proper conditions, sudden mass transformation of liquid water into ice by massive overseeding releases enough heat to raise the buoyancy of the cloud to the point where it develops into a new large system of considerable vertical and horizontal extent. This new cloud mass may ultimately produce much heavier precipitation than normal seeding of the original cloud would have produced.

In ESSA's tropical cumulus project over the Caribbean Sea and Florida, "explosive growth" of cumulus clouds has been achieved in a predictable fashion. The success of such an operation is essentially a matter of applying quantitatively within a cloud, the proper amount of silver iodide, at the correct elevation and time. These are dependent on atmospheric conditions given by such parameters as cloud diameter, temperature, and humidity lapse rates. Simple computer models of convective clouds have been successfully used in quasi-real time in this project.

A similar technique is applied in ESSA's Great Lakes project, though with an entirely different purpose. Severe snowstorms form east and south of the Great Lakes from the so-called "lake effect." Before the lakes are frozen over, cold air masses from Canada pick up large amounts of moisture and heat while crossing the lakes. The temperature excess of the water surface over the air may reach 20° centigrade. Organized convective systems develop in massive cloud-bands and dump the moisture in the form of snow along the shoreline. This snow is of a particular type, growing by the accretion of supercooled droplets. Due to its form and density, it has a high fall velocity. Sufficient seeding by silver iodide should prevent this type of growth and instead form numerous small ice crystals growing directly from the vapor phase. These fine particles have a low fall velocity and should redistribute the precipitation over a large area downwind of the lakes, relieving the coastal communities from severe snowfall. The first seeding tests are expected late this year. The stationary character of this phenomenon, which may last up to 48 hours, makes it technically one of the more feasible weather modification projects. We anticipate at least two more winters of field activities. If successful there should be beneficial applications in many parts of the world. Redistribution of snow is likely to become of increasing importance and to reach the operational stage in the 1970's.

Coming now to the second field of activity, I would like to describe our efforts to modify tropical storms and hurricanes.

ESSA is much concerned about the terrible toll hurricanes have taken in our Nation over the years, and hurricane mitigation is an important part of our weather modification program. Project Storm-fury, a large cooperative effort of several Government agencies, is essentially designed to disturb the energy balance of hurricanes by creating changes in the hurricane eye, or by causing artificial asymmetries or competing circulations. This is done by massive overseeding of specific parts of the supercooled cloud masses around the eye and the periphery of a hurricane.

At this time there is no firm theoretical or experimental basis to predict that the next decade will indeed bring us practical modifica-

tion of hurricanes and typhoons. However, progress in mathematical modeling, in the physical understanding, and in the prediction of the hurricane path has been quite encouraging over the last few years. The problem appears important enough to continue present experimental and theoretical efforts and to explore some new possibilities indicated by our rapidly developing technology. One approach under consideration is the investigation of the formative stage of hurricanes by a combination of aircraft and satellite probes. A new impulse has been given to this type of research by the advent of the synchronous satellite which is capable of monitoring a specific storm continuously—that is, at intervals of the order of 10 minutes. Furthermore, the water vapor flux from the ocean surface, the primary energy source of a hurricane, needs to be explored with the implication that deliberate interference with it may affect the development of the hurricane.

It is interesting that this problem, like many others in weather modification, is closely related to the problems of the world weather program. In its global atmospheric research program, the world weather program foresees a series of field projects to explore the ocean/air interaction. We expect a close cooperation between the weather modification and the world weather programs.

The third major area of our activities is concerned with the modification of severe storms including the suppression of major damage from hail, tornadoes, and lightning. The basic difficulty in severe storm modification is a lack of understanding of the dynamics of squall lines and tornadoes. A major effort is being made by our National Severe Storms Laboratory to eliminate this deficiency. The technology of observing the inside of these giant storms and of handling the mass of collected data without delay has been perfected in the last year to the point where we can hope to make major progress.

The primary problem in combating tornadoes lies in its very localized, rare, and short-lived nature. They occur inside or in the proximity of huge convective storms. As a consequence, tornadoes are hard to observe.

At the present time, we are exploring the possibility of attacking this problem by advanced tornado tracking systems based on a combination of acoustic and electromagnetic sensors. This, in combination with a newly developed doppler radar capability, gives us hope of observing the birth of tornadoes inside a major storm. This, we feel, is a first step in the direction which may lead to eventual modification of tornadoes. At this time, however, we must state that no convincing concept exists for suppressing these phenomena.

Another important but difficult problem is the suppression of hail. In such areas as Colorado, damage by hail is an economic problem of major dimensions. Many have made claims, including Soviet scientists, that hail can be successfully suppressed by overseeding that part of the storm which carries the largest amount of supercooled water. If this water were transformed completely into ice crystals, then the falling solid particles would have little chance to grow to hail stones. The determination of the extent to which hail can be suppressed must of course come from field and statistical analyses. Both present considerable difficulties.

We are now engaged in a pilot project with the National Center for Atmospheric Research and Colorado State University, partially sup-

ported by the National Science Foundation, to find an answer to this problem. Hail storms in the vicinity of Boulder, Colo., will be observed from the ground and the air with advanced sensors, and airborne rockets will be used to modify critical sections of the storm. In this way we not only hope to analyze the effectiveness of the modification attempts but to develop advanced techniques for hail suppression. This will probably be the first time that hail modification experiments have been conducted while the storm is being monitored thoroughly. We anticipate that a national hail program will emerge from this pilot project with the ultimate objectives for making hail suppression operational in the next decade.

I would now like to discuss a third aspect of severe storms, namely, lightning.

It is generally assumed that cloud electrification is connected with the formation of solid precipitation, specifically of the type which grows by accretion of supercooled droplets. It is therefore not surprising that attempts are underway in many quarters to influence electric fields and specifically to suppress lightning by modifying this specific type of precipitation. This is a commendable goal, for if it were possible and practical to suppress lightning, specifically ground discharges, one of the main sources of forest fires would be eliminated. This, of course, is of major concern to the Department of Agriculture.

One of the pertinent concepts is to oversee the thundercloud—at the right time—to such an extent that small ice crystals predominate, and practically no supercooled water droplets exist. Since the simultaneous presence of both types of particles is generally considered necessary for the electrification of storms, there would be only a slow generation of electric charge. In addition, as charge accumulates, the ice crystals may start multiple corona discharges, before the field reached the breakdown limit required for lightning. Further laboratory and field investigations will be required to determine if a substantial reduction of lightning can be achieved by this method.

Preliminary field and laboratory experiments suggest that conductors of about 10-centimeter length may be required to reduce the field strength sufficiently for lightning suppression. Chaff needles have been released experimentally beneath thunderstorms, and changes in the electric field were observed. Although these results are encouraging, many operational problems will have to be resolved before we can be sure that such techniques can achieve practical and economical feasibility.

I will now discuss our efforts in the last group of our weather modification program; namely, large-scale weather and climate modification.

Of course, it is just as important to know what we are doing inadvertently to the atmosphere as it is to anticipate what the results of deliberate modification will be.

As a background for inadvertent modification I would like to say a few words on the steady increase of the CO_2 content of the atmosphere due to fossil fuel consumption. CO_2 acts much as the glass roof of a greenhouse. Doubling the CO_2 content will increase the average temperature of the lower atmosphere by about 2°C . and decrease that of the stratosphere by about 15°C . Worldwide, this would have a significant influence on the general circulation and consequently on

weather and climate. There are other events in the stratosphere which may contribute to climate modification: exhaust from supersonic transport planes and rockets will increase the water vapor content, add combustion products, and cause modifications in the radiation budget. One consequence of air pollution may be a global increase in the concentration of condensation and freezing nuclei modifying the microstructure of clouds and precipitation and their geographic distribution.

ESSA is setting up a secular measurement program—"benchmark program"—for a study of inadvertent weather modification. At present, three global stations, one in Hawaii, one in the Antarctic, and one in the United States, are following the trends of CO_2 and ozone concentration and of certain radiation parameters. Monitoring of condensation and freezing nuclei and of other substances, such as SO_2 will be added. For the future we plan to expand the network around the globe. By the end of the next decade, we should have a much better knowledge of the natural background and its change due to man's activities. We will also be in a better position then to apply quantitative reasoning to deliberate climate modification.

Of increasing significance for the 1970's will be the outcome of studies on large-scale weather modification. The term "large scale" refers to both time and space and includes seasonal and climatic changes affecting areas as large as a considerable fraction of a continent. If man should acquire this capability, the economic and social consequences would be of unprecedented magnitude indeed. At this time it is impossible to predict whether this capability is achievable. However, the potential impact of large-scale weather modification is such that these answers must be sought.

We are presently in the planning stage for an attack on large-scale weather modification which will require parallel research programs in five areas.

First, the state-of-the-art in mathematical modeling of the atmosphere has made such rapid progress in recent years that we are close to a physical understanding of the general circulation. By stepwise refinement—for example, of geographical features—realistic simulation is within our grasp. Already some explorative studies have been made by our Geophysical Fluid Dynamics Laboratory to derive atmospheric temperature changes following the modification of certain parameters such as albedo, solar constant, cloud cover, water vapor, CO_2 , ozone. We can expect that the next decade will bring a real possibility to explore the potential of large-scale weather modification and to guide experiments by computer modeling.

Second, our knowledge of the radiative properties of the atmosphere, the earth, and the ocean surface needs to be enhanced, both from the instrumental and the observational side. This is especially true for the upper atmosphere. Additional knowledge of radiation is necessary since the energy balance of the earth-atmosphere system can best be modified by altering radiative properties.

