Y4
. C 73/2
89-58
GOVERNMENT
Storage
KSU LIBRARIES
A11900 501070
KANSAS STATE UNIVERSITY LIBRARY
MANHATTAN
DUE 13 1966

# WEATHER MODIFICATION

## HEARINGS

BEFORE THE

## COMMITTEE ON COMMERCE
## UNITED STATES SENATE

EIGHTY-NINTH CONGRESS

FIRST AND SECOND SESSIONS

ON

## S. 23 and S. 2916

BILLS RELATING TO WEATHER MODIFICATION

---

**PART 1**

---

NOVEMBER 5, 1965—LAS VEGAS, NEVADA, ON S. 23
NOVEMBER 10, 1965—ELKO, NEVADA, ON S. 23
FEBRUARY 21, 24, AND 25, AND MARCH 7 AND 8, 1966, IN
WASHINGTON, D.C., ON S. 23 AND S. 2916

---

**Serial No. 89–58**

---

Printed for the use of the Committee on Commerce

U.S. GOVERNMENT PRINTING OFFICE
59–528 WASHINGTON : 1966

AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

Y4
. C 73/2
89-68

## COMMITTEE ON COMMERCE

WARREN G. MAGNUSON, Washington, *Chairman*

JOHN O. PASTORE, Rhode Island
A. S. MIKE MONRONEY, Oklahoma
FRANK J. LAUSCHE, Ohio
E. L. BARTLETT, Alaska
VANCE HARTKE, Indiana
GALE W. McGEE, Wyoming
PHILIP A. HART, Michigan
HOWARD W. CANNON, Nevada
DANIEL B. BREWSTER, Maryland
MAURINE B. NEUBERGER, Oregon
ROSS BASS, Tennessee

NORRIS COTTON, New Hampshire
THRUSTON B. MORTON, Kentucky
HUGH SCOTT, Pennsylvania
WINSTON L. PROUTY, Vermont
JAMES B. PEARSON, Kansas
PETER H. DOMINICK, Colorado

GERALD GRINSTEIN, *Chief Counsel*
EDWARD JARRETT, *Chief Clerk*
JEREMIAH J. KENNEY, JR., *Assistant Chief Counsel*
RALPH HORTON, *Assistant Chief Clerk*
DONALD W. BRODIE, *Staff Counsel*



**Part 2 contains the hearings held in Denver, Colo.**

# CONTENTS


| | Page |
|---|---|
| Text of S. 23 | 1 |
| Text of S. 2916 | 80 |
| Statements of— | |
| Bates, Dr. Thomas F., Science Adviser to the Secretary, Department of the Interior, Washington, D.C.; accompanied by Dr. Archie Kahan, Director, Office of Atmospheric Water Resources, Bureau of Reclamation, Denver, Colo | 218 |
| Blatt, Joseph D., Associate Administrator for Development, Federal Aviation Agency, Washington, D.C | 244 |
| Booker, Dr. D. Ray, Weather Science, Inc., 1808 Newton Drive, Norman, Okla | 270 |
| Braham, Dr. Roscoe R., Jr., professor, Department of Geophysical Sciences, University of Chicago, Chicago, Ill | 289 |
| Byerly, Dr. Theodore C., Administrator, Cooperative State Research Service, Department of Agriculture; accompanied by Jack Barrows, Forest Service | 238 |
| Chamberlain, Dr. Adrian, vice president for administration, Colorado State University; Chairman, National Science Foundation Special Commission on Weather Modification, Fort Collins, Colo | 95 |
| Chisholm, John P., acting head, Laboratory of Atmospheric Sciences, Desert Research Institute, University of Nevada, Reno, Nev | 48 |
| Christenson, Gordon, Assistant General Counsel, Department of Commerce, Washington, D.C | 167 |
| Elliott, Robert D., president, North American Weather Consultants, Santa Barbara, Calif | 70 |
| Hardman, George, assistant director, State Department of Conservation and Natural Resources, Carson City, Nev | 42 |
| Haworth, Dr. Leland J., Director, National Science Foundation, Washington, D.C.; accompanied by Dr. Adrian Chamberlain, vice president for administration, Colorado State University, Chairman, National Science Foundation Special Commission on Weather Modification; Dr. Walter Orr Roberts, Director, National Center for Atmospheric Research; Dr. A. Richard Kassander, professor of meteorology, Director of the Institute of Atmospheric sciences, University of Arizona, Chairman of the Board of Trustees, University Corp. for Atmospheric Research: Dr. Edward Todd, special assistant to the Associate Director (Research), National Science Foundation; Dr. Earl Droessler, head, Atmospheric Sciences Section, National Science Foundation, and Dr. Horace R. Byers, Dean of College of Geosciences, Texas A. & M. University | 85 |
| Head, Pat, administrator, Colorado River Commission of Nevada, Las Vegas, Nev | 4 |
| Hollomon, Dr. J. Herbert, Assistant Secretary for Science and Technology, Department of Commerce, Washington, D.C.; accompanied by Dr. Robert M. White, Administrator, Environmental Science Services Administration, Department of Commerce, and Gordon Christenson, Assistant General Counsel, Department of Commerce | 167 |
| Houston, Comdr. Willard, Chief, Environmental Sciences Program, Department of Defense, Washington, D.C | 156 |
| Howell, Wallace E., president, W. E. Howell Associates, Inc., Bedford Airport, Box 163, Lexington, Mass | 248 |
| Jorgenson, Comdr. Paul T., Geophysics Group, Naval Ordnance Test Station, China Lake, Calif | 33 |
| Joyce, Dr. J. Wallace, Acting Deputy Director, International Scientific and Technological Affairs, Department of State, Washington, D.C | 235 |

Statement of—Continued
Page
Kahan, Dr. Archie, Director, Office of Atmospheric Water Resources, Bureau of Reclamation, Denver, Colo 218
Kassander, Dr. A. Richard, director, Institute of Atmospheric Sciences, University of Arizona; Chairman of the Board of Trustees, University Corp. for Atmospheric Research, Tucson, Ariz 118
MacDonald, Dr. Gordon J. F., Chairman, Panel on Weather and Climate Modification, National Academy of Sciences, Washington, D.C 144
McBride, Donald, staff assistant to Hon. A. S. Mike Monroney, U.S. Senator from the State of Oklahoma 270
Malone, Dr. Thomas F., second vice president and head of research department, the Travelers Insurance Co., Hartford, Conn.; Chairman, Committee on Atmospheric Sciences, National Academy of Sciences 134
Mordy, Prof. Wendell, director, Desert Research Institute, University of Nevada, Reno, Nev 11
Roberts, Dr. Walter Orr, director, National Center for Atmospheric Research, Boulder, Colo 104
Sawyer, Hon. Grant, Governor of the State of Nevada, Carson City, Nev., read by Pat Head, administrator, Colorado River Commission of Nevada 3
Shamberger, Hugh A., associate director, Desert Research Institute, University of Nevada, Reno, Nev 7
Sherwin, Dr. Chalmers W., Deputy Director of Defense Research and Engineering for Defense Research and Technology, Department of Defense, Washington, D.C.; accompanied by Comdr. Willard Houston, Chief of the Environmental Sciences Program, Department of Defense 156
St. Amand, Dr. Pierre, Geophysics Group, Naval Ordnance Test Station, China Lake, Calif 33
Thomas, Charles R., assistant director, Nevada Department of Economic Development, Carson City, Nev 32
Vonnegut, Dr. Bernard, Arthur D. Little, Inc., Cambridge, Mass 277
Warburton, Joseph, research associate, Desert Research Institute, University of Nevada, Reno, Nev 28
White, Dr. Robert M., Administrator, Environmental Science Services Administration, Department of Commerce, Washington, D.C 167
Wiseman, Walter G., engineer, Control Data Corp., Las Vegas, Nev 45
Statements and letters submitted—
American Society of Civil Engineers, United Engineering Center, 345 East Forty-Seventh Street, New York, N.Y., letter 301
Battan, Dr. Louis J., professor of meteorology and associate director, Institute of Atmospheric Physics, University of Arizona, Tucson, Ariz., and president, American Meteorological Society, Boston, Mass., statement 302
Bible, Hon. Alan, U.S. Senator from the State of Nevada, statement 41
Church, Dr. Philip E., chairman, department of atmospheric sciences, University of Washington, Seattle, Wash., letter 306
Mordy, Prof. Wendell, director, Desert Research Institute, University of Nevada, Reno, Nev., letter and statement 80
Neyman, Dr. J. Neyman, professor and director of the statistical laboratory, University of California, Berkeley, Calif., letter and statement 307
Schaefer, Dr. Vincent J., Atmospheric Sciences Research Center, State University of New York, R.D. 3, Box 36, Schenectady, N.Y., letter and statement 310

## INDEX OF ORGANIZATIONS AND GOVERNMENT AGENCIES

Agriculture, Department of 238
American Society of Civil Engineers 301
Atmospheric Sciences Research Center 309
California, University of 307
Chicago, University of 289
Colorado River Commission of Nevada 3
Colorado State University 95

| | Page |
|---|---|
| Commerce, Department of | 167 |
| Control Data Corp | 45 |
| Defense, Department of | 156 |
| Desert Research Institute | 7, 48 |
| Environmental Science Services Administration | 156, 167 |
| Federal Aviation Agency | 244 |
| W. E. Howell Associates, Inc | 248 |
| Institute of Atmospheric Physics | 302 |
| Institute of Atmospheric Sciences | 118 |
| Interior, Department of the | 218 |
| Arthur D. Little, Inc | 277 |
| National Academy of Sciences | 144 |
| National Science Foundation | 85 |
| National Center for Atmospheric Research | 104 |
| Naval Ordnance Test Station | 33 |
| Nevada Department of Conservation and Natural Resources | 42 |
| Nevada Department of Economic Development | 32 |
| North American Weather Consultants | 70 |
| Reclamation, Bureau of | 218 |
| Travelers Insurance Co | 134 |
| Washington, University of | 306 |
| Weather Control Research Association | 83 |
| Weather Science, Inc | 270 |

# WEATHER MODIFICATION

FRIDAY, NOVEMBER 5, 1965

U.S. SENATE,
COMMITTEE ON COMMERCE.

The committee met at 10 a.m. in the Safari Room (building 7), Hotel Sahara, Las Vegas, Nev., the Honorable Howard W. Cannon presiding.

Senator CANNON. Gentlemen, the hearing will come to order.

The Senate Commerce Committee today is beginning its formal hearing on S. 23, which would authorize a program in five arid areas of the United States to increase usable precipitation.

(The bill follows:)

[S. 23, 89th Cong., 1st sess.]

A BILL To direct the Secretary of the Interior to conduct a program in five areas of the United States to increase usable precipitation, and for other purposes

*Be it enacted by the Senate and House of Representatives of the United States of the United States of America in Congress assembled,* That the Secretary of the Interior, acting in cooperation with the National Science Foundation, shall initiate and carry out a program which is directed at increasing in substantial degree the annual average usable supply of water from rainfall and snowfall in areas of the United States where such increase would be beneficial.

SEC. 2. In the formulation of the program authorized in this Act the Secretary of the Interior and the National Science Foundation shall advise and consult with the Governors of the States to be affected by any such program, and shall not initiate any such program within a State without the approval of the Governor of such State.

SEC. 3. In order to carry out the provisions of this Act—

(1) the Secretary of the Interior and the Director of the National Science Foundation are authorized to establish such joint operating and coordinating procedures and committees as they may deem to be necessary or convenient for the conduct or administration of the program provided for in this Act;

(2) the Secretary of the Interior is authorized—

(A) to conduct (either directly or by means of grant, contract, or cooperative agreement) in not less than five different locations in the United States such engineering and meteorological studies and investigations of physical methods and devices as he deems advisable, including but not limited to cloud seeding to increase precipitation, and techniques of controlling snowpack storage and runoff;

(B) to acquire by purchase, license, lease, donation, or otherwise, such technical data, inventions, patent applications, licenses, real property and interests therein; and

(C) to cooperate with other Federal departments and agencies and State and local agencies and instrumentalities; and

(3) the National Science Foundation is authorized to exercise all powers and authority vested in it by sections 3(a)(9) and 14 of the National Science Foundation Act of 1960, as amended (42 U.S.C. 1862(a)(9) and 1872a).

Staff counsel assigned to this hearing: Donald Brodie.

SEC. 4. There are authorized to be appropriated such sums not in excess of an aggregate of $20,000,000, as may be necessary—

(1) to carry out the provisions of this Act during the period beginning July 1, 1963, and ending June 30, 1971;

(2) to finance, for not more than two years beyond the end of such period, such grants, contracts, and cooperative agreements as may have been undertaken pursuant to this Act before the end of such period; and

(3) to finance, for not more than three years beyond the end of such period, the correlation and coordination of the results obtained in the program undertaken pursuant to this Act.