Third, the problem of achieving efficiency in large-scale operations demands study of promising and practical schemes to treat the atmosphere or the earth surface. Proposals, such as changing the albedo or the roughness and evaporation characteristics of vast areas of the solid, liquid, or frozen earth have been widely discussed, but run into unsurmountable logistic and technical difficulties. It appears more

attractive to focus attention on atmospheric levels where the "applied mass" can be kept manageable. "Chemical modeling" of the upper atmosphere is an open field. At this time it requires a better understanding of the neutral and ion chemistry of the upper atmosphere. ESSA's Aeronomy Laboratory and Space Disturbances Laboratory have a good capability in this promising field. Layers of the upper troposphere where there is supersaturation with respect to ice (but not to water) and where sublimation nuclei are lacking, will also be explored with a view toward the creation of large artificial cirrus shields.

Fourth, the technology of delivery and distribution systems needs to be more fully developed. Today it is possible to double the concentration of certain chemicals in the upper atmosphere by a single rocket of the Saturn Apollo class. However, to distribute and maintain such a modification over an extended period poses serious technological problems.

Finally, the consequences with respect to the social, economic, legal, and political impact must be thoroughly understood before direct steps are taken to modify the weather and climate on a large scale. This is a most difficult undertaking, embracing many disciplines of human knowledge. Also because of its global nature one may expect that large-scale weather and climate modification will be a matter of international concern.

The five avenues sketched here can be explored simultaneously. We hope that the next decade may give us a first answer to the significant question of whether or not man will be able to modify weather and climate on a continental or global scale.

In conclusion, I would like to point out that, in accordance with S. 373, ESSA will direct its future efforts toward a truly comprehensive program in weather modification with special emphasis on the modification and control of tornadoes, hurricanes, and other severe storms. We are determined to reach a full understanding with other agencies on a meaningful national program avoiding duplication of effort.

Thank you.

Senator CANNON. Thank you very much, Doctor. That was a very fine statement. We appreciate your being here today and giving us the benefit of your views.

The next witness is Mr. Robert Elliott of North American Weather Consultants, Fresno, Calif.

Mr. Elliott, we're happy to have you back with us again.

Mr. ELLIOTT. Thank you, Senator. I would like to make one small correction. North American Weather Consultants, with headquarters at Santa Barbara, Calif.

Senator CANNON. Santa Barbara, Calif. All right.

STATEMENT OF ROBERT D. ELLIOTT, PRESIDENT, NORTH AMERICAN WEATHER CONSULTANTS, SANTA BARBARA, CALIF.

Mr. ELLIOTT. Senator, since my testimony is short, I would like to read it.

Senator CANNON. All right, sir.

Mr. ELLIOTT. Mr. Chairman, and members of this committee, I am pleased to appear before you to present my views on these two bills

which may have an important bearing on the future of weather modification.

I am Robert D. Elliott, president of North American Weather Consultants, a private meteorological firm which has been engaged in weather modification and other meteorological work since 1950. I have served as a consultant to President Eisenhower's Advisory Committee on Weather Control and, more recently, as a consultant to the Office of Science and Technology to conduct negotiations for a weather modification project on the Indian monsoon in a drought area of that country.

My company has conducted some 150 project-seasons of cloud seeding operations, primarily in western mountain regions, aimed at increasing water resources for hydroelectric power generation, irrigation, and domestic water supply. In doing so we have earnestly endeavored to gather scientific information and to prepare detailed summary reports. It is partly on the basis of these projects, and similar ones conducted by other private firms, that the Advisory Committee on Weather in its 1957 report, presented optimistic conclusions about the effectiveness of seeding in western mountain areas, and the Panel on Weather and Climate Modification of the National Academy of Sciences in their 1966 report expressed conviction that the Federal Government should greatly increase funding of research in this field.

There has been abundant testimony on the economic benefits at even small fractional increases in water supply.

Benefit-cost ratios are astonishingly high, and it is no wonder that hardheaded management has been willing to assume the risks of contracting for weather modification. The penalty for not doing so was too great. It is my belief that if such projects had not been conducted, we would presently find weather modification research confined to laboratory and theoretical works.

I should like first to testify on S. 373. I recognize this bill as providing a means for putting Federal Government sponsored weather modification research and development on a sound basis. The bill outlines in some detail the missions to be performed by the Departments of Commerce, Interior, Agriculture, Defense, and State, and by such Federal agencies as the Federal Aviation Administration, and the National Science Foundation. Mention is made of research and development of means for increasing water resources, diverting hurricanes, and controlling tornadoes and hail storms. If all of these techniques come into being, they will certainly be of enormous benefit to the United States and eventually to the world.

At present, we are operational with respect to increasing water resources in limited watersheds. Here we basically know what we are doing, but we also understand the need for further research to sharpen our tools and improve the state of the art. This costs a considerable amount of money and the utility company, the irrigation district, or the local government agency is not in the business of funding research.

The prospects for attacking atmospheric water production on the scale of a major river basin is indeed intriguing. Further in the future, after considerable research and development, lies operational severe storm cloud control.

I should now like to discuss what I regard as a shortcoming of the bill in this present form. On page 8, under the heading "Commercial

Operations," I obtain the impression from the present wording that the private practitioner, who has supplied so much of the background justification for expanding Federal activities in weather modification, is being put into the position of someone who may now be interfering with these new activities. I submit that there are some long continuing privately sponsored cloud seeding projects in western mountain areas that should not be interfered with by new Government projects.

This brings me to the point that regulation, to be fair, should provide for an impartial hearing in cases of conflict between Government and private groups, as well as between Government groups. This bill puts various agencies very much into the weather modification business and it would certainly violate the principle of separation of powers for one such agency to exercise overall regulatory powers.

Parenthetically, I would add, the implication here is that the Department of Commerce and ESSA could be put into this position, and I am not casting any reflections at all on the capabilities of the Department of Commerce or ESSA.

This concern has been voiced in the past, in particular in testimony given on February 21, 1966, and again on March 26, 1966, in connection with bills relating to weather modification. There was presented a statement prepared by the Weather Control Research Association, which has recently been renamed Weather Modification Association, an association which includes on its membership roster numerous utility companies, irrigation districts, universities, local government agencies, and professional weather modification firms that are interested in, or directly involved with weather modification activities.

This statement pointed out that a separate regulatory or licensing commission should be established independent of any operational or coordinating Government groups.

The statement further emphasized the need to utilize private manpower in both planning and operations, and that full use should be made of the facilities of private industry and local government.

In another instance, in hearings before the Subcommittee on Water and Power Resources of the Senate Committee on Interior and Insular Affairs, on April 4, 1967, there was presented a statement prepared by the National Water Policy Committee of the American Society of Civil Engineers, suggesting that regulation of weather modification activities, government and private, should be vested in an independent Federal commission appointed by the President. The point was also made that—

to avoid initial premature and unwarranted restrictions in developing the application of weather modification, any regulatory information on weather modification research and operation and/or licensing should be established either prior to legislation by hearings before congressional committees or subsequent to legislation after adequate opportunity for hearings by all interested parties before the commission.

I see no reason to change these position statements coming from the nongovernment sector, and only urge that this portion of the bill be redrafted so as to include the formation of a Presidentially appointed commission to develop regulations by the procedure recommended in the above-mentioned American Society of Civil Engineer's report.

A second item appearing in S. 373 which I feel to be unfortunate, and which has occasioned questioning by those familiar with the field

aspects of weather modification, is section 303(a) on page 11. This section states that before any Federal agency conducts any weather modification activity intended to affect the atmosphere more than 150 miles from the source, it is necessary to send to various Senate and House committees a detailed report. This would impose an extraordinary burden on project planners.

In the present state of knowledge, it appears that under special conditions it is possible to obtain a strong, positive effect, localized in a line, 100 miles away from a silver iodide smoke generator source. This effect is in addition to the increases normally experienced 5 to 35 miles downwind of the generator, and no appreciable effect, plus or minus, occurs in the intervening region. This offers a potentially valuable addition to our arsenal of modes of operation for enhancing watershed snowpack. There is nothing extraordinarily hazardous, unusual, or threatening about targeting something 100 or even 150 miles away from the generators themselves.

I should like now to testify on S. 2058, Mr. Dominick's bill. This bill pertains explicitly to the Colorado River Basin. Our company experience has been primarily in the Sierras, the Cascades, and the Rockies; however, we did conduct seeding for 10 years in the Uinta Mountains, which are part of the Upper Colorado River Basin. An independent analysis of the results of this seeding showed that substantial increases in snowpack had occurred. There is no reason why productive weather modification work cannot be done in the Colorado Basin, and the need for additional water supplies there is quite evident.

Current discussions within the weather modification community suggests that projects fall into three categories. And, I might add parenthetically, that these three categories were discussed at the last Skywater Conference, which has already been referred to in Dr. Stinson's testimony. The three categories are: research projects, pilot projects, and operational projects.

Under the present Bureau of Reclamation program, all projects are of the research type; however, there is now no scientific or engineering reason against instituting pilot projects in the Colorado Basin. Nor is there any reason for delaying, until the research projects are completed, the start of pilot projects, or even operational projects subject to design studies. Indeed, there will be a continuing need for research projects concurrent with operations because the information feedback loop between research and operations is vital in improving the state of the art.

I feel this is a rather important point, that operations are not going to displace research.

At present my firm is under contract for a cloud seeding project which perhaps falls into the category of a minimal pilot project, although it is officially listed as a Bureau of Reclamation research project. This is the Hungry Horse project in Montana, in which the aim is to increase snowpack primarily for hydroelectric water resources for the benefit of Bonneville Power Administration and various other downstream water users. At present the methods being employed conform, or will soon conform, to best commercial practice.