Senator CANNON. These hearings are the outgrowth of considerable interest in the field by legislators, scientists, the States, and the executive branch of our Government.

As a cosponsor of the bill I am very pleased that extensive hearings are beginning. Weather modification is a subject that is older than generally recognized. Plutarch noted a valid correlation between great battles and gentle rain.

In 1891 Congress appropriated $12,000 for experiments. The modern periods of scientific investigation began with cloud-seeding experiments in 1946.

Weather modification has obvious international significance. Successful weather modification could be an important detail in our national defense posture. The Russians are known to have a vigorous program of research and experimentation underway.

The Committee on Commerce has jurisdiction over the subject consistent with the Legislative Reorganization Act of 1946.

S. 23 introduced by Senator Anderson and cosponsored by myself and other members of this Commerce Committee is a bill designed to increase in substantial degree the annual average usable supply of water from rainfall and snowfall in programs under the direction of the National Science Foundation and the Secretary of the Interior. Many other agencies of Government are also involved in weather modification activities, including National Science Foundation, the Weather Bureau, the Department of Agriculture, and the Department of Defense.

Today's hearing represents the first of a series of hearings into the question of weather modification. It is our hope today to gain a clear picture of the needs of the State of Nevada and of the activities now being conducted here and in this general area. This information is necessary in order to answer the basic questions of national goals, appropriate programs, and the best administrative coordination to achieve these goals.

My colleague, Senator Bible, has demonstrated great interest and knowledge in the weather modification field. He had hoped to testify here today but his schedule demanded his presence in other parts of the State. I know he would like to be associated with those who have evidenced a keen desire to move forward and develop a dialog on this very important subject.

We will now begin to develop that dialog by calling the first witness. The first witness is Mr. Pat Head, administrator of the Colorado River Commission, who will present a statement on behalf of Governor Sawyer and present a statement for the Colorado River Commission. The Governor, unfortunately, is not able to be with us today.

## STATEMENT OF HON. GRANT SAWYER, GOVERNOR OF THE STATE OF NEVADA, PRESENTED BY PAT HEAD, ADMINISTRATOR, COLORADO RIVER COMMISSION OF NEVADA

Mr. HEAD. Thank you, Mr. Chairman.

The Governor asked me to express his sincere regrets that he was unable to schedule his time so as to be in Elko on November 10. He asked me to present his testimony here for him. [Reading:]

I am Grant Sawyer, Governor of the State of Nevada. I sincerely appreciate your Committee on Commerce conducting this hearing in Las Vegas this morning and in Elko on November 10 to give our State and local people an opportunity to express their views on S. 23, a bill to direct the Secretary of the Interior to conduct a program in at least five areas of the United States to increase usable precipitation through weather modification.

A great agricultural, industrial, and recreational economy has been developed in our Western States. Today we stand on the threshold of an expanding economy greater than could possibly have been foreseen as late as 10 years ago. However, your committee knows well one grave danger lies in the path of this expanding economy—water.

I was greatly impressed and pleased by the recent actions of Congress relative to the desalination research program. I consider this to be one of the prime potentials for increase of usable water supply available to this and other areas of the Southwest. I would hope that the same emphasis can be directed toward research and development in weather modification to increase the usable precipitation from the atmosphere.

I realize that research in such a field as weather modification is very costly and time consuming and requires the highest degree of scientific application from highly trained scientists. Much work, sometimes hit or miss, has been done in this field since World War II, but it has been only recently that research and development has begun to be directed down a path that has promise of yielding information and procedures to give hope for exciting resultant benefits through some control of our unpredictable weather.

I am familiar with the Elko weather modification research project in eastern Nevada and, more recently, with the work being carried out in the Laboratory of Atmospheric Sciences of the Desert Research Institute, a part of our University of Nevada in Reno. Prof. Wendell Mordy, director, and Hugh Shamberger, associate director, will testify before you this morning in detail on the work of the Desert Research Institute in this field. I would like to say, however, that I would like to see this program expanded and accelerated here, as well as in other areas throughout the country.

The program now being carried out by Federal and State agencies appears to be now well coordinated. However, as I understand those programs, they are on a year-to-year basis, where S. 23 being considered today will give some continuity to the program by defining a period of years for research and development in this field and, in addition thereto, will set the goal for funding such a program. I would suggest in this regard that section 4 of S. 23 be revised to appropriately define a minimum period of 10 years for this program.

As can be gathered from my testimony, during my administration as Governor I have continually encouraged research and development programs aimed at increasing our very inadequate water supply. Every effort must be made to see that our water supply meets our requirements. It only follows, Mr. Chairman, and members of the committee, that I fully support S. 23 and the program outlined therein.

Mr. Chairman, that is the completion of the Governor's statement.

Senator CANNON. Thank you, Mr. Head. Do you now wish to present your own statement, which you have submitted?

Mr. HEAD. Would you like to have me do so?

Senator CANNON. Yes, if you have the time, as there are some things that we may wish to discuss in relation to the Colorado River.

Mr. HEAD. Fine. This then is my statement.

## STATEMENT OF PAT HEAD, ADMINISTRATOR, COLORADO RIVER COMMISSION OF NEVADA

Mr. Chairman, members of the committee, my name is Pat Head, administrator of the Colorado River Commission of Nevada, with headquarters in Las Vegas. I am pleased to have this opportunity to appear here before you today to give the views of the Colorado River Commission on the exciting program of research and development of increasing precipitation in the Colorado River Basin by artificial means.

As others appearing before you here and in Elko will discuss, the research activities of the University of Nevada, and the Desert Research Institute, I will refrain from any testimony in that regard.

During 1963 and 1964 we who rely upon the Colorado River for a large portion of our water and power requirements saw the Colorado River flow decline to the lowest annual runoff on record. Within the next 20 years we can expect to see the Colorado River waters put to full use. In other words, the development of that part of the Southwest that relies on the Colorado River for water must come to a standstill if additional water supplies are not available.

We are, therefore, vitally interested in any means of increasing the water supply available to those depending upon the Colorado River for their water. It is with a great deal of interest that we look toward increased precipitation in the Upper Colorado River Basin as a result of weather modification programs.

Most of the precipitation resulting in runoff into the major reservoirs on the Colorado River falls during 10 or more major storms. Estimates vary as to the efficiency of cloud precipitation during storm situations. However, I believe it is safe to assume that that efficiency is somewhere in the neighborhood of 25 percent. In other words, 75 percent of the potential precipitation from storm clouds never falls on the watershed.

In the Colorado River Basin, if we were to increase that efficiency of precipitation by, say, 10 percent through artificial means such as cloud seeding, a resultant additional annual inflow into Lake Powell and thence into Lake Mead of about 600,000 acre-feet would occur. This would result in more than $2.5 million in additional revenues from power as the water passes through the generators at Glen Canyon and Hoover powerplants. In addition, the water made available through this process would have a value of over $25 million in increased agricultural crop production. The value of the 600,000 acre-feet of water for municipal and industrial use would also be great.

A concentrated program is underway in weather modification and research development by the U.S. Bureau of Reclamation. This program is concentrated in the Colorado River Basin, but has programs, of course, in other areas. It is my understanding that during this winter some cloud seeding, as research, will take place in the basin.

Mr. Chairman, this weather modification and research development program has been underway by various agencies of the Federal Government, State governments, and in some cases, private interests, since World War II.

From what knowledge I have of results of programs to date, it is now time that we get on with an operational program. The develop-

ment program, however, needs data-gathering mechanism which gives the scientists an opportunity to properly evaluate the success of any weather modification operations. The lack of adequate measuring devices appears to have been the fault throughout the last 20 years. Many claims have been made by cloud seeders and others. However, there has never been any real substantiation of the success of their operations.

The proposed legislation before you in the form of S. 23 would, I understand, be coordinated with, and complement the present program that is financed with the appropriation of $2.9 million to the U.S. Bureau of Reclamation for fiscal year 1966.

The Colorado River Commission of Nevada, therefore, fully supports the purposes of S. 23 and urges its favorable consideration in order to hasten the day when man can manipulate weather to some extent to reap the benefits from increased precipitation and resultant flow on the Colorado River.

Thank you, Mr. Chairman, for the opportunity to appear before you this morning.

Senator CANNON. Thank you, Mr. Head.

In the first part of your statement you pointed out that during 1963 and 1964 the Colorado River runoff declined to the lowest annual amount on record. What did that figure amount to?

Mr. HEAD. Where the average April to July runoff is in the neighborhood of 8 million acre-feet, each of those 2 years, for those 2 years, averaged less than 4½ million acre-feet a year during that April to July runoff period, which is the contributing time of the watershed.

Senator CANNON. April to July is your runoff period then?

Mr. HEAD. That is right.

Senator CANNON. It dropped to just a little over 50 percent of normal; is that right?

Mr. HEAD. Just about 50 percent; that is right.

Senator CANNON. What is it running in 1965?

Mr. HEAD. This last year we had a very good year on the Colorado River. The April–July runoff this last year was a little over 11 million acre-feet, which provided the means of bringing Lake Powell up to operating level and at the same time bringing Lake Mead up to elevation 1,123, which is the rated efficiency level of the reservoir.

Senator CANNON. That gives you full efficiency as far as Hoover Dam is concerned?

Mr. HEAD. That is right.

Senator CANNON. Is it presently at 1,123?

Mr. HEAD. Yes. It is remaining at 1,123, while Lake Powell is increasing in storage and Lake Powell will increase with storage at Lake Mead at elevation 1,123 until Lake Powell reaches elevation 3,570.

Senator CANNON. At that point if you have additional runoff, will you be able to add to Lake Mead?

Mr. HEAD. Yes; it is our hope that the operating criteria that would go into effect at that time—which, Mr. Chairman, has not been formulated yet—would provide for then increasing the water level at Lake Mead and Lake Powell at the same time to optimize the use of the two reservoirs.

Senator CANNON. If the experiment should determine that artificial methods could be used to increase the flow, do you have the capacity in

both lakes to handle an added flow over and above your normal requirements?

Mr. HEAD. Yes, Mr. Chairman. At the present time there is about 40 million acre-feet of vacant storage space in the Colorado River Basin reservoir system with an average annual runoff of 12 to 13 million acre-feet. With 8 million acre-feet demand on the river below Lake Mead you can see where it would be many, many years before it would fill both of those reservoirs even under a normal flow. Therefore, there is capacity—if we were to increase the precipitation, say, by that 600,000 acre-feet I spoke of, it would take at least 10 years along with—put on top of the normal runoff of the Colorado River to fill the storage in the Colorado River Basin.

Senator CANNON. Before it would be up to your full storage capacity?

Mr. HEAD. That is right. I would like to repeat that figure of 40 million acre-feet of vacant storage space in the Colorado River system.

Senator CANNON. Is anything being done on the Colorado River system to suppress evaporation?

Mr. HEAD. There are experiments being conducted by the Bureau of Reclamation and others, but my understanding of the program is that they have not found any means yet to suppress evaporation on large reservoirs. The molecular film which they have developed to place on small reservoirs will not hold up on the large reservoirs and piles up on the shore due to the winds. To my knowledge, there has been no successful methods of suppressing evaporation on our larger reservoirs.

Senator CANNON. Do you have a figure for the annual evaporation from the reservoirs in the Colorado River Basin?

Mr. HEAD. With Lake Mead at its present elevation of 1,123, the evaporation would be about 800,000 acre-feet annually, and with Lake Powell at a rated head of elevation of 3,570, the figure would be about the same. Our measured annual evaporation at Lake Mead is about 7 vertical feet per year.

Senator CANNON. Actually you are losing more by evaporation than the figure you indicated might be obtained from artificial means of inflow is that correct?

Mr. HEAD. The figure I used of the 600,000 was only assuming an increase of 10 percent in efficiency of cloud precipitation. Of course, it might be far greater, but—yes, it is greater than the 600,000 figure.

Senator CANNON. Are any other methods being used in the Colorado River Basin such as planting, soil covers, and so on, around the lake edges to try to reduce the evaporation?

Mr. HEAD. I don't know about the program in the upper basin. However, in the lower basin there has been a concentrated program going on for years to suppress the phreatophytes along the river below Hoover Dam by burning, by channeling and drying up swamp areas. These phreatophytes, of course, use more water than could be evaporated from the water surface. They are very high water users.

Senator CANNON. Is that effort very extensive?

Mr. HEAD. Oh, yes; it is quite extensive. I don't know the monetary magnitude of the program, but the United States has been carrying on a channeling program along the Colorado River for years and they periodically burn the existing phreatophytes along the river. It is a continuing program.

Senator CANNON. Your testimony that a 600,000 acre-feet increase would result in $2.5 million in added revenue from power as the water passes through the generators at Glen and Hoover, and in $25 million in increased agricultural crop production is very interesting. That is a substantial increase.

Mr. HEAD. And an immeasurable benefit to municipal-industrial uses. There is no real way of putting a yardstick on the value of municipal-industrial water.

Senator CANNON. You also stated that the development program needs data-gathering mechanisms to give the scientists an opportunity to properly evaluate the success. What do you mean?

Mr. HEAD. I am not a scientist nor an expert in this field, but it is my understanding from talking to scientists that they need certain instrumentation and gaging of the streams to properly evaluate the precipitation. These instruments are placed in their control areas and in their target areas. The target areas are compared to the control areas. These instruments do not do the seeding. They are precipitation-gathering rain gages, snow gages, stream gages, and so forth.

Senator CANNON. Is this directed to the argument on whether the added precipitation would have occurred without the artificial means?

Mr. HEAD. Yes. In any extensive cloud seeding I have seen no concrete evidence that precipitation was increased. Undoubtedly it was, but there was no way of measuring it, and all we have are the claims of those who were doing the seeding.

Senator CANNON. You may find something rather interesting here today, because I think Dr. Mordy has one of the best examples that I have seen. It will be presented later in the hearings today and it is a very concrete example helping to resolve the argument that now exists.

Mr. HEAD. I am acquainted with some of their work. What I am referring to was some of those extensive cloud-seeding programs have taken place on the Western Sierra and the Eastern Rockies without proper instrumentation.

Senator CANNON. Counsel, do you have any questions?

Mr. HURLEY. No, sir.

Senator CANNON. Thank you very much for your testimony on behalf of the Governor and on behalf of yourself and the Colorado River Commission. We appreciate your being with us today.

Mr. HEAD. Thank you. I appreciate the opportunity of being here.

Senator CANNON. The next witness will be Mr. Shamberger.

## STATEMENT OF HUGH A. SHAMBERGER, ASSOCIATE DIRECTOR, DESERT RESEARCH INSTITUTE, UNIVERSITY OF NEVADA, RENO, NEV.

Mr. SHAMBERGER. Mr. Chairman and members of the committee, I am pleased to appear before this committee in support of S. 23, a bill now before your committee aimed at increasing Federal support in weather modification research.

My name is Hugh A. Shamberger, and I am now associate director of the Desert Research Institute of the University of Nevada. I am in charge of the center for water resources research established at the

University of Nevada and within the framework of the Desert Research Institute pursuant to the provisions of the Water Resources Research Act of 1964. Until the first of this year, I was director of the Department of Conservation and Natural Resources of the State of Nevada, a position I held from the inception of that department in 1957 until January of this year. Prior to that time, I was in the State engineer's office, starting in 1935, and from 1951 until 1957, I was State engineer.

My interest in weather modification goes back a number of years. During the time I was State engineer, some cloud-seeding projects, financed by local interests, were carried on in the Humboldt River watershed. In each case, the project was carried on only for 3 or 4 months, and there was no way to evaluate the work. Some ranchers felt that precipitation had been increased while others felt that it hadn't. Such projects are costly and usually inconclusive.

With this in mind, 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 countries 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 must utilize the services, as much as possible, of the Desert Research Institute in such undertakings.

Such a research project was 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.

In 1935, the Bureau of Reclamation completed the Rye Patch Reservoir project located easterly of Lovelock, for storage and flood control in the Lovelock area. This dam, about 40 miles easterly of the terminus of the river, is the only control structure, at present, on the entire Humboldt River system.

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 North American Weather Consultants to do the actual field work.

It was determined that an expenditure of at least $40,000 a year would have to be made to obtain the objectives of the program. Up to the present time, the State of Nevada has appropriated $150,000 and the counties along the Humboldt River system, together with a number of ranchers and some irrigation districts, one being located in the Owyhee project in Oregon, and another on the Salmon Falls Creek in Idaho, have contributed over $50,000. It is expected that this project will be completed by July 1, 1967.

This research project has been increased in scope by funds made available to the Desert Research Institute by the National Science Foundation and the Bureau of Reclamation. I am sure that Prof. Wendell A. Mordy, director of the Desert Research Institute, will comment on the full scope of this particular program.

I wish to emphasize that this research project is 100 percent research. It is primarily aimed at determining whether precipitation,

in the form of snow, could be increased in the high elevation watersheds of the Humboldt River system.

I would also like to point out that in arid States, such as Nevada, the great value that would result if weather modification techniques are developed which would augment the precipitation in the form of snow on the high elevations which, in turn, would ensure a more stable spring and summer water supply.

While my immediate concern has centered here in the West, I realize that the value of weather modification techniques would apply equally well nationwide, and everyone would benefit from it. Therefore, it appears to me that since the results would be so widespread, that it would be proper for the Government to assume the main burden of an increased research program in this field.

Thank you very much.

Senator CANNON. Thank you, Mr. Shamberger. You referred to the Rye Patch Reservoir being the only control structure on the Humboldt River system. If increased precipitation were developed on the mountains, in the form of snow, as you indicate here, would you have an adequate control system, to handle the increased runoff?

Mr. SHAMBERGER. Yes, Senator. At the present time, we have three authorized Corps of Engineer flood control projects on the Humboldt River: one on Marys River, one on the North Fork of the Humboldt River, and one on the South Fork of the Humboldt River, all being in Elko County. Congress authorized these projects in about 1950, I believe, and at the present time, studies are being carried on to determine the feasibility of these reservoirs in connection with the irrigation operation on the Humboldt River.

Some of this work was carried on at the Desert Research Institute, and results indicate conclusively that the ranchers would benefit by these dams even though there were no increased precipitation, but the dams and reservoirs would make available the storage of a great deal of any added precipitation.

Senator CANNON. Does the present control system reduce the runoff into the Humboldt Sink and the loss of water there?

Mr. SHAMBERGER. Very much so. About once or twice in each 10-year period, we have floodflows that reach the Humboldt Sink, but that happens very seldom. Usually, the Rye Patch Reservoir will control all the water. Two years ago, the runoff from the Humboldt River was so small over a period of 2 or 3 years, the farmers were limited to about a half acre-foot per acre of land during the irrigation system. That was in the Lovelock area.

Senator CANNON. Has the runoff increased this year, comparable, for example, to the Colorado River, which is substantially up?

Mr. SHAMBERGER. This has been, I think, the best runoff year in all the time I have been in the State, and I understand that it is the best runoff year of record on the Humboldt River and in the other rivers in the State.

Senator CANNON. Is the area such that the added runoff in the Humboldt River area is closely associated, for example, with the runoff in the Colorado River Basin?

Mr. SHAMBERGER. I wouldn't think so, Senator. As far as I know, there is very little similarity between the runoff in the Humboldt River area and in the Colorado River Basin.

Senator CANNON. The fact that there is an added runoff in both of them this year is not indicative that the pattern normally runs the same?

Mr. SHAMBERGER. That is right.

Senator CANNON. Even though in 1963 and 1964, they had a very low runoff which was much below normal?

Mr. SHAMBERGER. That is correct. I might add, too, Senator, that as you well know, with the completion of the Washoe project on the Truckee and Carson Rivers, we will have a greatly increased storage capacity on those stream systems that flow out of the Sierra Nevadas mainly from the high California watersheds into Nevada.

Senator CANNON. Now, as director of the Center for Water Resources Research of the Destert Research Institute, have you had any experience in licensing the private operators in this particular area?

Mr. SHAMBERGER. The legislature, at the time they enacted the legislation authorizing the research projects, passed another act which placed in the hands of the director of the department of conservation and natural resources, the licensing of all cloud-seeding operations within the State, and that is in the hands of the director of the department that I left in January.

Senator CANNON. So it is not under your present office?

Mr. SHAMBERGER. Not any more.

Senator CANNON. Did you have any specific experience in that area before you left the department?

Mr. SHAMBERGER. No; only in the projects that were started prior to this legislation, and when the research project was enacted in 1961; and after consultation with Professor Mordy, we refused to allow any private operators to go into the area because of the effect it might have on this particular research project.

Senator CANNON. Is there a need for a central information collection agency to keep records on these various programs—the State, Federal, and private programs?

Mr. SHAMBERGER. I would presume, Senator, that as far as the State of Nevada is concerned, the director of the department would work very closely with the Desert Research Institute. In fact, the legislation requires that the director appoint an advisory committee on weather modifications, and Professor Mordy is on that advisory committee, so that any application made by a private organization to seed the clouds would have to be reviewed by this advisory committee.

Senator CANNON. Then I take it that you feel that there would be no need for a central information collection agency based on the present situation?

Mr. SHAMBERGER. I would think, nationwide, there would be; yes.

Senator CANNON. What about here in the State?

Mr. SHAMBERGER. The director of the department has that responsibility now.

Senator CANNON. Do you know how many private operators there are licensed at the present time?

Mr. SHAMBERGER. At the present time, there are none.

Senator CANNON. None?

Mr. SHAMBERGER. In Nevada, there is one. I might say that the North American Weather Consultants were listed because they were carrying on some additional studies on the Owyhee River watershed,

a river which is also in Elko County, but that was financed by the Owyhee irrigation project in Oregon. That project has terminated and, right at the moment, there are no listed operators because, under the act, any private organization carrying on State sponsored research doesn't have to be listed.

Senator CANNON. Has there been any scientific study of why the runoff was reduced in recent years?

Mr. SHAMBERGER. I would suggest, Senator, that you ask that question of Professor Mordy because I am not qualified to discuss meteorological phenomena, or the weather.

Senator CANNON. But you don't know whether there has been a scientific study made?

Mr. SHAMBERGER. I know there have been scientific studies made by Professor Mordy's Laboratory of Atmospheric Sciences, but to what extent, I couldn't answer.

Senator CANNON. Thank you very much, Mr. Shamberger.

In the next to the last paragraph of your statement, you said that a great benefit would result if weather modification techniques are developed which would augment the precipitation in the form of snow on the high elevations and insure a more stable spring and summer water supply.

Would this deny rain or snow to areas which were downwind of the artificial precipitation methods?

Mr. SHAMBERGER. Not necessarily, Senator. When I wrote that particular paragraph, I was thinking of our situation here in Nevada, because our irrigation water supply all comes from the snow pack in the high elevations, that is, the major portion of it.

We do have, as you know, some spring rains, but those are somewhat infrequent. We depend on the snow pack in the high elevations for irrigation water supply. That necessarily wouldn't apply in this part of the State, and it certainly wouldn't apply in the eastern part of the State, but on the Colorado River, of which Mr. Head testified, the main water supply, and practically, I imagine, almost 100 percent of the water supply comes from the higher elevations resulting from snow pack.

Senator CANNON. Thank you very much, Mr. Shamberger, for being here with us today.

Mr. SHAMBERGER. Thank you, Senator. It was a pleasure.

Senator CANNON. The next witness will be Prof. Wendell Mordy, director of the Desert Research Institute, University of Nevada.

Professor Mordy, we are happy to have you with us today. You may proceed with your statement.

## STATEMENT OF PROF. WENDELL MORDY, DIRECTOR, DESERT RESEARCH INSTITUTE

Professor MORDY. Mr. Chairman, my name is Wendell Mordy. I am Edgar J. Marston professor of atmospheric physics and director of the Desert Research Institute of the University of Nevada. My purpose in being here today is to speak in strong support of Senate bill S. 23 which provides for funding of weather modification research through the offices of the Department of Interior in cooperation with the National Science Foundation.

59-528—66—pt. 1——2

I have been involved in cloud physics research since 1947. This experience includes almost 10 years of work in Hawaii, 4 years at the University of Stockholm in Sweden, 5 years in Nevada, and a number of months spent in Australia and Europe in laboratories doing such research.

Earlier related experience includes nearly 4 years as a meteorologist with the Air Force and experience as an airline meteorologist for United Air Lines and Pan American Airways. Thus most of my professional life has been committed to the subject of cloud physics and weather modification and this is because of my strong conviction that these fields of research are of substantial benefit to our society and holds great promise for the future.

I'm certain I do not need to call to the attention of this committee the growing awareness in this country of the value of our water supplies or of the potential value of cloud seeding to augment them. Nor I suspect do I need to elaborate on the problems which hail, fog, and lightning present in our economy and which may, according to many competent authorities in the field, be substantially alleviated by weather modification techniques.

Because weather modification has been a subject of controversy for many years I believe that it is not generally known and understood that it can in fact be accomplished. There are very few, if any, meteorologists with firsthand experience in cloud-seeding experiments who will question this statement today.

Let me illustrate this point.

In January of this year scientists of the Desert Research Institute were asked to assist in some experiments initiated by United Air Lines to clear low-lying clouds and fog which had inhibited air traffic at the Reno airport for several days. These low-lying clouds were about 1,500 feet thick and extended 50 miles or so to the east of the Sierra Nevada range and ran a distance of roughly 100 miles in a north-south direction.