In addition, several innovations have been investigated for development as possible operational tools. One of these has been the col-

lection of samples of snow and their analyses by a highly refined technique capable of detecting minute traces of silver in them. This technique has been developed at the Desert Research Institute here in Reno.

I might add parenthetically that Professor Warbuton has already made some comment on that.

From these collections it was discovered that the target area silver content of the snowpack was five to 10 times greater than that found upwind where only the natural background concentration of silver would be expected.

There are national reasons for concentrating on developing prototype and operational projects within the Colorado Basin. The growing population of the Southwest demands more domestic water supplies. From the agricultural viewpoint, production is in order in the face of a dwindling commodity surplus and in view of the Vietnamese conflict.

I would like to suggest certain minor modifications of wording. On page 4, lines 22 and 23, I suggest inclusion of private research groups as well as institutions of higher education. Some private groups also have the required research and study capabilities.

On page 5, line 17, I suggest inclusion of business concerns, since they also have capabilities in evaluation. Some recognition should be given on the administrative level to the need for the performance of evaluation and of operations by separate groups, but the law should make provision for the necessary flexibility in decisionmaking at that level.

The timing of the commencement of pilot and operational projects requires careful consideration. For example, it is obligatory that funding for a winter project start during the preceding summer so that remote field instrumentation can be fully installed before snow becomes a problem.

Another factor is the need for a design study. The Bureau of Reclamation has one underway at present for the Colorado Basin.

That is the end of my testimony.

Senator CANNON. In other words, the planning agency has to have their funds available well in advance so that they can get set up and be prepared to become operational at a certain time?

Mr. ELLIOTT. That is correct, sir.

Senator CANNON. Now, we received your report on the Hungry Horse project in Montana. I wonder if you could make similar reports available to us on your work that may be designed to increase water resources in limited watershed areas?

Mr. ELLIOTT. I would be glad to do that.

Senator CANNON. It certainly would be of interest to the committee.

Of course, where you refer to the necessity of increasing the flow in the Colorado Basin area, I think that generally would apply to many, many other watershed areas, certainly right here in Nevada, and, of course, the areas that you have been working on in California.

Mr. ELLIOTT. Yes; that is correct.

And it's rather odd to me, in looking back at it, though, that so many of our projects have been in relatively water-rich areas. And I think that probably is only because the water resources have been developed, the reservoirs are available, and it is part of the system. All this is in

the form of potential for the future as far as Nevada is concerned and the Colorado Basin.

Senator CANNON. Well, thank you very much. We appreciate your being here and presenting your testimony today.

Mr. Elmo DeRicco, director of the Nevada Department of Conservation and Natural Resources, is unable to be here. We have Mr. Norman Hall here, the assistant director, who will present Mr. DeRicco's statement.

Mr. Hall?

Mr. HALL. Thank you, Senator.

STATEMENT OF ELMO J. DeRICCO, DIRECTOR, NEVADA DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES, PRESENTED BY NORMAN S. HALL, ASSISTANT DIRECTOR

Mr. HALL. Mr. Chairman and members of the committee, Mr. Elmo DeRicco, director of the Department of Conservation and Natural Resources, sends his regrets for not being able to be present at this hearing. My name is Norman Hall, assistant director of the Department of Conservation and Natural Resources.

Nevada, being the most arid State in the Union, has always been extremely interested in weather modification. This State is still 87.2 percent federally owned, mainly due to lack of water for agricultural development. We are not so optimistic as to believe that weather modification would make the deserts bloom, but just a small percentage increase of average annual precipitation or snow pack at a feasible cost would be of tremendous value to our agricultural, recreational, and social well-being.

The State of Nevada fully supports S. 373 and also S. 2058. Needless to say, the Colorado River is in deep trouble due to being overcommitted. It has been said that an increase of precipitation of approximately 5 percent would increase the average flow around 1 million acre-feet of water, which would be worth millions of dollars.

In 1961 the Nevada State Legislature authorized the department of conservation and natural resources to carry on weather modification research projects. The legislature provided that the counties within the area in which the project was under study would have to contribute at least 25 percent of the total cost of such research. It also provided that the director of the department of conservation and natural resources utilize the services, as much as possible, of the Desert Research Institute in such undertakings.

Such a research project started in the fall of 1961 on the upper reaches of the Humboldt River. The Humboldt River is the largest river totally within the State of Nevada. It originates in Elko County, in the eastern part of the State, and runs westerly some 300 or 400 miles, terminating in the Humboldt Sink.

Pursuant to the legislation, the department of conservation and natural resources entered into a contract with the Desert Research Institute to take on the full responsibility for carrying out this research project. In turn, the Desert Research Institute contracted with the North American Weather Consultants to do the actual field work.

The tabulation below shows the source of the \$211,750 spent during the 6 years of operation. And this tabulation was included, Senator,

just to give an indication of the interest up and down the Humboldt River in weather modification. I thought it was rather interesting to show the local finances that were contributed to this project:

State of Nevada.....	\$150,000	Ellison Ranching Co.....	\$500
Elko County.....	11,750	Humboldt County.....	10,500
Timothy Doheny.....	500	Petan Corp.....	1,000
T. S. Ranch.....	400	Blue Dick Sheep Co.....	50
Pershing County.....	1,000	W. T. Jenkins Co.....	500
Stevens Ranch.....	50	W. E. Licking.....	50
Doheny Ranch.....	250	Circle L. Ranch.....	500
Charles Norman.....	50	Willis Packer.....	100
Fernando Goicoechea.....	50	Joe Saval.....	200
P.X. Ranch.....	200	Saval Ranch.....	100
Salmon River Canal Co.....	1,000	Allied Land & Livestock.....	1,000
Lander County.....	2,500	Owyhee Irrigation District.....	6,000
Nevada Nile Corp.....	500	Elko Fair and Recreation	
Big Meadow Ranch.....	1,000	Board.....	3,500
Pershing County.....	9,500		
Pershing County Water Con-		Total.....	211,750
servancy District.....	9,000		

This was strictly a research project aimed at determining whether precipitation in the form of snow could be increased in the high elevation watersheds of the Humboldt River system.

The research project is still in progress. At the present time the Desert Research Institute has been analyzing the valuable data that has been collected. They are making a determined effort to conclude this project and develop a meaningful report.

In conclusion, the department of conservation and natural resources fully supports a properly funded and properly planned weather modification program as envisioned by S. 373. More expertise perhaps could be added if the Department of Defense, Corps of Engineers, was included as one of the participating Federal agencies.

Thank you for the opportunity to appear before you today.

Senator CANNON. Thank you, Mr. Hall, for presenting that statement. Our staff may have some questions that they might want to forward on to your department for responses for the record and, if so, we will do that.

Mr. HALL. We would be most happy to respond, Senator.

Senator CANNON. Thank you very much.

I have also received a communication from Mr. Thomas Rice, administrator of the Colorado River Commission. He regrets that he could not be here because of another meeting previously scheduled. He has forwarded a statement that will be made a part of the record at this point.

(Statement of Thomas R. Rice follows:)

STATEMENT BY THOMAS R. RICE, ADMINISTRATOR, COLORADO RIVER COMMISSION OF NEVADA

Mr. Chairman and members of the committee, it is a pleasure for me to present to your committee this statement in support of legislation concerning weather modification programs.

Nevada's economic position among the States of the Southwest is well established and is thriving. However, we, along with our neighbors in the other States, are continually concerned over the availability of water to meet the needs of our ever-expanding development. Southern Nevada in the past has experienced a phenomenal growth rate and at the present time is seeing a resurgence of this rapid growth.

Naturally, there is a limit to the extent we can go on our present supply of water. We can foresee in the not-to-distant future the time when our present water supplies will be inadequate to support further growth in our economy. We therefore look to means of augmenting the supplies available. We are encouraged by the work being done in desalination and we are very enthusiastic about the possibilities of augmenting our water supply economically through weather modification programs.

I have seen films and have listened to talks by experts in weather modification concerning the experiments being conducted in the Western part of the United States. I feel that anyone seeing these films and hearing these people must be enthusiastic about this means of increasing precipitation.

In the hearings which we held in Las Vegas in November 1965 my predecessor Mr. Pat Head, presented a statement supporting weather modification programs and presented data concerning the runoff and flow on the Colorado River in recent years as compared with long-term averages. I will not repeat those figures for you at this time. Mr. Head is also making another statement for your committee today.

The Colorado River Commission of Nevada fully supports and urges your favorable consideration of legislation to implement weather modification programs and to continue research and data collection in this area.

I thank you for the opportunity to present this statement to you.

Senator CANNON. Now, we have statements, also, from Dr. George Reynolds, Utah Research Laboratory, Logan, Utah; and a statement from Dr. Merlin Williams, Department of Atmospheric Science, Fresno State College, Fresno, which will be made a part of the record.

(Statements of George W. Reynolds and Merlin C. Williams follow:)

JUNE 12, 1968.

HON. HOWARD W. CANNON,
U.S. Senator,
4024 Federal Bldg., 300 Booth St., Reno, Nev.

DEAR SENATOR CANNON: This is in response to a letter (June 3, 1968) from Senator Warren G. Magnuson inviting my comments on S. 373, S. 2058, and H.R. 9212.

Attached for your consideration are comments, suggestions, and questions each for S. 373 and S. 2058. H.R. 9212 has not been discussed directly, since most of the remarks pertaining to S. 373 also apply to H.R. 9212. As indicated in these remarks, S 373 seems preferable to H.R. 9212, since it specifies the amounts of funds.

Although I was already somewhat familiar with these bills, I know very little about the details of legislative procedures. Consequently, some of my comments and suggestions may be unreasonable from this viewpoint.