Five times on three different days, in two different locations, these clouds were seeded with several pounds of granulated dry ice. In each instance holes were opened in the clouds which permitted the light aircraft used by the scientists to ascend and descend through them to and from an otherwise closed airport.

But even more significantly perhaps was the fact that in each instance snow fell from these comparatively thin clouds in large flakes and in sufficient quantity to remain on and whiten the ground. By way of comparison, nowhere else below this huge horizontal expanse of cloud did it snow on any of these days.

The precipitation falling from a single cloud-seeding event was estimated to be about 0.01 inch of water. The holes opened by the seeding remained open for an interval of time ranging from about 15 minutes to more than 1 hour. Thus if this cloud seeding had been repeated as often as possible for the purpose of gaining precipitation, I believe that more than 0.10 inch of precipitation could have been added to the 1965 amount for each of the more than 7 days in which these meteorological conditions prevailed.

In view of the fact that the Truckee meadows in which Reno is located gather an average of only about 8 inches of precipitation per year this amount of precipitation would be a beneficial quantity.

May I show you some photographs which illustrate these events? I have here on a diagram photographs of the Truckee meadows——

Senator CANNON. Would you show them here so that the people in the audience can see as you demonstrate?

Professor MORDY. These photographs show the expanse of cloud which covered the Reno Airport. Truckee meadows and the reaches east and north and south from Reno during this interval of time.

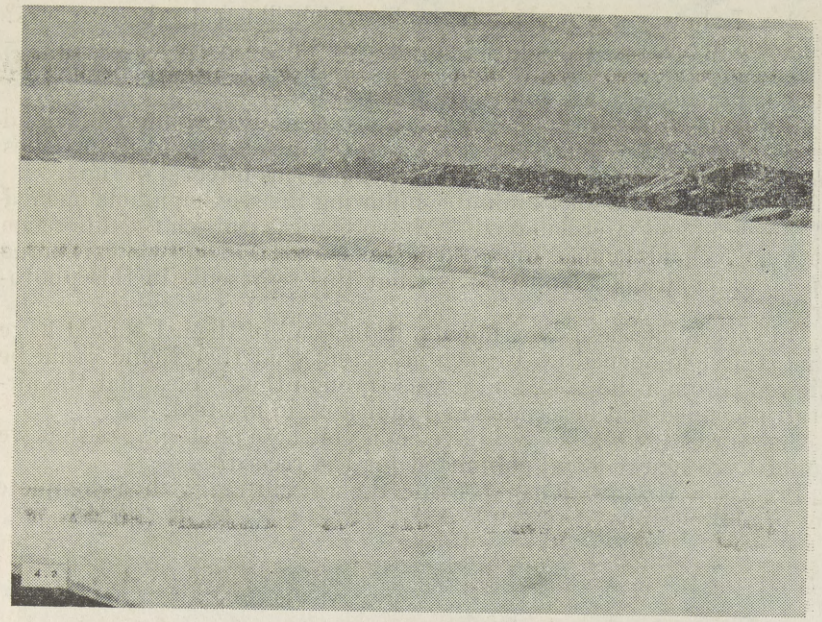
Here in a manner of 18 minutes following the seeding a hole opened in the cloud and later enlarged. Meteorologists can tell the difference between a cloud which is made up of ice crystals and one which is made up of water droplets and that is what this represents in this photograph.

On several of these experiments, in fact, all of them I should have said, the hole opened up to such an extent that the ground could be viewed through the hole, and it was through these holes that the aircraft ascended and descended as I indicated in my text.

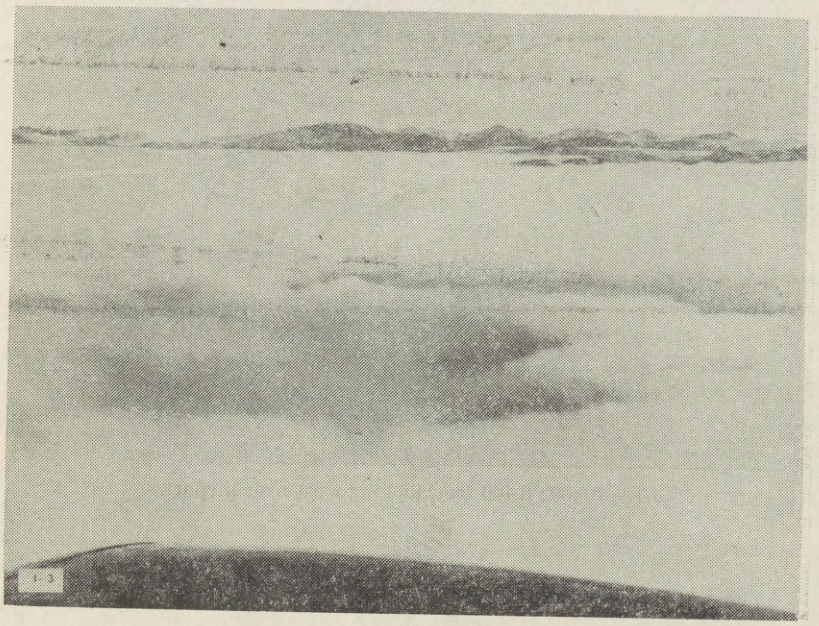
Senator CANNON. Do you have copies of these photographs that we could have marked and submitted for the record?

Professor MORDY. I can provide the committee with a complete set of photographs.

4.1.—10:00; 6,400 feet, looking west over airport.

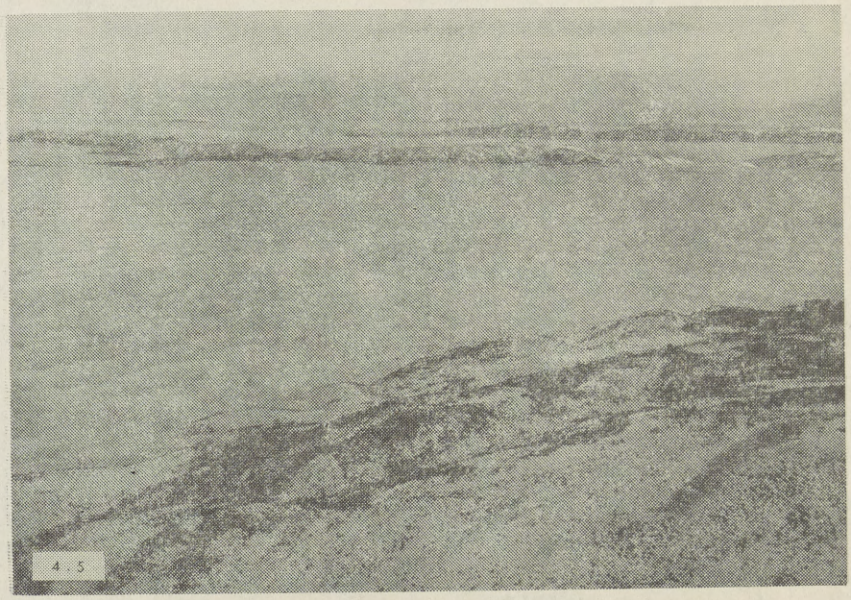


4.2.—10 :48 ; 6,800 feet, looking southwest from north of seeded area.

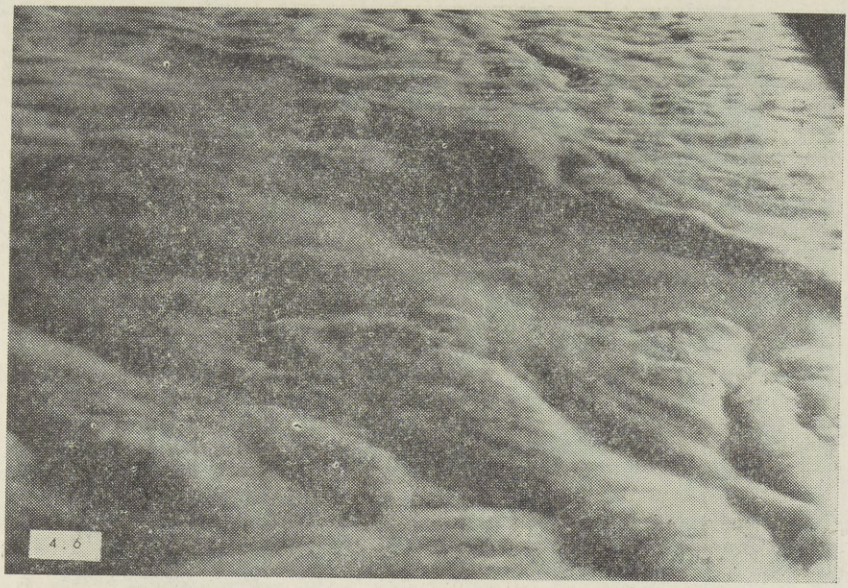


4.3.—11 :30 ; 7,000 feet, looking southeast from seeded area.

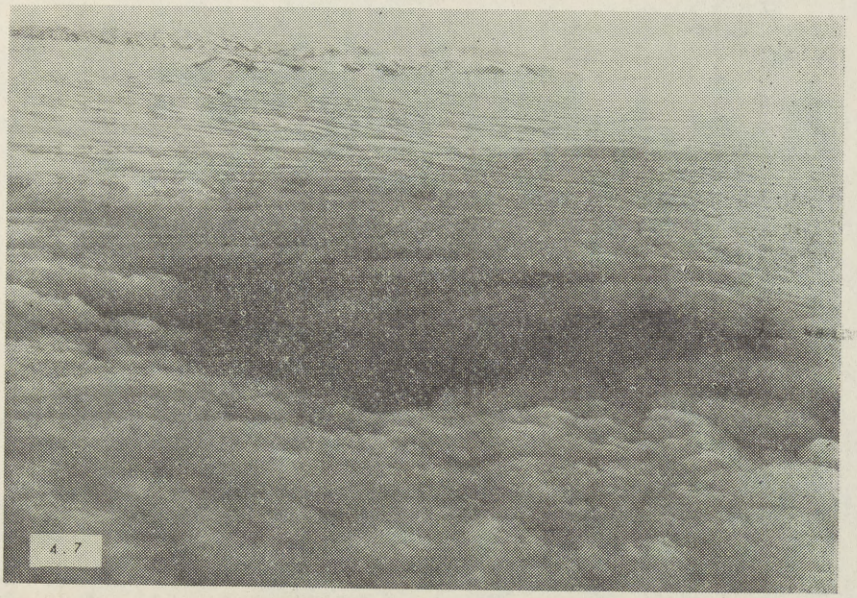
4.4.—11:30; 7,000 feet, looking down at seeded area.




4.5.—14:50; 8,500 feet, looking south-southeast from a few miles south of Tahoe timber.




4.6.—15:15; 8,500 feet (aerial camera), looking almost straight down into seeded area.




4.7.—15:35; 8,500 feet, looking east from seeded area.

4.8.—15:45; 7,000 feet, looking down at Sparks Sanatarium through hole cleared by seeding.

Senator CANNON. You have indicated here 4–1—I am saying this for the purpose of the record—4–1; this is the airport area before any cloud seeding had taken place above the Reno airport area.

Professor MORDY. Yes.

Senator CANNON. And 4–2, is that before the seeding or immediately after?

Professor MORDY. That is 48 minutes later, showing the hole that opened up as a result of the seeding.

Senator CANNON. Forty-eight minutes after the preceding picture or after seeding?

Professor MORDY. After the preceding picture.

Senator CANNON. And 4–3 represents what?

Professor MORDY. That would be an hour and a half in this instance after the seeding, showing the hole in the clouds.

Senator CANNON. And 4–4?

Professor MORDY. Again an hour and a half, from a different direction, with the hole closing in now.

Senator CANNON. And how about 4–5?

Professor MORDY. This is a different experiment in the afternoon.

Senator CANNON. A different experiment on the same day?

Professor MORDY. Yes. January 15, in the afternoon.

Senator CANNON. So that both sets—4–1, 4–2, and 4–3 and 4–4 were experiments over the Reno airport and 4–5, 4–6, 4–7, and 4–8 were a different experiment over the Reno airport on the same date?

Professor MORDY. Yes.

Now if you could indulge me just a little further, I would like to show you some photographs taken by the television station KOLO, of the snow that fell beneath these experiments.

Senator CANNON. Will you narrate that as we go along so that the reporter will have this as a matter of record.

Professor MORDY. The purpose of showing this film is to show you the intensity and size of the snowflakes which fell at the Reno airport following seeding and these are shots taken by the television cameraman at the time the snow was beginning.

Now you see the size of the snowflakes which occurred from this relatively shallow layer of clouds. The snowflakes were quite varied in size but the largest of them were a quarter of an inch in diameter, bundles of crystals of snow, and as you can see, there is enough snow here in this photograph to cover the ground and as I say, we had only the measurement at the U.S. Weather Bureau station. The greater part of the snow fell from there eastward.

We have a measurement by the Weather Bureau which indicated a trace of snow. We have downwind from this point a whitening of the ground with a maximum somewhere east of the Reno airport.

Senator CANNON. Did any snow occur surrounding the area that you seeded?

Professor MORDY. No.

Senator CANNON. Only the seeded area?

Professor MORDY. Only the seeded area had snow.

Senator CANNON. What was the amount of the seeding material that you used in each instance?

Professor MORDY. It was roughly 50 pounds of granulated dry ice for each pass of the aircraft.

Senator CANNON. How many passes of the aircraft did you make?

Professor MORDY. In some of these photographs you will see three distinct passes. Here, in this photograph you see three distinct passes of the aircraft.

Senator CANNON. Your testimony is that you believe that this could have been increased to 0.7 of an inch over a 7-day period or 0.1 of an inch a day, approximately?

Professor MORDY. I said I thought that was a conservative estimate of what might have been done.

Senator CANNON. Had that been done, that would have been almost 10 percent of the total average annual precipitation at that location?

Professor MORDY. That is what I was implying; yes, sir.

Senator CANNON. You may proceed.

Professor MORDY. Why then is there so much argument about weather modification? It is because nature does not always provide so nearly perfect conditions for an experiment. Storms are complicated and many variables function to make it difficult to sort out what is happening naturally from what is being influenced by the experimenter. And sorting out these influences has been all the harder because of the meager tools available to the scientist.

Most of us have traveled on the sea at times and are impressed with its immensity. Well, the atmosphere is not only every bit as big but in fact much bigger, which is to infer the difficulty in getting enough measurements to make reasonable descriptions of the cloud systems we are attempting to influence.

As a result, most large-scale cloud-seeding experiments have been verified by looking at variations from normal precipitation over as

long an interval of time as possible and by comparing several seeded weather situations with similar unseeded ones.

I might have put quotes around that "similar" because it is very difficult to find two weather situations which are identical. Such experiments always leave room for doubt since direct measurements are omitted due to limited funds, available instrumentation, or inadequate methods.

If such an experiment is improperly designed or carried out it will yield inconclusive results. Such inconclusive results have as often as not been interpreted as negative results.

I might just give a little analogy here.

Whenever I hear the results of these experiments I am reminded of the kinds of exchange that might occur between a boy and his father, the boy wanting to go fishing for the first time. And he asks his father, "How do I go fishing?"

His father says, "You get a line, you get a hook, and you get a worm, and you drop it in the pond and you wait until the fish bites the hook."

The boy fishes all day long and he doesn't catch a fish so he comes to the conclusion that there are no fish in the pond.

This, to my way of thinking, has been a part of the problem of the cloud-seeding field experiments on a broad scale.

By way of illustration one may say that the noise in meteorological data is large. We can make an analogy with a poor telephone connection. One must shout long and loudly to get a message through, or maybe there is no connection and we don't know it and no amount of shouting will get the message through.

The point in the above discussion is that if we are to separate and properly evaluate the influences of weather modification techniques from normal weather patterns much more engineering and direct measurement programs are called for, and this means adequate funding over sufficiently extended periods of time to allow research and development activities to evolve to the point where we can adequately observe and describe whole cloud systems with a large part of the confidence that a laboratory scientist can observe and describe his experiment.

The tools to be used for this work are expensive. Instrumented aircraft, radar systems, widespread field instrumentation, telemetering equipment for remote stations, and upper-air sounding equipment all must be knit together into one organized engineering system.

To date, to my knowledge, no such complete system has been put together in this country. Only parts have been explored in one experiment or another. This has been due to the limited funds available to any one scientist, and the results have continued to reflect uncertainty when weather modification techniques have been applied on a broad scale. My conviction is that the reason for this uncertainty is the rather halfhearted commitment made for this work in this country.

It has been reported recently by Dr. David Atlas of the Air Force Cambridge Research Laboratories that Russia has made a substantial commitment and has developed adequately measured and controlled experiments which show yields of 50 to 100 percent increase in precipitation through cloud seeding. I believe we can do anything

the Russians can do and probably can do it better if we set ourselves to the task, but we haven't done it yet, although, like rocket research, cloud seeding, and weather modification originated in America.

Dr. Walter Orr Roberts, Director of the National Center for Atmospheric Research in Boulder, Colo. in an address to the American Meteorological Society recently raised the banner of weather modification as a primary goal for our profession. In his speech which will shortly be published in the Bulletin of the American Meteorological Society (December 1965) he states:

> I can see no need for hairsplitting over weather research aims at forecasting or modification, or whose mission the one or the other may be. The enemy is not a competition for funds or political power. The enemy is hail, blizzards, floods, droughts, hurricanes. The enemy is the innate intransigence and inscrutability of nature. Our prediction of its vagaries and our mastery of its excesses will depend on the same knowledge that we all so earnestly seek.

I have a copy of Dr. Robert's speech with me which I would be happy to leave for the committee's information.

Senator CANNON. Would you submit that for the committee's files, please?

Professor MORDY. S. 23 offers many advantages in insuring progress in this field. Essential features are long-range support and promise of adequate funding by agencies of the Government experienced in supporting scientific and engineering programs. May I urge you to give this measure your most considered attention?

Thank you very much for the opportunity to appear before this Commerce Committee.

Senator CANNON. Thank you, Professor Mordy.

You have presented a most interesting statement and two most interesting experiments.

Are there dangers of contamination of other experiments or to the atmosphere generally from this type of activity?

Professor MORDY. The experiments which I described here today were conducted with dry ice which has a very limited carryover effect into other areas.

One of the things that needs to be publicly acknowledged is that the amount of water taken out of the atmosphere in the form of precipitation is relatively little at any one time. I didn't come prepared to give a ratio between, say, the amount of precipitation falling in a region as opposed to the amount of moisture vapor passing over a particular point, but the ratio is a very small one, like taking drops out of a bucket.

In view of the fact that the influences are characteristically sought in limited areas it is most unlikely in my opinion, with the types of experiments currently underway, that any influence would be found at any distance downwind from the experiment area.

Senator CANNON. Are you experimenting with thermal convection—that is, large fires such as in Vietnam where a fire raid was recently put out by the rain that followed and such as in the Phillipine Islands where we had the volcano eruption and very shortly thereafter heavy rains? Have you done any experimentation along this line?

Professor MORDY. I can't say honestly I have done any experimentation in this field but I am acquainted with what the problems are.

In Hawaii where I spent 10 years, it is customary to burn off 15 or 20 acres of sugarcane to dispose of the leaves and unusable trash and,

quite characteristically, in winter because of the very large amounts of water vapor in the atmosphere there, a cloud will form over these burned-off areas.

Now the problem is determining what is accomplished—first of all I heard, during the first year that I was in Hawaii, of one of these clouds which provided a fair amount of precipitation. I then made it a point to follow up on this idea and to see what I could learn about these artificially occurring clouds over cane fires and I never found another instance where one of these clouds rained.

It was argued among meteorologists there as to whether or not the increase in the number of condensation nuclei in the atmosphere, the increased amount of moisture given off when the plants are burned, or the heat energy which was released at the time the fire was burning, was primarily responsible for the formation of the clouds, and I suspect that all three entered into the problem.

Because of the large number of condensation nuclei the clouds were made up of more droplets than other clouds. Therefore, the depth of the cloud would have to be greater before rain could form.

There have been experiments in Africa and in France suggesting that this might be a fruitful area of research but I have not entered into that line of research.

Senator CANNON. Are you conducting any research in hail suppression?

Professor MORDY. Not in the State of Nevada. We have been invited to participate with our cloud physics group next summer in a program which has been tentatively named Project Hail Swath, in which we are to cooperate with other physics groups at the Universities of South Dakota, Wyoming, and elsewhere, utilizing all of the instrumentation which we currently have to assist in getting as adequate a picture as possible of a hailstorm and what might be done to alter it.

Senator CANNON. Are you doing any research in seeding from the ground or is all of yours air activity?

Professor MORDY. The project in Elko which Mr. Shamberger referred to is a project in which 5 years as a minimum will be required to evaluate it. This project is seeding two areas, one north and one south of Elko, alternately, in suitable weather, to determine the effect of cloud seeding by silver iodide generators on the ground, and we won't have the results of that experiment for another 2 years at least.

Senator CANNON. Will you present someone from your department who will testify in more detail in relation to this particular project?

Professor MORDY. Yes. Not only from the Laboratory of Atmospheric Sciences but also from North America Weather Consultants. Mr. Robert Elliot will appear before this committee in Elko on the 10th.

Senator CANNON. Professor Mordy, you have an extensive background in the areas of weather forecasting and meteorological experience. I wonder what role accurate forecasting plays in this experimental field?

Professor MORDY. I have one of our field experiments based, to begin with, on our judgment as to what the weather will be. Will it be suitable or will it be unsuitable for the particular experiment in question?

It is not difficult in an experiment such as I described here which is persistent. It is more difficult in the migrating storms that come in from the Pacific, in the large-scale systems which we are attempting to influence but with very inadequate instrumentation.

Senator CANNON. You had an ideal situation for your test in the two experiments you related to us. In other experiments, how do you pick a control area so that you have a valid basis for a test in a measurement of some sort?

Professor MORDY. In the case of the Elko experiments, the talk of the university in this experiment is to evaluate the results of a field experiment carried out by a commercial cloud-seeding firm. We had a part in the design of the experiment and we have a role in the measurements which will be used for the evaluation.

The basis of the experiment is a statistical design in which we choose the weather in which we will work. This is done by the commercial operator. When they have made a decision that they will seed clouds in the particular storm in question, they telephone the University of Nevada where we have, in sealed envelopes, a series of numbers which indicate that the area which could be seeded will be seeded on that day.

This provides us with two areas, one which is seeded and one which is not, on a particular day. It also provides us with a randomized program of seeding for one area in which we compare this storm with the following storm, and so forth.

So we have what is called a randomized crossover experiment, in statistical terms.

Senator CANNON. Would the two examples that you gave us be a randomized test-type operation?

Professor MORDY. The one we described here?

Senator CANNON. Yes.

Professor MORDY. This is about as difficult to evaluate as a spot of gravy on a tablecloth. You don't need a statistical evaluation for an experiment like this. It removes all doubt in the eyes of observers who are present. I don't think there was any doubt in the minds of those who participated in this experiment.

Senator CANNON. What is the lifetime of the seeding agent that you used there?

I noticed the results didn't occur for a considerable period of time after the actual seeding had taken place.

Professor MORDY. The mechanism which occurs is very simple. If you cool water droplets below minus 40° C. or thereabouts, you provide ice crystals spontaneously.

Nature doesn't always provide ice in clouds when the temperatures are colder than freezing. By using bits of dry ice the air immediately adjacent to the grain of dry ice is cooled colder than this minus 40° figure and a lot of ice crystals, literally millions of them, form adjacent to the grain of dry ice.

Also, the dry ice falls through the cloud and doesn't evaporate right away so you have a depth of cloud that is infected with ice crystals. These are well-known facts.

Where water and ice are side by side the vapor pressure over the water is greater than the vapor pressure over the ice crystal so the ice crystal grows and the water drop evaporates and the time that is

required to do this from the few molecules in the first ice crystal to the time it appears as a visible snowflake is about the 15 to 20 minutes that I indicated in my talk.

Senator CANNON. How much of a cloud system is seeded? What I am concerned about is: Could you have seeded a much larger area than you did in these two particular experiments?

Professor MORDY. Had we been prepared with larger equipment and more dry ice there is nothing to have prevented us from seeding the entire Truckee Meadow area and to do this on an hourly basis.

The fact was that we were operating on very short notice and used light aircraft and as I indicated about 150 pounds of dry ice at a throw, so this is the reason why these were limited, but these are very large areas in relation to the size of the light aircraft that we were using. One must remember that a good many acres or even square miles are under these holes.

Senator CANNON. Did your results there indicate that this could be very useful—you stated it was over the airport—in clearing an airport for aerial operations?

Professor MORDY. This year it is my understanding that 17 airports in the West will adopt this practice routinely when supercooled fog conditions exist. There will be in Oregon, Utah, Nevada, and I don't know the other localities.

Senator CANNON. What dissemination of information has been accomplished as a result of these particular tests you conducted?

Professor MORDY. Who have reports been distributed to?

Senator CANNON. Yes.

Professor MORDY. The Bureau of Reclamation and the National Science Foundation and the State Department of Conservation and Natural Resources.

Senator CANNON. Do you find any difficulty in this sort of jurisdictional controversy that has been going on some period of time, as to who has jurisdiction in this particular field?

Professor MORDY. Only the uncertainty of the funding which results from wondering whether the agency which is assisting you is in fact going to be able to continue to assist you.