In addition, I am not informed concerning the detail of the background investigation and the recommendations of the various departments and agencies that preceded the framing of these bills. As a result, no doubt at least some of the comments, suggestions, and questions, have already be considered.

It is hoped that the profusion of remarks will not be taken as a disapproval of these bills. I feel that they are highly desirable, would be quite effective exactly as written, and the cost-benefit ratios would be heavily in the favor of the American taxpayer. I am sure that some of my remarks would be significantly modified, or even deleted, if I knew all of the particulars.

Perhaps it should be noted that S. 373 and S. 2058 are not considered to be mutually exclusive. That is, the passage of one does not obviate the desirability of the other.

It should also be noted that the opinions expressed are entirely my own, and they should not be considered to be in any way an expression of the attitude of the University.

If further information is desired, please do not hesitate to ask.

Sincerely,

GEORGE W. REYNOLDS,
Professor of Meteorology, Utah State University.

COMMENTS ON S. 373, A BILL TO PROVIDE FOR A WEATHER MODIFICATION PROGRAM, JUNE 12, 1968

A. *Title I, Sec. 101, page 3, lines 11-16.* The following comments are based upon the interpretation that this paragraph directs the President to shift the "Functions of Federal Agencies," as outlined in Title II, Sec. 201, as he sees fit.

Although one cannot argue against doing the "necessary," the decision that an action is necessary is often somewhat arbitrary and usually subjective. An action that is necessary to one may even be considered undesirable by another.

Continuity of support is one of the most important requirements for productive research. There is almost certain to be some loss of continuity if there is a change in the managing agency. Not only is there usually at least some shift in emphasis, but there are actually in-house changes in the personnel carrying out the objectives. The possibility of this transfer is deleterious to the morale of the working and directly managing scientists, and it encourages higher level personnel to spend too much time trying to generate a self-favorable transfer of functional responsibility and in self-protection against an unfavorable transfer.

Therefore, it is felt that, insofar as it can reasonably be accomplished, S. 373 should discourage, but not forbid, "the transfer of a function of any department"

B. *Title II, Sec. 201, page 4, lines 7-11.* The following comments are based upon the interpretation that this paragraph authorizes a "comprehensive program" which specifically includes, but is not restricted to the modification of "tornadoes, hurricanes, and other severe storms." That is, by this charter, the Department of Commerce may carry out activities specifically authorized for one of the other departments or agencies. The omission of the word "comprehensive" from the assignment of all of the other groups seems highly significant.

The most obvious overlap is with the Department of Agriculture's assignment with respect to lightning and hail, but the authorization for "a comprehensive program in the field of weather modification," without specifically limiting the areas of activities, invites redundancy and undesirable competition with other departments and agencies.

The purpose of this unrestricted statement may have been to allow for research in areas not specifically mentioned in Sec. 201. Isn't this contingency provided for in the charter for the National Science Foundation?

It is believed that Department of Commerce weather modification activities authorized by S. 373 should be limited to tornadoes, hurricanes, and other severe storms, with lightning and hail specifically excepted as parameters of primary interest. An alternative to this exception is to specifically assign the responsibility for lightning and hail to the Department of Commerce, with no assignment for the Department of Agriculture. This is probably more reasonable, since it is very difficult to separate lightning and hail studies from severe storm studies. That is, lightning nearly always and hail often are expected in severe storms. Further, one would expect ESSA to be better manned and equipped to carry out this research.

C. *Title II, Sec. 201, page 4, lines 19-23.* It seems to me that "the protection of vegetation from the effects of other weather phenomena" is an ordinary interest of the Department of Agriculture, and therefore not properly chargeable to S. 373.

D. *Title II, Sec. 201, page 4, lines 24-25, and page 5, lines 1-3.* It seems to me that air pollution control should be omitted from this bill. Although it is obviously an atmospheric phenomenon, it is quite different from all of the other kinds of weather control and modification under consideration in this bill. In general, S. 373 is concerned with trying to change natural cloud systems. With respect to air pollution, the modification is of an artificial phenomenon, and it may be accomplished simply by shutting off a valve, screening contaminants, improving incineration, etc.

The assigned programs of the other departments and agencies are meteorological and highly related with respect to the governing scientific principles. It does not appear to me that this paragraph limits in any way the techniques to be used to control "air pollution and other deleterious effects of urbanization upon the composition of the atmosphere." That is, it seems to be talking about air pollution control by any method. Therefore, most of the appropriate actions for air pollution modification will involve the application of totally different, unrelated concepts.

It is my impression that the Congress has already provided considerable funds for the study and control of air pollution. Shouldn't any additional activities and funds be included in the same package in order that the portion of our wealth going into the solution of this important problem will be readily recognizable? Shouldn't the research be managed by the same groups in order to assure continuity and the proper assignment of priorities, as well as to avoid redundancy?

It is believed that consideration should be given to the removal of this paragraph (d), from S. 373. An alternative consideration would be to limit the air pollution activities to those projects which are similar in principle to those to be undertaken by the other departments and agencies, as authorized by this Bill.

E. *Title II, Sec. 201, page 5, lines 4-11.* Are "operational activities" (paragraph (2)) excluded from "a program" (paragraph (1))? If not, why is paragraph (2) included? If so, does this then mean that "operational activities" are not authorized for any of the other departments and agencies discussed in this section (201), since each is "authorized to carry out a program" or a "comprehensive program" or to do "basic and applied research"?

This is a very important issue with those who have been engaged in operational weather modification activities. It can be expected that unless the issue is clearly stated to the contrary, the management agencies will get a lot of pressure from commercial operators, and from groups who have an immediate recognizable need, to undertake operational activities. Operational activities, as used here, have the production of usable results, as opposed to the quest for useful knowledge, as the primary objective.

Although I feel that the improvement of the weather modification capability, and development of the recognition of just what the capability is, should be the primary objectives of S. 373, there are many who will not agree. Certainly, if there were any reasonable opportunity to destroy or weaken an approaching tornado, for example, "operational activities" would be obligatory, but perhaps with separate funds.

At any rate, in view of the inclusion of paragraph (e) (2) under discussion, it is recommended that consideration be given to whether similar statements should be included for the other departments and agencies, and perhaps whether the term "program" should be clarified with respect to its research, development, and operational connotations.

F. *Title II, Sec. 201, page 5, lines 12-18.* It is felt that the provision for the advancement of the state of the knowledge is highly desirable, and that the National Science Foundation is the proper agency. In my opinion, each activity of the departments and other agencies should specifically contribute toward a pre-defined practical objective. That is, each applied research activity should be part of an integrated practical program, in order to establish proper priorities. If accelerated effort is needed within a particular province, additional money should be assigned to the appropriate group, as opposed to the work being accomplished through the National Science Foundation, at their discretion.

Therefore, it is believed that the "applied research" activities authorized for the National Science Foundation should be limited to those projects not properly within the assigned provinces of any of the departments or other agencies.

G. *Title II, Sec. 205, page 8, lines 8-15.* This paragraph is not at all clear to me, since all commercial operators will be operating under "contract, lease, cooperative agreement, grant, or other transaction." Is the word "not" (3rd word line 11) a misprint? HR. 9212 reads the same.

"Encourage" (line 14) also seems improper. Will a regulation be effective without provision for its enforcement? If a commercial operator refuses to cooperate, the results of two or three years of previous, expensive research work could, but not necessarily will, be lost, since often the first year or two is spent in the design, installation, and checking-out of the support systems. The time loss alone might be very important, with significant effects on other projects not directly involved. That is, it is easily conceivable that whether or not Project B would be undertaken would depend upon the results of Project A, which was made fruitless after two years of preparation, by commercial operations.

Therefore, it is believed that reasonable authority should be assigned to these regulations.

On the other hand, would any such regulation be a federal infringement upon States' Rights?

H. *Title II, Sec. 205, page 8, lines 16-25.* This action is highly desirable. However, it should be expected that a report after only one year of study probably will be tentative in nature. Therefore, provisions should be made for additional recommendations probably, at yearly intervals.

I. *Title III, Sec. 301, pages 9-10.* In many cases, sufficient personnel, time, money, and facilities are not provided to allow proper planning for research activities, even though provisions for the subsequent field operations are adequate. As a result, information and time are lost, potentially successful projects fail or produce much weaker results, and the taxpayer in general is subjected to needless expense. A whole approach may be abandoned simply because improper planning failed to provide the necessary ingredients for success, with the subsequent argument that the activity was tried without results.

To be most effective, detailed plans must be generated by the organization that is responsible for their fulfillment. This principle should be as applicable to the comprehensive program proposed by S. 3723 as it is to a small research project.

Therefore, it is felt very strongly that a special Weather Modification Agency should be established for a program of this magnitude. This Agency should have equal official stature with NASA, the NSF, FAA, etc. It should not be a part of any of the groups receiving authorizations under Sec. 201. The Director should be a meteorologist with the broad background specifically compatible with weather modification research and operational activities.

It is felt that the Congress should specifically provide for this Agency as the first step toward the accomplishment of the objectives of S. 373, and that the selection of the Agency to implement S. 373 should not be left to the discretion of the President. The function of this Agency would be pretty well as outlined in Sec. 301, but it would start with laying out careful detailed plans for fulfilling the objectives of S. 373.

J. *Title III, Sec. 301, page 10, line 6.* Shouldn't there be recommendations each year, not just at the end of the 1st year? However, these recommendations could be negative. For example, "no additional legislation is needed or required."

K. *Title III, Sec. 304, p 12, lines 1-13.* This is an important and desirable proviso. Wouldn't the 1st report probably be tentative with subsequent reports highly desirable?