I have had excellent cooperation from the National Science Foundation and the Bureau of Reclamation and Mr. Shamberger admitted that we have also had some support from the Office of Naval Research, minor support this year, for work in our laboratories.

All of these agencies in my view have been extremely cooperative as has also the U.S. Weather Bureau here in Nevada which has provided us with much equipment such as radar to assist us in our measurements.

I would say that the fact, really, is that it is the very spirit in science that all views are aired and that there is plenty of room for controversy, and it is my view that the diversification of support for this work has been a very healthy thing for it.

The amounts of support for, let's say, large engineering projects have been inadequate but the diversification of support from several agencies of the Government I think is very desirable.

Senator CANNON. Do you think we are ready for large-scale experiments in this area or are we still in need of more basic research?

Professor MORDY. I would say that when the public demands an answer to the question of whether a large cloud system or a large

storm can be affected, and by how much, by cloud seeding or other modification techniques, that we must have a much larger effort go into this before we can answer that question adequately.

Questions are being put to us now that we can't answer because we really don't have the information.

Senator CANNON. You pointed out in your statement the tools that are used in this work. I noticed you didn't mention computers. Is there any place or what is the place of computers in large-scale experiments of this nature now?

Professor MORDY. Computers are being used very widely as I am sure you are aware, in the field of meteorology and Mr. John Chisholm when he appears before this committee in Elko will describe an engineering approach to the problem of getting adequate information in time to alter your experiment in progress, in a weather modification experiment.

This will involve ultimately an integration of a lot of diverse information into an easily understood pattern of the experiment in terms of plots of meteorological information, radar displays, aircraft positioning, wind data, and so forth.

To do this, I suspect that we will be drawing more and more on small computers to organize this information so we can readily understand it at the time. Large computers have been used in order to—in hemispheric-scale numerical weather prediction problems in such a way by varying various meteorological factors, what happens as a result of some artificial influence can be determined.

Thus far numerical weather prediction isn't good enough so that we could use it as a criterion for the evaluation of a cloud-seeding experiment.

One other application of computers is that we are able to model experiments—when they are modification experiments—in a mathematical description. In other words, we formulate a theoretical cloud with a certain number of droplets growing and the way they grow in nature, and then we alter the number of ice crystals or the number of condensation nuclei in the problem as we set it up and see what effect this will have on the total development of this theoretical cloud.

So we are using computers as a means of designing experiments which can be adequately tested in the field, and each theoretical model is tested at its most critical point by a field experiment.

Senator CANNON. Do you feel that there is a need for a central registry of all experiments in commercial seeding-type operations?

Professor MORDY. I think that every scientist believes that the results of his work must be published and must be open to debate in order to allow those of other views to express their views and to argue the truth of the information which is represented.

In this sense we have journals and have had for many years, in the field of meteorology and geophysics for the publication of such results. I believe that it is very important and I think the National Science Foundation has been doing this for a number of years, to monitor all experiments so that we don't conflict with one another and so that we are aware of progress elsewhere.

So my answer to your question would be "Yes."

Senator CANNON. Most of the testimony today has been on seeding. Is this the sole area of major potential success?

Professor MORDY. Are there other things that we could do that would modify the weather—is this the nature of the question?

Senator CANNON. Yes.

Professor MORDY. Well, there are all sorts of things that are within the engineering capability, it seems to me, that can alter weather locally or generally. Often we are sure that it would alter the weather but we don't know just how, and that, of course, makes experimentation very unlikely.

As a case in point, the rainfall in Hawaii on the island of Oahu doubles roughly for each mile and a half you go inland. If you start off at Waikiki Beach and you walk up to the upper end of Manoa Valley and you start off with 15 or 20 inches of rain a year, by the time you walk this distance—you could walk it in a couple of hours—you are at a rainfall of 185 inches.

The maximum rainfall along the Koolau Mountain Range on Oahu is about 300 inches of rain a year. That range of mountains is only about 3,000 feet high and is a ridge roughly perpendicular to the trade winds. There are deeply eroded valleys that run on the leeward side of the mountain range so that there is an abrupt escarpment or amphitheater at the top of each of these valleys.

It would be perfectly possible to bulldoze a "V" in those mountains and allow the tradewinds to escape through the cut. This would dramatically alter the average annual precipitation at the upper end of that valley. I am confident that one couldn't get permission for the State of Hawaii to carry out that experiment but this is a case in point where there isn't any question but that one could alter the climate.

Similarly, it has been suggested by a number of people that one could do something to change the reflectivity of snowfields in the Arctic regions, to change the flow of the ocean currents near the Bering Straits, to dam Gibraltar and let the Mediterranean dry up. These things are feasible from an engineering point of view, but I happen to like the Mediterranean climate the way it is.

This is a case in point as to where we will go when we can alter meteorological conditions.

Senator CANNON. Is there any study being made, for example, of why the recent runoffs here in Nevada and in the Colorado River Basin were very, very low?

Professor MORDY. Not as such. These are not atypical of long-range weather variations. Thus you could make a census of the number of storms that came in or the shifting patterns of the world weather patterns on the hemispheric weather charts. All these things would show not a cause but a relationship between the weather here and the weather somewhere else.

This is part of this meteorological noise in the system which I indicated in my statement.

Senator CANNON. I was going to ask you about that. What do you mean by "noise"? You say, "The noise in meteorological data is large."

Professor MORDY. One refers to systematic variations in science as things one could detect and describe whereas unsystematic variations have recently been described in science as noise in a system—something in which one is not able to sort out any systematic varia-

tions. Because there are so many variables in the weather, all changing with time, when one sets out to measure one variation in precipitation resulting from one part of an experiment, it is very difficult to sort that influence out from all the other influences on the weather.

Senator CANNON. Do you think that seeding in one area is likely to reduce precipitation in another?

Professor MORDY. Not at our present stage of experimentation. If we ever reach the point, as Dr. St. Amand may tell you here, where we can seed huge areas of the globe, then it may very well affect it, but at the present time on the scale that we are experimenting I think it is very unlikely that one could show any influence a hundred miles or even less downwind from the experimental area.

Senator CANNON. In other words, in a certain cloud system is the seeding activity going to take a rain or snow that would otherwise fall someplace else, or is there going to be a net increase?

Professor MORDY. If I could second-guess you on this I would say that the answer I would like to give you without qualifications is "No." It isn't a matter of taking water away in this case because as I indicated, the amount taken out is a relatively small amount of the total amount there so the amount removed would be almost undetectable.

But there are the possibilities downwind that if seeding is done without the knowledge of all concerned and not watched by the public, that large amounts of seeding agents could drift long distances downwind and confound other experiments of affect weather downwind this way.

Senator CANNON. You indicated you thought that not enough effort was being devoted to this field.

Approximately $6.9 million is being spent in this area this year. What do you feel actually is needed?

Professor MORDY. We have estimated that an expenditure within 3 to 5 years of $20 million a year by the Federal Government, concentrated in a relatively few experiments, would get at the engineering problems that I was talking about earlier.

Senator CANNON. Why does weather modification represent such a small percentage of the efforts in this area of atmospheric science at the present time? Is it because of the controversies that have existed?

Professor MORDY. To some degree; yes.

I think that the science of meteorology is a little different from a laboratory science. We have people working as practicing meteorologists who never make observations, who never go outside the room where the computer is.

We have other people who collect observation information and never see the use that is made of it. We have a large number of meteorologists who are members of the American Meteorological Society. A large number of them are employees of the Federal Government.

This means that a great body of opinion in our field is represented by people who are highly specialized in their work and never actually become involved in experimental work. This I think is one reason why it has been hard for the relatively few to be heard among those who are skeptics and who have not been involved in the experimental programs.

Senator CANNON. Your observation that many of them never look at the instruments and never see what the weather is actually like is reminescent to me, as a pilot in most recent years, when very frequently there was a saying among pilots that you get a weather report but the best way to tell is to ask the meteorologist to look out the window and tell you what he sees.

Is there a possibility of overseeding clouds that would produce any bad effects?

Professor MORDY. If you overseed a cloud, the probability is that you won't get any precipitation from it. If you overseed a cloud that might form hail you may prevent large hailstones from developing. This is the basis for that work.

If you overseed a cloud in which thunder and lightning are likely to occur, there are those who believe that you may change the electrical fields around the cloud and diminish the possibility of lightning and forest fires.

Senator CANNON. In other words, the experimental areas of lightning and hail damage and violent storms is being approached from the standpoint of overseeding rather than normal or underseeding?

Professor MORDY. Yes; or changing the cloud from a water cloud of supercooled water droplets to a cloud of ice crystals which won't collect in these large hailstones for example.

Senator CANNON. What is the difference in supercooled and the terminology that is used?

Professor MORDY. We broke the rain-forming mechanism really into two models. In clouds which never reach the freezing level, tropical clouds in which large amounts of rain form, it is believed that precipitation due to the natural variations in vertical velocity, the number of salt particles, on which cloud droplets form, and to the different droplet growth rates which occur with different naturally occurring conditions.

This is called warm cloud. That is, all of the cloud is warmer than freezing.

In supercooled clouds, the objective when one uses dry ice or silver iodide or some other seeding agent is to affect the number of ice crystals present with droplets which are already colder than freezing. Water won't freeze at 32° F. (0° C.) if it doesn't have some impurity in it or isn't disturbed in some way.

A great many clouds are made up of water droplets colder than freezing. When you put in ice crystals you completely change the character of the cloud. So a supercooled cloud is a cloud made up of droplets colder than freezing.

Senator CANNON. And there are only then, obviously, certain types of clouds that you can have success with in a seeding-type operation?

Professor MORDY. Yes.

Senator CANNON. What are the legal and social implications, if any, of the work being carried on, for example, at Desert Research Institute in this weather modification program?

Professor MORDY. I am not qualified to talk about the legal implications in weather modifications or the social implications. I intended to infer that when I was talking about these other ideas for weather modification of weather and climate of large geographical areas.

Senator CANNON. Do you have someone in the organization who is qualified in this field who could perhaps submit a statement to us?

Professor MORDY. We have a consultant whose name is Edward Morris, of San Bruno, Calif., who is perhaps the most knowledgeable person on the legal implications of weather modification. He has an article in the current issue of the Bulletin of the American Meteorological Society (October 1965).

Senator CANNON. We would be very happy to have him appear at our hearings in Washington which will resume early next year. We will be holding rather extensive hearings there.

Now, Professor, as I understand it, do you want us to have these pictures here that you talked from? If so, they will be made a part of the record, or would you be willing to reproduce those and give us a copy?

Professor MORDY. It is probably easier to put them in a booklet form for you.

Senator CANNON. If you would do that and put the same identification that we talked about for the record here today because I think we have them very well identified with those two particular experiments.

Mr. CHISHOLM. Would you like a copy of the film, Senator?

Senator CANNON. I would doubt that. If you have any still pictures with a legend on them it would be helpful, from the results of the experiment, we would be delighted to have those.

But it is very difficult for us to use a film effectively before the committee.

Do you have anything further to add, Professor, on this subject?

Professor MORDY. I don't think so.

Senator CANNON. I want to thank you for your appearance here. It has been most helpful to us.

We will now stand in recess for 10 minutes and then resume the hearings.

[Recess.]

Senator CANNON. The next witness will be Mr. Joseph Warburton, from the Desert Research Institute. Mr. Warburton, we are very happy to have you here. You may proceed, sir.

## STATEMENT OF JOSEPH WARBURTON, DESERT RESEARCH INSTITUTE

Mr. WARBURTON. Senator, I am a senior research scientist of the Commonwealth Scientific and Industrial Research Organization of Australia, and I am presently on 2 years' leave to occupy a position as a research associate at the Desert Research Institute at the University of Nevada.

As a Commonwealth officer of Australia, I must point out that the views I am expressing are my own, and not necessarily those of the organization to which I belong. I have been engaged in the field of cloud physics in our organization for a period of 6 years, and this work has been principally along the lines of designing physical and chemical types of experiments which can be used in the interpretation of weather modification results.

I have had experience in five large-scale weather modification experiments in Australia, the first of which began in 1955 and lasted for 5 years. Another one lasted for 6 years. Two of them lasted for 3 years, and one of them lasted for 2 years.

All of these experiments were designed to see if it was possible to increase the average annual precipitation over a large area of our country. This is an arid country, and the areas studied were of the order of 1,000 square miles, over periods of a year or more. The experiments were not of the type which Professor Mordy described; that is, the type for clearing of airports, and so on.

They were aimed at trying to increase the average precipitation over a large area of the country where a large amount of farming was going on. The methods of seeding have all been airborne and have all used silver iodide as the seeding agent.

When these experiments began, the world, in general, was in possession of a certain number of physical facts about the atmosphere and clouds and all of these experiments—and I include those which are based on similar principles in this country—were all based on these few facts which were known.

Professor Mordy has outlined some of these; namely, the water droplet growth of precipitation. I am not referring to the warm cloud precipitation; I am only referring to the cold cloud type.

Now, intrisically, the natural variability of the precipitation is found to be very high. There was a paucity of historical data in the research areas in which we were conducting the experiments, and there were not very good records of precipitation in these areas.

Most of the data which has been gathered during these 10 years of experimentation has been obtained from these experiments and the airborne observations of the clouds in the areas. As a result of the paucity of historical data, it was very difficult, statistically, to set up the experiment and very difficult, statistically, to prove that you had, in fact, increased the precipitation.

Now, the results of some of these experiments have been published in the journals. The experiment in the Snowy Mountains was shown to have increased the precipitation over the 5-year period by 19 percent.

Senator CANNON. That was 19 percent total for the 5 years?

Mr. WARBURTON. Nineteen percent per year. That is what is called at the 5 percent significance level, which means a very good chance of this being statistically significant.

The New England experiment which was conducted in New South Wales over a 6-year period showed an increase of 9 percent. One of the outstanding results of that experiment was that the first year of observation showed an increase of something on the order of 45 percent. Other years showed an increase of 1 percent. Others showed a decrease of 5 percent.

When they were all added up over the 6-year period, it finished up with a total of 9 percent on the average. This all points to the fact that there is a great deal of variability in the precipitation, and one of the observed facts in most of these experiments was that the variability of the precipitation was increased by cloud seeding.

Now a post hoc analysis has been taking place on a lot of data from these experiments.

At the time these experiments were designed, as I pointed out earlier, there were certain physical facts available, so they were not built into the design. This post hoc analysis has shown that there are some other very important points in all of these experiments.

First, it was found that differences in the cloud type were important. The cumuliform clouds gave different results from the stratiform

clouds. The cloud temperatures are important. There is evidence that if the clouds don't get colder than minus 10°, then you are not producing effective results by seeding by the present techniques. There may be various reasons for this. There is also a time effect that has been observed.

After seeding, the precipitation goes on for a much longer period of time, so measuring at a point on the ground could be a serious mistake in the design of these experiments. All of these data have pointed up the fact that we need better types of instrumentation for the measurement of the results.

Since these experiments have been going on, we have also had the opportunity to develop in the laboratories more sensitive methods of detecting, for example, the chemical contents of the precipitation, whether the seeding materials are, in fact, getting into the precipitation, how effective they are, whether there is a variation in this across the area, and so on. So we are now in a position to set up more sensitive area-type experiments because we are now in possession of all this new data. The data has come from all of these large-scale experiments as well as individual cloud studies. Two of these new types of experiments have just been set up in Australia, one in Tasmania, which is a 10-year experiment, 5 years on and 5 years off, and there is a second experiment in the New England district which is also of the same kind. A lot of these physical and chemical facts that I have pointed out have been incorporated in the design of these new experiments.

Senator CANNON. Can you measure the silver iodide in rain or snow that would then give you a comparison of the areas that have not been seeded?

Mr. WARBURTON. Yes. This is the experiment in which I am personally engaged, and it was to design even more sensitive techniques for this purpose that I came to the Desert Research Institute. We are going to work on neutron activation analysis methods for the detection of the materials in precipitation.

Senator CANNON. You developed that system yourself, did you not?

Mr. WARBURTON. Yes.

Senator CANNON. Are the experimentation programs that you defined, now in your country, still being carried on?

Mr. WARBURTON. Yes.

Senator CANNON. What is the extent of the effort there?

Mr. WARBURTON. We have these two large-scale weather modification experiments, one of which is in Tasmania. That is a three-area experiment. It is a different design from the ones we mentioned here this morning.

Instead of having just two target areas and switching them about on a random basis, the way we have set up our experimental design is slightly different; basically on the same principles, but we have chosen smaller areas and a larger number of areas so that we can get much higher correlation coefficients in the precipitation and much more sensitive methods of detecting the changes in the precipitation.

Senator CANNON. What is the size of the overall area that the experiment is being conducted in?

Mr. WARBURTON. In Tasmania, the area covered would be of the order of 3,000 or 4,000 square miles and, in New England, it would be about the same.

Senator CANNON. So it is a very substantial effort?

Mr. WARBURTON. Yes.

Senator CANNON. What type of a funding does the Government put into those projects?

Mr. WARBURTON. I am afraid I don't know the answer to that, but I can get the answer for you.

Senator CANNON. Could you supply that for the record so we would have some comparative idea of the extent of the activity?

Mr. WARBURTON. Yes.

(The information requested follows:)

UNIVERSITY OF NEVADA,
DESERT RESEARCH INSTITUTE,
*Reno, Nev., February 18, 1966.*

Senator HOWARD W. CANNON,
*U.S. Senate,*
*Washington, D.C.*

DEAR SENATOR CANNON: This letter is in reply to your question submitted to me in the Las Vegas hearings on bill S. 23, concerning the expenditure by CSIRO Australia on weather modification research from 1956 to 1966. The approximate total expenditure including the purchase of two light aircraft for this period was A£ 2.5 million.

In terms of the relationship of this sum to the Australian economy, I would say this would correspond approximately to $10 million in the United States. Over a 10-year period this represents an annual expenditure of $1 million.

Sincerely,

J. A. WARBURTON,
*Research Associate.*

Senator CANNON. On this need for better instrumentation, do you have anything specifically in mind there? I think we all recognize the need, but what is it we need to have, specifically?

Mr. WARBURTON. If I can answer that question in two ways, perhaps, what we have here at the Desert Research Institute, for example, is going a long way toward, I feel, the type of design which is going to achieve good results. We want to be able to get a cloud census in the area. You can't get this, necessarily, from the ground. It is very difficult to know what the cloud tops are and the types of cloud and their temperatures, accurately.

So we need good aircraft observations; we need good radar cover, because I am personally of the opinion that this time effect is important, and to only measure the precipitation on the ground, I think, could be a mistake.

From observations of single clouds, that have been seeded randomly in Australia, we have found that the lifetime of the cloud has been increased by about a factor of two, and they keep on raining all through this time. They are drifting right across the area, so if you set up your measurement system immediately below, you could be missing a lot of the effect. So we need good radar cover to measure this effect. We need good time-dependent precipitation measurements on the ground. We don't want to know just the type of precipitation; we want to know it as a function of time, as well.

The chemical analysis of the precipitation, I think, is important, and we now have some techniques which we can employ in this sort of way. We need more observations on individual clouds, to find out whether, in fact, it is more important to seed at the base of the cloud, or is it more important to seed above the freezing level.

There is a chance, for example, that large numbers of the particles of the seeding material are taken up by the water droplets in the clouds and are being deactivated. The action of nuclei is the main purpose of the seeding, so I think observations of this kind are important.

So a combined type of study in which you can see all of these things happening within the clouds, as well as measuring the precipitation in time and amount, is the type of experiment we should be planning here. Locations in the Reno area are being designed for doing this.

Senator CANNON. Does that conclude your statement, Mr. Warburton?

Mr. WARBURTON. Yes, I think that concludes my statement. Thank you.

Senator CANNON. Thank you very much for appearing here. We appreciate very much your views, and if you will furnish us that additional information for the record, I think it would be helpful to us.

Mr. WARBURTON. Thank you.

Senator CANNON. The next witness, Mr. Charles Thomas, from the Nevada Department of Economic Development.

## STATEMENT OF CHARLES R. THOMAS, ASSISTANT DIRECTOR, NEVADA DEPARTMENT OF ECONOMIC DEVELOPMENT

Mr. THOMAS. Mr. Chairman and gentlemen, my name is "Chuck" Thomas. I am assistant director from the Nevada Department of Economic Development. My testimony is quite brief and of a very general nature.

I am here today on behalf of the Nevada Department of Economic Development, which is vitally interested in the proposed legislation under discussion.

Our department was created by the Nevada Legislature in 1955; and we were assigned the duty of advertising, publicizing, promoting, and aiding in the development of the vital economic interests of the State of Nevada. We are committed to the support of all activities relating to the economic development of the Silver State.

Nevada is experiencing a tremendous rate of growth. For example, our population has increased by 71 percent since 1960. The number of manufacturing firms has increased by 44 percent since 1958. And this year, we expect to host 19.6 million out-of-State visitors, compared with the 12.9 million who came 8 years ago.

The adequate availability of water has been a key reason for Nevada's mammoth growth. However, as we project ahead, we realize that there might not always be ample supplies of this precious liquid.

And so we must plan ahead, we believe, searching for new sources of water for consumption in our urban and rural areas, and for use by industry, agriculture, mining, and recreation.

We believe that Senate bill 23 provides a means for orderly research, leading to the development of more usable water through weather modification and through techniques better utilizing the moisture sent to earth.

The Nevada Department of Economic Development heartily endorses the provisions of S. 23 and hopes that the bill will be most expeditiously implemented.

Thank you.

Senator CANNON. Thank you very much, Mr. Thomas. We appreciate your being here and giving us the views of the department of economic development.

Mr. THOMAS. Thank you, Senator.

Senator CANNON. Commander Jorgenson, do you and Dr. St. Amand want to appear together on this?

Commander JORGENSON. It would be probably shorter and easier if we both appear.

Senator CANNON. Comdr. Paul T. Jorgenson, Geophysics Group, Naval Ordnance Test Station, China Lake, Calif., and Dr. Pierre St. Amand, Geophysics Group, Naval Ordnance Test Station, China Lake, Calif.

## STATEMENTS OF COMDR. PAUL T. JORGENSON AND DR. PIERRE ST. AMAND, GEOPHYSICS GROUP, NAVAL ORDNANCE TEST STATION, CHINA LAKE, CALIF.

Senator CANNON. We are very happy to have you here.

We are aware of the important work you are doing in this field and will be happy to have your views. You may proceed as you wish.

Dr. ST. AMAND. The Naval Ordnance Test Station began work in weather modification in 1961 taking advantage of the fact that we have an almost unique position in the country to do development work in the production of nuclei for cloud seeding. The original work depended on an invention by a pair of chemists who worked there—a Dr. Burkhart and Dr. Finnegan—in which they developed a method for producing a reaction from silver iodide or lead iodide smoke. As time has gone by the program has expanded. The number of things we now produce for weather modification has greatly increased and the scope of our interest has increased.

Primarily the work is aimed at giving the U.S. Navy and the other armed forces, if they should care to use it, the capability of modifying the environment, to their own advantage, or to the disadvantage of an enemy. We regard the weather as a weapon. Anything one can use to get his way is a weapon and the weather is as good a one as any.

This part of our work is coming along very slowly, although we are working as steadily as we can with the manpower and facilities available to us. The byproducts of our work have been made available to other members of the scientific profession. We have furnished our equipment and nucleants that we have made available to other people in the country, and they have used them for experiments.

One cannot be all things to all men and very often it is nice to let somebody else perform the experiment with what you have provided. We have, for example, worked with the U.S. Weather Bureau on this Project Storm Fury. The project was hypothecated on our ability to massively seed clouds rapidly reaching a capability which did not exist before we began making them pyrotechnically. We have worked with the Bureau of Reclamation——

Senator CANNON. Excuse me. Now is this project related toward hurricane activities?

Dr. ST. AMAND. Yes, sir. It is intended for the control and amelioration of hurricanes. We have worked with the Bureau of Reclama-

tion on their project in the southern Sierra Nevada, we have collaborated with the Colorado State College and with South Dakota in their hail-suppression program, and the coming summer we will be working with them on their hail-suppression project.

We have collaborated with the State of Washington in an effort by that State to increase the rainfall in the mountains and to determine the effectiveness of seeding in their climatic regime there.

We have pioneered in the use of pryotechniques in this field because it gives a capability of putting nucleants in a precise spot in a cloud in any desired quantity within a period of time short with respect to the lifetime of the cloud.

Senator CANNON. Would you describe how you do this?

Dr. ST. AMAND. There are a number of different ways we do this. We have prepared a number of devices which caught fire and burned and the smoke from these devices is the nucleating agent you want. These nucleating agents include silver iodide, which is a comparatively short-lived agent that converts water vapor into ice in the cloud. We have lead iodide which is a long-lived agent which is not destroyed by sunlight. We have various hygroscopic materials which remove water vapor from the air in liquid form droplets.

These devices can be carried on board an airplane or balloon or any other similar artifact and flown into clouds in the position best calculated to yield the effect the person wants in the course of an experiment.

Materials can be dropped from an airplane and burned while they are in the air, or they can be burned on the ground.

One of the handier items that we manufacture for a limited use is a signal flare pistol, something that can be held out of the window of an airplane and shot. This can be used for cloud seeding and has been very effective.

The overall effectiveness of the nucleants that we produce is being tested all the time both in the laboratory and in the field. Some of the field testing we do ourselves; a lot of it we do in collaboration with others, as I have already stated.