L. *Title III, Sec. 304, p 12, lines 14-21.* Can the results after two years be any more than tentative? Should S. 373 provide for additional reports?

M. *Title III, Sec. 304, page 12, lines 22-25, and page 13, lines 1-8.* Would this assignment more properly fall within the province and background of the Department of Agriculture, which has been doing plant and animal research for years? The NSF should also be ahead of the Department of Commerce in these disciplines, but the Department of Agriculture should be even much more advanced.

Even with appreciable effort, it will take for more than 2 years to determine the biological and ecological effects of weather modification. A useful report probably can be generated in 2 years, but it will be primitive and limited. For many of the geographical areas, the basic information is not even available. Since we are dealing with integrated effects on the lives of plants and animals, in many cases 5 years or more will be required to get even inferential information. Lest these statements be misleading, there is much that can be done on a more immediate basis, and therefore it is agreed that a tentative report in two years would be desirable.

N. *Title IV, Sec. 404, p 15, lines 5-9.* In my opinion, it is very important to establish specific amounts of appropriations well in advance. This is a distinct improvement of S. 373 over H.R. 9212. But even S. 373 doesn't go far enough, if the wording, "not to exceed," means that specific amounts are to be appropriated annually.

In order for the research scientist to use the money with maximum effectiveness, he must know in advance how much he will have to spend. Again, planning is exceedingly important. Since this research in particular must take several years for culmination, he should know how much he can expect to have during each of these years.

The Congress has many urgent matters to consider at the beginning of the fiscal year. This often delays the date of appropriation by months. Apparently, the Bureau of Budget then has the power to regulate the rate of release of these funds. The problem becomes especially acute with an accelerating program, such as this one. Operating at "last year's level," forbids the hiring of additional personnel, and the procurement of vital equipment until the new funds are authorized. In some cases the new monies have not become available until the fiscal year was more than half over. Until that time, at least certain government contractors did not know how much they would get.

The problem is further compounded by the delay in hiring key personnel, especially if they are associated with a university. They may have to delay

reporting by as much as 6 months, since they often must conform to the academic year. Delays are also quite common in the procurement of equipment and parts.

Another important factor is the seasonal nature of weather modification activities. For example, in general, equipment in the high mountains, within the Utah State University Experimental Area, must be installed between the 1st of July and early in November. On the other hand, the snowpack modification season is from November through April. These are nature's controls, and a delay of a few months in receiving funds may set a project back a whole year. Therefore, it seems highly desirable to establish the amount of monies to be available and for as long a period as is permissible.

O. *Title IV, Sec. 404, p 15, lines 7-9.* The amounts of money may seem large, but the required instrumentation, aircraft, etc. come high, and much and many highly qualified personnel will be required. To specifically comment on the amount of money is not proper without more detailed plans. Certainly, this much and more could be well spent on the fulfillment of the stated objectives.

From my viewpoint, it would be preferable to have the amounts of money specified for each department and agency. Some of these tasks are much more costly than others, and one would be better able to assess the cost-benefit ratios. However, such a breakdown no doubt was used in selecting these figures.

Should these amounts be reconsidered from the viewpoint of inflation between FY67 and FY69?

COMMENTS ON S. 2058, A BILL TO PROVIDE A PRACTICABLE WEATHER MODIFICATION PROGRAM FOR THE UPPER COLORADO RIVER BASIN, JUNE 12, 1968

Sec. 2, page 2, lines 10-13. Is it the purpose of this Act to actually "increase the supply of water" or to develop a "practicable weather modification program"? This question is not the quibble it may seem to be, since the approach depends upon the answer. The pressures put on the program management by commercial operators will also be much greater if it is not made clear that the objective is the development of a capability rather than the production of water.

In my opinion, the development of a practicable program should be the objective. Although it is widely accepted that precipitation can be increased by cloud seeding activities, we still have much to learn about the best way to go about it, the amounts of the increases, exactly where and at what rates these increases will fall, atmospheric conditions, receptive and non-receptive to cloud seeding, etc. Considerable additional detailed information on the specific characteristics of this particular experimental area, from the viewpoint of cloud seeding, is also needed. Of course, the needs for the future will be greater than those of the present, so we need to develop the best methods possible. It is felt that seeding strictly for the production of water will not be the most conducive to the development of optimum procedures.

Sec. 3, page 4, line 3. Is \$100 per day enough? You will be seeking top level people. Isn't this considerably less than the standard consulting rate for such persons?

Sec. 5, page 5, lines 5-10. This is a very important provision. However, is six months "after enactment of this Act" enough time for completing and reporting this planning study? Will the money be released immediately by the Bureau of Budget? Will it not be necessary for the Department of the Interior to recruit additional suitable personnel and perhaps negotiate contracts? Will a suitable contractor be available to start on the project immediately? My point is that planning is one of the most important phases, and to be done well will require the collection, organization, and interpretation of considerable and varied information. How much of this six months will be left to do this work, after the necessary administrative problems have been accomplished?

Sec. 7, page 6, lines 24-25, and page 7, lines 1-2. This paragraph wisely sets forth specific amounts for each year. This is a highly desirable provision in order to assure real continuity of effort. A definite 3-year program is usually much more efficient and productive than 3 one-year programs directed toward the same objectives.

The question does arise as to whether the amounts should be the same for each year. Would it be better to put part of the first year's money into the second year? Actually this is a question that can best be, and probably has been answered by the Department of the Interior. At any rate, the total amount, \$9,000,000 seems quite reasonable, both from the viewpoint of cost requirements and from the viewpoint of ultimate benefit to society.

Sec. 7, page 7, lines 4-6. The phrase in question is "for each \$1 expended on operational techniques." It is felt that it should be specified that these funds are to be spent on "the development and testing of operational techniques." This would leave no doubt in the minds of those who might wish it to be otherwise, that the authorized activities during this period are to be directed toward the improvement and development of weather modification techniques for the experimental area. That is, the project is concerned with the very near future, rather than the present.

STATEMENT OF MERLIN C. WILLIAMS, DIRECTOR, ATMOSPHERIC WATER RESOURCES RESEARCH, FRESNO STATE COLLEGE FOUNDATION, FRESNO, CALIF.

I feel that an appropriate beginning to my statement is to commend the Congress and this Committee in particular for their efforts to further the program in weather modification. The development and use of weather modification as a watershed management tool have not received the attention in many respects that the current state of the art warrants. Efforts to further develop and employ this tool in a professional manner at this time can provide both economic and social benefits.

Increases in water supply resulting from weather modification activities in distinctly orographic areas have been known for a number of years. Recognition of this fact has led to the conduct of commercial weather modification operations in the Sierra Nevada Mountains of California for the past 18 years. The number of such projects and the areas affected can readily be seen from the map given in Figure 1. The areas designated in this figure represent projects conducted for varying purposes and varying periods of time. One important feature, however, is the fact that two of these projects have been conducted continuously for more than 15 years.

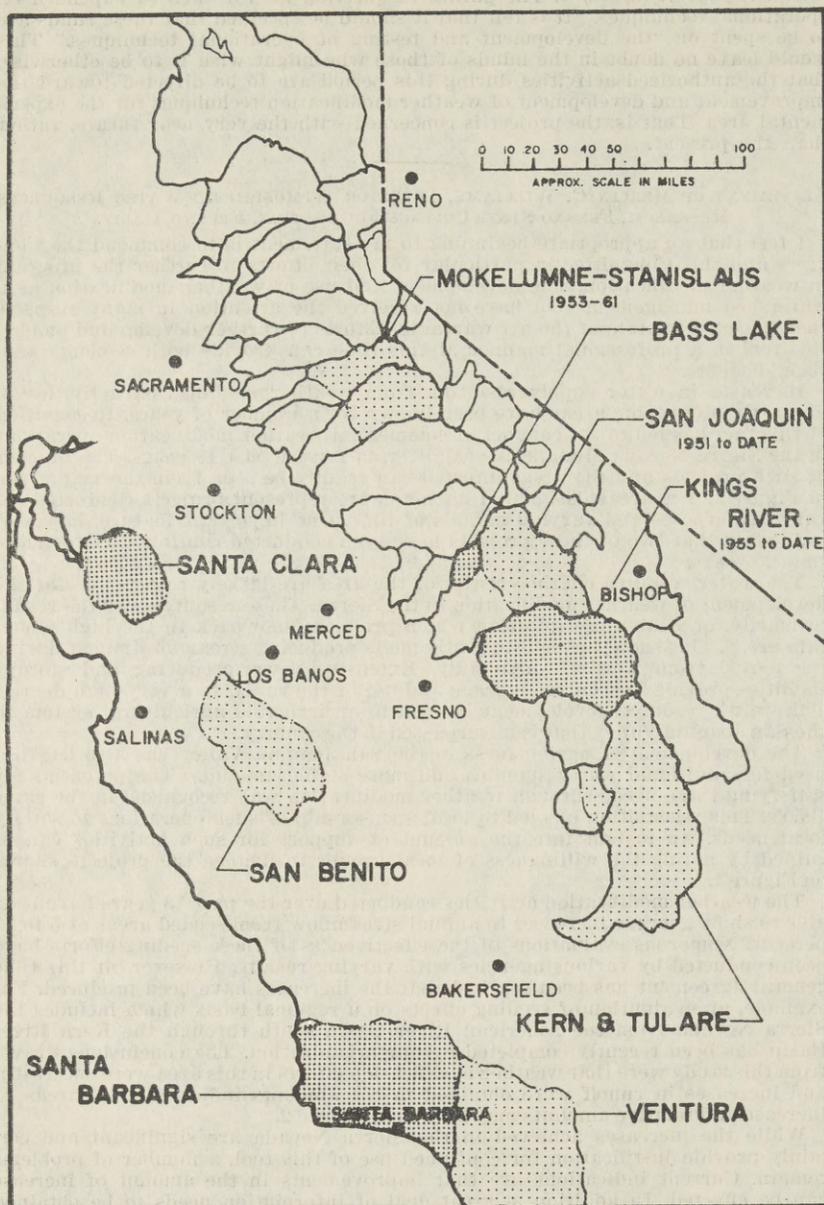
The water resource characteristics of the area are largely responsible for the development of weather modification in the Sierra. These resources are the result, primarily, of winter precipitation which produces snowpack in the high mountain areas. This snowpack subsequently melts producing streamflow runoff during the period from April through July. Extensive power-producing and storage facilities provide for control, storage and use of the runoff to a very high degree. This water resource development has led to an irrigated agricultural system in the San Joaquin Valley that is unsurpassed in the country.

The development of agribusiness in the San Joaquin Valley has also led to a need for additional water supplies and more stable amounts. The potential for satisfying these needs through weather modification was recognized in the early 1950's. This recognition has led to local sponsorship of such operations to satisfy local needs. An insight into the amount of support for such activities can be gained by noting the willingness of local groups to finance the projects shown on Figure 1.

The weather modification activities conducted over the past 18 years have been able to show average increases in annual streamflow from seeded areas of 5 to 10 percent. Numerous evaluations of the effectiveness of these seeding efforts have been conducted by various agencies with varying results. However, at this time general agreement has been reached that the increases have been produced. For example, an evaluation of seeding effects on a regional basis which includes the Sierra Nevada from the American River Basin south through the Kern River Basin has been recently completed by our organization. The conclusions drawn from this study were that weather modification efforts in this area were successful and increases in runoff were obtained in the amounts indicated. The areas of increase and relative amounts may be seen in Figure 2.

While the increases achieved in the Sierra Nevada are significant and certainly provide justification for continued use of this tool, a number of problems remain. Current indications are that improvements in the amount of increase can be effected. In addition, a great deal of information needs to be obtained regarding the mechanisms and parameters involved in successful seeding operations. Only in this manner can existing operations be improved and expanded to include other areas. Thus, while no requirement exists for operations to prove that weather modification is an effective means for producing additional water supplies in the Southern Sierra, significant research activities designed to optimize and expand current operations through detailed information are required.

It is toward this goal of optimization that the atmospheric water resources research at Fresno State College under the sponsorship of the Bureau of Reclamation has been directed. Activities during the past two years have concentrated



HISTORICAL SEEDING PROJECTS
CENTRAL PORTION OF CALIFORNIA
1951-1967

FIGURE 1

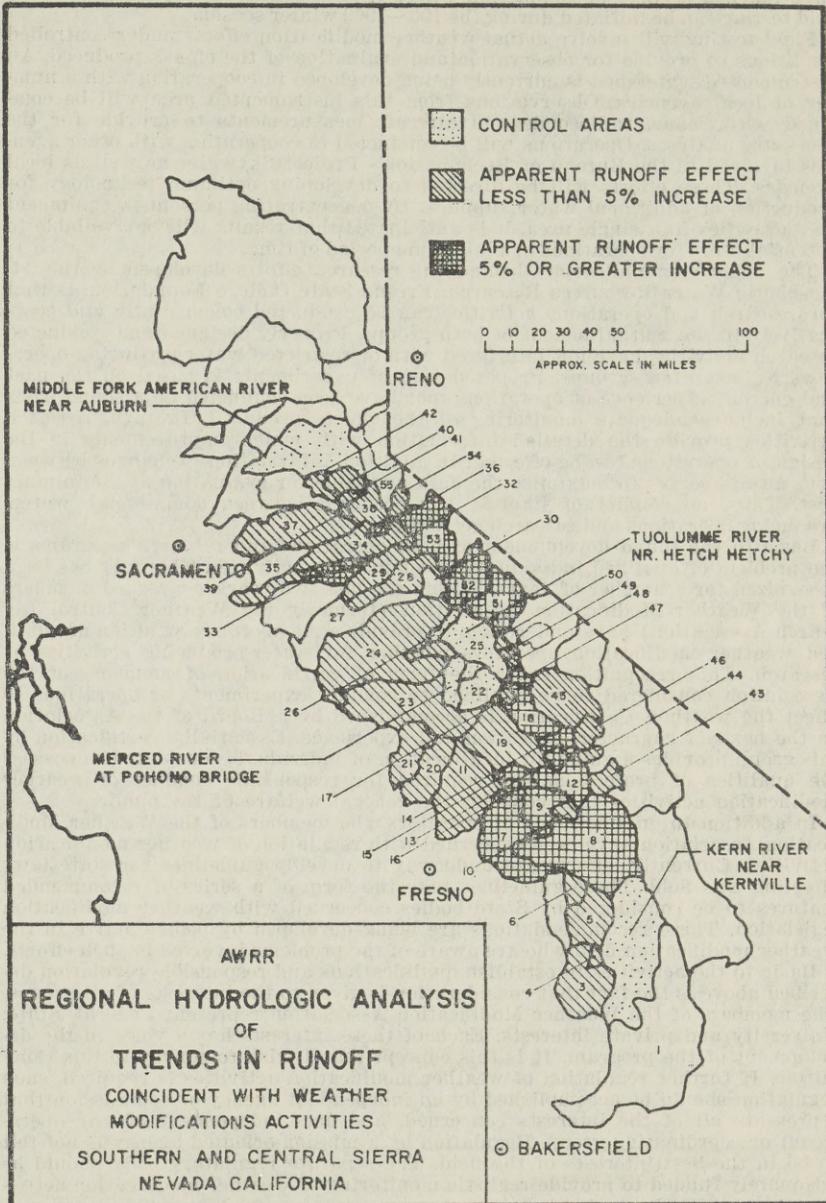


FIGURE 2

on the development of a detailed design for experiments to be conducted for this purpose. Included in these activities has been the development of equipment, techniques and personnel with which to carry out the program. These efforts have reached a stage of completion where it is now felt that operational scale field testing can be initiated during the 1968-1969 winter season.

Field testing will involve actual weather modification efforts under controlled conditions to provide for observation and evaluation of the effects produced. An instrumented watershed is currently being developed in cooperation with a number of local agencies. Observations from this instrumented area will be combined with radar, radiosonde and aircraft measurements to provide for the necessary analyses. Operations will be conducted in cooperation with other agencies involved in the Bureau of Reclamation's Project Skywater as well as local agencies. These efforts will be directed to developing optimum technology for production of additional water supplies. By concentrating personnel, equipment and activities in a single area, it is anticipated that results will be available to potential users for operations in a minimum period of time.

The underlying philosophy behind the research efforts developed by the Atmospheric Water Resources Research, Fresno State College Foundation, is that the research and operations activities can be conducted concurrently and cooperatively to the mutual benefit of both groups. Properly designed and conducted research activities have not interfered with or restricted water-producing operations by competent groups. Proper design of experiments is based on the past and current experience of operations that have been conducted on a sound basis that includes adequate monitoring of the effects produced. In turn, research activities provide the detailed information with which improvements in the design of operations can be effected. In addition, information exchanges between both groups serves to maximize the data available for evaluation at a minimum cost. Thus, no conflict of interest has occurred between commercial, water-producing operations and research activities.

Basic to the sound development of both operations and research programs is the problem of qualified individuals to conduct the activities. This fact has been recognized for a number of years. Within the last two years, concerned members of the Weather Modification Association (formerly the Weather Control Research Association) have undertaken to provide a means for recognition of qualified weather modification operators whether for water-producing activities or research. This recognition takes the form of certification of members of the Association considered to be qualified to conduct experiments or operations to affect the weather. Certification is accomplished by a Board of the Association on the basis of character, education and experience. Essentially, certification by this group provides a guide for identification of individuals considered to possess the qualities of professionalism required for responsible conduct of weather modification activities that consider the general welfare of the public.

In addition to qualifications of operators, the members of the Weather Modification Association have been concerned with regulation of weather modification activities. Currently, efforts are underway to develop guidelines for state laws affecting this field. These guidelines take the form of a series of recommended features to be considered by State bodies concerned with weather modification legislation. These recommendations are being developed by people active in the weather modification field who are aware of the problems involved in such efforts.

Basic to the activities to establish qualifications and responsible regulation described above is the fact that consideration is given to the interests of all groups. The members of the Weather Modification Association represent Federal, State, University and private interests. Each of these interests has a voice in the development of the program. It is this concept that I wish to convey to this Committee. If further regulation of weather modification activities is required, such regulation should be accomplished by an independent agency or commission that represents all of the interests concerned, and acts independent of any operational or coordinating group. Regulation by a mission-oriented agency is not felt to be in the best interests of the field. The separate regulatory body should be adequately funded to provide realistic monitoring of weather modification activities. Summary to be read at hearing.

Senator CANNON. Is Mr. Williams here?

Mr. WILLIAMS. Yes, Senator.

Senator CANNON. Would you care to summarize from your state-

ment? If so, we would be very happy to have you make a statement, as well as making your statement a part of the record.

Mr. WILLIAMS. I really have nothing more specific to add than already given in my written statement. Most of the things have been very adequately covered by the other speakers this morning.

**ADDITIONAL STATEMENT OF MERLIN C. WILLIAMS, DIRECTOR,
ATMOSPHERIC WATER RESOURCES RESEARCH, FRESNO STATE
COLLEGE FOUNDATION, FRESNO, CALIF.**

Mr. WILLIAMS. I would like to point out that we can't ignore the fact that operational programs have been taking place for a number of years, particularly in the Sierra Nevada.

And our particular research activity has been designed with the feeling that research and operational activities can be carried forth concurrently and cooperatively, and to the mutual benefit of both groups. The results that are obtained from operational programs can be utilized as a basis for designing good, solid experiments with which to further the field and optimize the results and the technology currently available. By the same token, the research efforts that are going forth in the Sierra can be utilized to upgrade and improve operational techniques that are underway.

I have also made some statements with regard to the Weather Modification Association's activities during the past 2 years, with respect to State regulations and the State laws pertaining to weather modification. Also, the activities by that organization to develop meaningful criteria for certifying certain individuals whom we feel are qualified to carry forth field activities, both research and operations, pointing out that the field itself recognizes a need for designation of qualified individuals and a need for regulation, and good, solid legislation.

Senator CANNON. Do you agree with others who have testified, who say that this regulation must be on a national scope, rather than State regulation, to really get at the problem?

Mr. WILLIAMS. To an extent, I do. Without really having a detailed knowledge of current regulatory practices, other than the studies that are being conducted by the WMA, this seems to be a desirable feature at this point. However, I would like to reiterate the statement of some of the other speakers, that studies of regulations, and regulation itself, should be carried out by an independent commission or agency that represents all of the interests involved, those of Federal, State, university and private interests, rather than being placed in a mission-oriented agency.

This is the position taken by the WMA, the ASCE, and most of the people that I know, including the Atmospherics, Inc. people, who are unable to be here today. They take this position, that this should be an independent agency.

If I may, I would like to read the summary to my paper.

Senator CANNON. All right, sir.

Mr. WILLIAMS. In summary, I feel that excellent progress has been made in the field of weather modification in the past few years. This progress has brought the field to a point where it is now possible to develop projects which apply the best technology and equipment avail-

able to the problems of optimization of weather modification activities designed to produce additional water supplies. Vast amounts of information requiring detailed research activities are necessary to provide this optimization and the funding required for this research should be made available. However, sufficient information is currently available to permit operations in certain areas concurrently and cooperatively with research efforts.

Thus, an overall program which utilizes the talents of private, university, and governmental groups for parallel research operations can be used to advance the program. The development of an agency to regulate all weather modification activities in the Nation does not appear to be necessary or desirable if the progress of the past 2 years can be used as a measure of the ability of groups active in the field to work together toward a common goal.

The importance of water to most areas of western United States is such that concurrent operations and research should be conducted as soon as possible. The efforts of this committee to provide support for such activities should be developed and encouraged. And I personally endorse the proposed bills, S. 373 and S. 2058, with the qualifications regarding regulation of activities as stated above.

Senator CANNON. Thank you for your statement.

I perhaps should have asked this question of Mr. Elliott, but can you give me a figure as to what your water costs have been? You have operated some projects that have been both operational and from a research standpoint, joint project; is that right?

Mr. WILLIAMS. No, sir; we have not.

Senator CANNON. Oh, I thought you had. I'm sorry.

Mr. WILLIAMS. As yet our efforts have been totally research, and we have developed a program which utilizes the seeding activities of previous commercial operations. We intend to start seeding activities this coming year on a research basis.

As far as costs are concerned, the estimate given by the Kings River people for the Kings River project over the past 12 years has been on the order of 50 cents to a dollar an acre-foot. That's as opposed to the value of water in the San Joaquin Valley, which ranges up to, say, \$0.80 to \$1.20 an acre-foot. This is value to the farmers that are using it.

Senator CANNON. Mr. Elliott, would you like to respond to that question. What in your experience does the cost per acre-foot run, as best you can pin it down from an operational standpoint?

Mr. ELLIOTT. I would say that was in the correct ballpark. However, our clients don't like to spread that word around. It's too good.

Senator CANNON. One of the witnesses, I think in Denver, testified—of course, they were testifying on the amount of the increase in the flow that could come out of the Colorado River Basin, and I believe, if I remember correctly, we had estimates as low as about 30 cents an acre-foot, but anywhere from 30 cents on up, 30 to 50 cents, in that general area.

Mr. WILLIAMS. If I might, a great deal of the figure that you quote as the cost of producing this water depends upon how extensively you instrument to evaluate and to monitor what's going on during the time the activities are occurring.

The 50 cents to a dollar an acre-foot figure that I gave was published in a paper given in November to an ASCE meeting in Sacramento.

Senator CANNON. Thank you very much, Mr. Williams, for your appearance here, and your fine statement.

Is Mr. Thomas Henderson here?

Mr. Henderson, from Atmospherics, Inc., has submitted a paper, and that will be made a part of the record.

(Statement of Thomas J. Henderson, follows:)

JUNE 10, 1968.

PREPARED STATEMENT OF THOMAS J. HENDERSON, PRESIDENT, ATMOSPHERICS INC.,
FRESNO, CALIF.

Well designed and professionally operated weather modification programs will continue to play an important role in the full development of water resources in the United States. In the near future the importance of this relatively new science could well rate with space exploration, foreign policy, international aid or national defense. The field may already be that important. For this reason we feel S. 373 and S. 2058 are extremely important bills and deserve substantial in-depth considerations.

On a national level, there is an increasing general acceptance of weather modification by various members of the scientific community and there now seems to be general belief that current cloud seeding technology can inexpensively produce supplemental water under some rather specific and rigid conditions. I am sure you are familiar with the current positions of our scientific community but for the record, and perhaps a few members of your staff, the following excerpts will reemphasize the present level of understanding.

1. "Weather and Climate Modification, Problems and Prospects", Vol. II. Research and Development Publication No. 1350. National Academy of Sciences, Washington, D.C. 1966, Pg. 32-33.

"Extended operational programs are found mainly in mountainous areas of the Western United States, where silver iodide ground generators have been used in the same areas continuously for many seasons to seed winter orographic storms with the goal of increasing winter snowpack. We checked four such projects, totalling 41 project seasons. In all evaluations the variates were seasonal watershed runoff values, obtained from the U.S. Geological Survey Record, with regressions based on nearby control watersheds for which runoff values correlated strongly (order of $R=0.9$) with the target runoff. Table No. 2 summarizes the Panel's independent evaluations of the four orographic projects (Kings River included), in which runoff was employed as the test variate. Project durations ranged from 8 to 14 years. The duration-weighted average runoff increases of these four projects is about 12% and it is apparent that their combined significance level is such that natural variability is not a likely explanation for these increases."

2. "Weather Modification—Seventh Annual Report, 1965", National Science Foundation Report No. NSF 66-4, Page 32.

"During the summer of 1965, an analysis jointly sponsored by the Kings River Conservation District in California and the National Science Foundation, has been completed for ten years of commercial cloud seeding operations carried out by Atmospherics Incorporated. The results indicate a 6% increase in the runoff into the Kings River Drainage area occurred due to the seeding of winter storms under orographic conditions. While many commercial operators have reported increases in precipitation over short periods of time, this NSF sponsored study is one of the first to indicate results over a significant long period of time. There seems to be every indication that under the conditions of operations in the Kings River drainage area, the use of silver iodide has enhanced the rainfall totals."

3. "Weather Modification—Seventh Annual Report, 1965", National Science Foundation Report No. NSF 66-4, Page 61.

"The Kings River drainage area of the Western Slope of the Sierra Nevada Range in California, provides an excellent natural study area for investigation of winter storms under orographic influence. During the past 10 years the Kings River Conservation District has given support to a full-scale cloud seeding program conducted by Thomas J. Henderson of Atmospherics Incorporated. This

grant supports a study of the physics of clouds and precipitation in this ongoing cloud seeding program. The object is to obtain a better understanding of the winter storm mechanisms and to provide a means of evaluating the results of the operation. Necessary aircraft support is provided by the Conservation District contract. An analysis has now been performed by Henderson on the ten-year results of the Kings River seeding operation and indicates clearly an increase of 6.1% in the runoff over an average ten-year period in which seeding was performed."

4. "Weather and Climate Modification—Report of the Special Commission on Weather Modification", National Science Foundation, Report No. NSF 66-3. Page 45-46.

"For the past ten years the Kings River Conservation District has supported cloud seeding programs by Atmospherics Incorporated in the Kings River drainage area on the Western Slopes of the Sierra Nevada Range in California. A grant from the National Science Foundation provided for additional measurements for study of cloud physics and precipitation. Recent analysis of the data indicates an average 6.1% increase in the runoff in the drainage area due to seeding for the period. This supports preliminary results of a research study by Colorado State University in the area of Climax, Colorado, and of other commercial seeding operations extended over shorter periods of time, that seeding can give a moderate increase in precipitation in orographic situations. An analysis of these and other seeding experiments is included in the National Academy of Sciences Panel Report."

I am hopeful that some of the above quotations may be helpful to you and your staff in providing basic information on the current status of weather modification technology. I further emphasize, we are no longer involved in projects designed to prove whether or not it is possible to enhance precipitation by cloud seeding techniques. This has been adequately demonstrated in the past 20 years, particularly so in the past two or three years with the development of improved materials and application techniques. Our goal now is to optimize this technology and move these increases upward from the apparent 6-12% levels.

In the eyes of some members of your staff, there still might remain two areas of concern. First, they might question that such programs have apparently succeeded over the Kings River area and perhaps in other mountain sections but this does not necessarily mean the technology can be applied to the Upper Colorado River basin. It seems apparent to us that, while snow and rainfall rates in the Upper Colorado basins are much less than in some areas of the Sierra Nevada Range in California, there is enough meteorological similarity in storms to provide the appropriate basis for a meaningful operational program. This belief is strongly substantiated by Mr. Lewis Grant's research activities conducted near Climax, Colorado, by Colorado State University.

The second question which might still concern many on your staff deals with whether or not cloud seeding results are worth the expenditure of funds. Answers to this are difficult and must necessarily deal with supplemental water above certain storage reservoirs as well as in adjacent areas. The problems are further compounded by factors dealing with multiple use water and lands. It must also deal with the total amount of water available in any given year. In the case of the Kings River area in California, if the value of water is placed at the modest \$5.00 per acre foot level, then the cloud seeding program has produced a ten-to-one return on the Kings River Conservation District's investment.

Similar estimates can be made for possible programs designed for the Upper Colorado River basin. For example, assuming an operational period of October through May the total annual cost for a field program designed to increase the water supply of the Colorado River would be approximately \$547,000 per year. This would include professional level personnel, radar surveillance, aircraft, ground generators, communications, support equipment, all necessary supplies, and a reasonable statistical evaluation. Assuming a minimum 5-10% increase in river flow due to weather modification activities, the cost benefit ratio appears similar to the long-term well-established program here in the Southern Sierra Range of California.

We feel that Senate Bill S. 2058 would provide sound legislation and promote the establishment of a meaningful weather modification program on the Upper Colorado River basin. We would heartily endorse its passage.

Senate Bill S. 373 does not provoke a similar enthusiasm. We are certainly in agreement with the general concepts presented in the bill but we are uneasy about possible implications in a number of its sections. Pages 1-3 state the neces-

sary fundamental philosophy precisely and well. We feel the statements provided on Pages 4-7 correctly and fairly delineate the responsibilities under the various areas of meteorological phenomena. Beginning with Line 8 on Page 8, we sensed our first uneasiness. Perhaps we are demonstrating an extreme bias but whenever we see the term "Secretary of Commerce", the implication of Weather Bureau or ESSA is instantaneous. With all due respect to current personnel under the Department of Commerce, their background has always indicated a persistent lack of enthusiasm for a bold and imaginative thrust toward the design, implementation, operation and evaluation of a meaningful weather modification operation. These strong feelings are the result of 20 years exposure in this particular field and we tend to be just a little "gun shy" when the terms "Secretary of Commerce" and "regulation" are used in the same sentence.

Fundamentally we would strongly oppose any legislation which allows an agency of the Federal Government to conduct weather modification operations and issue regulations governing the weather modification activities of private business. For this reason, we would strongly urge the formation of a separate 11-man regulatory board composed of representatives from the six federal agencies mentioned in S. 373, three members from universities currently engaged in meaningful weather modification research, and two certified consulting meteorologists from private business.

Weather modification is a subject of considerable importance to all of the people in the United States. In addition, we feel the implications on an international level are almost beyond imagination. We note the inclusion of this thinking in Lines 5-10 on Page 3 of S. 373. We suggest the field of weather modification can act as an international tool for peace much like the variety of "Atoms for Peace" programs. We would enthusiastically endorse federal projects oriented in this direction. Personnel in our group have dealt with weather modification and associated problems in great depth during the past 20 years, and we are hopeful those viewing the current technology and future problems will do so on a similar level. From this background of experience, we would be most happy to provide any information your committee might feel is appropriate to present and future federal legislation.

Senator CANNON. I also have a statement from E. Bolla Associates, Inc., which will be made a part of the record. This is from Mr. E. Bolla, president.

(Statement of Mr. E. Bolla, follows:)

E. BOLLAY ASSOCIATES, INC.,
23 West Micheltorena St.,
Santa Barbara, Calif.,
June 14, 1968.

U.S. Senator HOWARD W. CANNON,
4024 Federal Building,
300 Booth St.,
Reno, Nev.

DEAR SENATOR CANNON: At the invitation of Senator Warren G. Magnuson, I am submitting the following comments on S. 373 for the record of hearings that you are holding in Reno on June 17, 1968.

S. 373, as currently drafted, places both regulatory and operating authority in a single government agency. I believe it is generally accepted that this is contrary to good administrative practice.

S. 373 would place a major responsibility for weather modification in the Department of Commerce. I believe that each mission-oriented agency should have authority to do research on, and apply, those aspects of weather modification that contribute to the success of its mission.

With reference to the coordination of weather modification activities in this country, I support the suggested criteria and guidelines for legislation on weather modification, prepared for, and accepted by, the National Water Policy Committee, American Society of Civil Engineers:

- (1) We suggest that the regulation of all the weather modification activities (Government and private) be vested in an independent Federal Commission. It is considered undesirable for a Government agency to have the combined task of regulating private, university, and other Government agency's projects and conducting projects of its own. Principles in administrative law and sound management suggest that the regulatory functions should be

separated from operating functions. A good precedent for a regulatory commission exists in the case of the Federal Power Commission, established for regulation of the electric utilities. The Federal Communications Commission is another such example.

(2) It is recommended that such a Commission be created by Congress. This Commission should enforce the regulatory functions and would be appointed by the President and composed of distinguished private citizens.

(3) The Commission should have an Advisory Board consisting of prominent citizens active in the field of weather modification and from related business and professional activities.

(4) Each Federal operating agency should continue to plan its own programs in weather modification which should then be coordinated through the Interagency Committee on Atmospheric Sciences (ICAS) of the Federal Council for Science and Technology in order to fall within the budgetary limitations set by Congress. In order to avoid conflicts of interest the Chairman of ICAS should not be a member of an operating agency but should be selected from the staff of the Office of Science and Technology as in the case for the Committee on Water Resources Research.

(5) To avoid initial premature and unwarranted restrictions in developing the applications of weather modification, any regulatory limitation on weather modification research and operations and/or licensing should be established either prior to the legislation by hearings before congressional committees, or, subsequent to the legislation after adequate opportunity for hearings by all interested parties before the Commission.

(6) Any legislation should insure, by specific language, that planning and operation be conducted in such a way as to utilize fully the capabilities of universities and industries through grants and contracts. Consideration should also be given to the development of manpower, possibly by authorizing a specific portion of the funding under a title such as "contracts, grants, and fellowships."

Thank you for requesting my comments on S. 373.

Very truly yours,

EUGENE BOLLAY,
President, E. Bollay Associates, Inc.

Senator CANNON. Do we have any other witnesses here now who I have not called on, that were prepared to testify today?

If there are no other witnesses here to testify, that will conclude the hearings at this location.

The meeting will be adjourned.

(Whereupon, at 12:05 p.m. the hearings was adjourned.)

FEDERATION OF ROCKY MOUNTAIN STATES, INC.,
Denver, Colo., June 13, 1968.

Hon. HOWARD W. CANNON,
U.S. Senate,
Denver, Colo.

DEAR SENATOR CANNON: As Chairman of the Board of Directors of the Federation of Rocky Mountain States, Inc., I extend the appreciation of the Governors of the States of Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah and Wyoming, for this opportunity to advise your Committee of the Federation's support for legislation which will permit the development of an operational program in weather modification to augment the available sources of water for the Colorado River System.

The Federation of Rocky Mountain States, Inc. was organized in 1966 by the Governors of the Rocky Mountain States to promote the economic development of this vast area. At that time it was recognized that economic development of the Rocky Mountain States could not take place without full development of its limited water resources.

There are many arid areas in the eight Western States which require substantial supplies of water in addition to the natural rainfall. Only a comparatively small portion of the territory west of the Mississippi River enjoys enough regular precipitation to meet its needs. Consequently, the flows in our local streams and rivers are insufficient and must be supplemented by water from other sources.

If the Rocky Mountain States are to meet their challenge for growth, the future will require the importation of water, better use of existing ground water, reclamation of municipal waste water, desalination of sea water and multiple reuse of all water, but none of these alternatives offers the immediate potential of an operational program in weather modification.

Recorded estimates indicate that a weather modification program will make additional water available at a cost ranging from 50¢ to \$1.50 per acre foot. These costs are substantially less than any other available estimates of cost if the same amount of water were to be developed under any of the other methods identified above. Additionally, a program of weather modification can be undertaken with a minimum delay and without high operational costs.

In recognition of the population growth in several of our Western States, we must accept the fact that the requirements for new sources of water are already here. The present growth of industry in our eight states also highlights the need for an operational program now—not just more tests.

The relatively low density of population in the Colorado River Basin area is a strong factor in the support of using the region for the development of an operational weather modification program. Much of the additional rainfall and water flow would have limited effect on inhabitants of the area for much of the land is publicly owned. Accordingly any anticipated adverse results arising from the program conducted in the Colorado River Basin would be minimal at this time. It is also felt that there is today a greater public acceptance of the concept of weather modification because of the encouraging results attributed to the experimental programs and tests conducted to date.

Because water augmentation is one of our most pressing problems the Governors of the Rocky Mountain States seek every opportunity to develop new sources of water. Since weather modification shows great promise for benefiting all of the states at no particular expense or sacrifice to any one of the states, a consolidated position of support is possible. Uniquely, the potential of maximum good for all of the states is inherent in this kind of program. Although it is recognized that weather modification will not provide the entire solution to our regional water needs, it does in fact suggest an intermediate solution which will permit the states to use the borrowed time to plan imaginatively for substantial water importation from Canada and provide the time needed for the states to develop the cooperative plans that reflect the interdependence of the mountain states.

It is with this in mind that we submit this letter in order to recommend to the Committee that operational programs in weather modification be undertaken as soon as possible.

Sincerely yours,

STANLEY K. HATHAWAY,
Governor of the State of Wyoming, and Chairman, Federation of Rocky Mountain States, Inc.