Do you have anything to add to this, Commander?

Commander JORGENSON. No. You have covered the main points. Our interest, of course, is military, but we have and intend to continue to collaborate with other people.

Senator CANNON. With your interest being military I presume that you have not necessarily engaged in ground measuring activities and that sort of thing; or have you?

Commander JORGENSON. No, sir.

Dr. ST. AMAND. No, sir. We have neither the time nor the personnel nor the money for this, and in connection with our work with the Bureau of Reclamation, this work has been done or is being done by other people that they employ for that purpose.

Senator CANNON. You said that you were working in connection with the Department of Commerce and the Weather Bureau. Does your funding come from the Navy Department or do you secure funding assistance from some of the other agencies?

Dr. ST. AMAND. Our money has come entirely from the Navy Department.

Senator CANNON. Do you have a cooperative activity in the Storm Fury project with the Department of Commerce and the Weather Bureau?

Dr. St. Amand. That is correct. Each funds his own activities.

Senator Cannon. Have you actually participated in this project? Are you doing just an R. & D. effort now or have you actually carried out some practical tests in this field?

Dr. St. Amand. We have seeded hurricanes in 1961 and in 1963. We seeded hurricanes twice and we seeded cumulus clouds twice.

Senator Cannon. What are your observations on the results of those four activities?

Dr. St. Amand. The observations, expressed very briefly, are that when clouds are massively seeded, the effects are immediately noticeable to a casual observer, but that at the present time a sufficiently concerted effort has not been made on a hurricane to be able to produce anything very definite. I suspect that too little is known of the mechanism of the hurricane to really be able to do something at the present time. With continued experimentation, more would be learned of the effects, and I suspect that in a number of years it might be possible to alter the storms to our advantage.

Senator Cannon. Are you working on some programs along that line? Are you working on operational experiments or are you still engaged in basic R. & D.?

Dr. St. Amand. The basic research and development in nuclei for freezing clouds is about through. We are busy improving things now but that is about finished as far as we are concerned. We now are interested in developing field experiments for the specific use of the military and among these I should mention are experiments with dispersible fog. Fog of the sort that Professor Mordy was showing here can be easily dispersed by the use of dry ice or silver iodide, because it is cold and can be made to freeze. Warm fogs are an extremely difficult problem, but they are an extremely important problem, and the Navy in almost every climate in the world has to contend with these, especially in getting aircraft safely off and on aircraft carriers and also to cover targets.

Senator Cannon. What is your approach with respect to warm fog?

Dr. St. Amand. We have attempted to change the fog by introducing into the fog droplets of material that take the water vapor from the air. A cloud such as a fog is stable because the droplets are all of the same size. A collision between droplets of the same size is difficult to obtain, because they do not develop a velocity relative to each other, and even if they do, aerodynamic forces prevent collision between the droplets and subsequent coalescence in droplet growth.

What we attempted to do was to obtain hygroscopic droplets which, introduced into the fog, would dry the water vapor from the space between the droplets, causing the fog droplets themselves to subsequently evaporate and contribute their water vapor to the droplets of the seeding material, and their size is much greater than the other droplets, and they fall, sweeping the fog droplets from the air.

Senator Cannon. Do you feel that the status of weather modification research is such at the present time that we are ready for a large scale experiment?

Dr. St. Amand. I feel that at the present time unless we go into a large scale experiment we will not learn enough, soon enough, about the problem. We are now at the point in the art where large scale experiments are needed to be able to determine how effective they are going to be.

Senator CANNON. Do you feel that weather modification activities should be centralized in one bureau?

Dr. ST. AMAND. We do not. I think that diversity here is extremely important. There are various aspects to the work.

Now the National Science Foundation supports primarily a high quality of theoretical research and high quality laboratory research of an academic sort necessary to answer the fundamental questions.

The Bureau of Reclamation supports engineering research intended strictly for the production of water. This is different than the National Science Foundation, which is interested in the physics of the cloud and perhaps in things other than the making of rain.

The centralization of authority in a subject in science, before the subject is well understood, usually results in the stultification of the material because I don't think any one person has enough vision to appreciate the possibilities of everybody else's approach to the matter.

At present I would like very much to see a flexibility in this and a diversity of effort.

Senator CANNON. I was going to ask you if you felt that a substantial increase in Federal expenditures is warranted at the present time, but I presume that the answer is self-evident in view of the fact that you thought we were ready for large-scale experiments. That would of course be the inhibiting factor, would it not, on large-scale experiments?

Dr. ST. AMAND. Yes, sir.

Senator CANNON. What is the monetary extent of the effort that the Navy is putting into this now?

Commander JORGENSON. As far as our own organization is concerned, last year it was $250,000 and this year it is $200,000.

Senator CANNON. So actually your effort is reduced this year over what it has been?

Dr. ST. AMAND. This is due to circumstances beyond our control, shall we say.

Senator CANNON. I can well imagine that. In any event you have had quite a substantial reduction in your program, not only because of the rising costs but because of a smaller amount of funds?

Commander JORGENSON. It does hurt. It hurts particularly because we think that we have made progress in the last year, and if we are able to move somewhat faster and perhaps into other areas—much of the previous research was engaged particularly on the silver iodide, cold clouds. Now we are attempting to shift over to an area of prime interest to the Navy into the warm cloud area and still finish up some of the cold cloud silver iodide research.

Dr. ST. AMAND. $200,000 is about 10 man-years if one does not have to buy equipment and supplies. Actually we are managing to get about, I would say, 6 man-years out of that money. The rest of it is going in to support Project Storm Fury and other expenses that are more or less beyond our control.

We could, I think, very efficiently handle another $100,000 or perhaps $200,000 a year without beginning to build an empire.

Senator CANNON. What was your effort prior to the last year which you said was $250,000?

Commander JORGENSON. This was primarily the support of Project Storm Fury Center and it varied with the activity of the project.

It was somewhat of a spasmodic thing depending on activity of hurricanes.

Dr. ST. AMAND. In 1961 it was a grand total of about $70,000. In 1962 we received no money whatsoever. In 1963 we received some for the support of Project Storm Fury.

Senator CANNON. As a part of your funding program, do you have to fund your own aircraft or is this furnished?

Commander JORGENSON. This is furnished by the Navy as far as the provision of the aircraft and the operational funding requirements. If we require separate or additional instrumentation that is not common to the particular type, we must buy, build, or invest, as the case may be, to pay for the installation and maintenance.

Senator CANNON. Are specialized aircraft needed for this job?

Commander JORGENSON. Yes, indeed.

Senator CANNON. Do you have them permanently assigned to you or is this on an on-call basis?

Commander JORGENSON. We have one that is assigned to us. It is on a more or less permanent basis. It can be recalled at any time, however.

Senator CANNON. How long have you had that particular one?

Commander JORGENSON. Just about 1 year now.

Senator CANNON. Is the extent of Project Storm Fury or the level of that program going to be about the same this year?

Commander JORGENSON. The coming year the current agreement under which Project Storm Fury has been operated was between the Navy and the Department of Commerce. It has been terminated and I understand that there are discussions now going forward for possible renewal. What its status is for future years I have no knowledge at this particular time.

Senator CANNON. So for all you know you might be out of business next year?

Commander JORGENSON. I don't think we will. We have plenty of work to do that is of interest to the Navy over and above Project Storm Fury.

Senator CANNON. Is there any indication of what your funding is going to be in the forthcoming year?

Commander JORGENSON. Approximately the same as this year to my knowledge.

Senator CANNON. Approximately $200,000?

Commander JORGENSON. $200,000 to $250,000, I suspect.

Senator CANNON. Is anyone in your shop studying the legal and social aspects of hurricane seeding?

Commander JORGENSON. No, sir.

Dr. ST. AMAND. We are watching the matter very closely and considering this sort of thing, especially social aspects.

Senator CANNON. What do you mean you are considering it? Just thinking about it, is that what you mean?

Dr. ST. AMAND. Yes, sir.

Senator CANNON. You are not actually doing anything on it at the present time?

Commander JORGENSON. No, sir; not as far as China Lake is concerned.

Senator CANNON. Is someone in the field doing something on it as for as you know?

Dr. St. Amand. Attorney Morris, whom one of the previous witnesses mentioned, specializes in this.

Senator Cannon. In San Bruno?

Dr. St. Amand. Yes, sir. There is one aspect that I would like to speak to. That is the question of the harvesting of water from the atmosphere. I can foresee that in the future the problem is going to become a large engineering operation, and one is not going to be able, for example, to seed clouds over a valley in which agricultural products are being raised, with any degree of impunity, because there is a diversity of the crops and farmers who raise one thing will not want water at the same time another farmer will want it. So the answer to this is going to be the declaration of certain areas in the country, the mountainous regions, the watersheds, the larger rivers, to be declared possibly as areas in which cloud seeding or water accumulation is the chief business.

Then there will be a system of canals and pipes for distributing the water to the people who use it. It is going to be a very systematic sort of project on a scale that is very hard to conceive, and I can imagine in the future a tie-in with Mexico and Canada for the utilization of the rivers in this respect.

I can foresee also that it is going to be only a very few years before this sort of work is going to become necessary as the rate of the population is increasing. It is going to require a very long, very consistent effort on the part of some particular agency or agencies, and in the case of the Bureau of Reclamation I think it is glimpsing the problem in its entirety at this point and is working toward the overall management of watersheds in the distribution of water.

The harvesting of water is quite a different problem from predicting the weather, and although prediction of the weather is certainly necessary to doing this effectively, but looking to the future I can see a much bigger, much more complicated operation coming out of this than anybody I think at present fully realizes.

The international implications are going to be something probably of almost overriding importance because it will be possible, by a proper weather modification program, to control other people's climate as well as our own. Economic warfare, for example, is probably going to come up in the future and whether it comes up or not, or is intentional or not, we are going to be accused in the event we start taking a lot of water out of the cloud systems in Western Europe or perhaps in the United States.

Ultimately agreements on an international scale are going to come about in this field.

Senator Cannon. Do you envision or attach more importance to the so-called seeding or modification in mountainous type areas where the crops are not grown so heavily and you might increase a snow pack to increase a runoff in our streams rather than direct benefits because of the diversity of crops as you indicate?

Dr. St. Amand. Yes, sir. I think that is the sensible way to proceed. Most of the rain falls in the hills anyway because of the orographic effect. The wind when it comes in the mountains is uplifted, air cools, and water falls as rain.

Our attempts at making rain have been very successful in this type of situation. I think we can safely say that we can ultimately make

rainfall although we don't know how much. When the water enters the streams from the mountains it is possible to collect the water because it is concentrated into dams and put into canals and distributed to where you want.

Water falling on the plains may furnish temporary relief to the crops or it may encourage the grass to grow, upon which cattle graze, but the water is largely lost through evaporation almost immediately and very little of that water ever enters the underground water table where it can be retrieved by wells. Hence, I feel very strongly that the only proper way is to take the headwaters and develop these catchbasins intentionally as a harvesting area for water.

Senator CANNON. Based on the information presented earlier today it is apparently equally as important that we do something about this evaporation problem. I think you were here when the witness testified that the loss out of the Colorado River Basin by evaporation is actually more than if we were able to increase the runoff by 10 percent or 600,000 acre-feet a year.

Dr. ST. AMAND. That is correct, and evaporation loss is proportional to the surface area of the reservoirs and if we increase the water in the reservoirs we increase the surface areas.

Senator CANNON. And we may get into an argument there too as to whether or not storage facilities then should be increased, because each time you increase a storage facility from a particular watershed you are going to increase the evaporation loss of that system, is that right?

Dr. ST. AMAND. That is correct. The management of a watershed is a very exacting science and each step in the development of a watershed has to be considered very, very carefully by the people who do it.

Senator CANNON. Are you continuing now to improve your pyrotechnic devices that you were working on, improve their efficiency or effectiveness?

Commander JORGENSON. Yes, indeed.

Dr. ST. AMAND. We are trying to improve their effectiveness; we are trying to decrease their cost; we are also exploring other means of cloud seeding that do not involve pyrotechnics.

As I said before, the spraying of liquids, for example, in fogs. One of the things that we are currently engaged in is endeavoring to seed clouds by using compressed air from our jet airplane. The air in the front part of the jet engine is compressed to a pressure of several hundred pounds per square inch. We take some of that air and cool it a little bit and then expand it through a nozzle. It immediately makes large clouds of ice crystals and then on a supercold fog of this sort it would be only necessary to flash the very top of the fog with this apparatus turned on and we would have to introduce ice crystals without the use of silver iodide or without the use of dried ice. This could be made an operational feature on any airplane that had a small motor of that sort or had a small air compressor.

The airplanes could then open their own holes. The advantage of this in seeding storm fronts would be that a man can seed a storm front and bring about the effects he wanted and as soon as these effects were over there would be no carryover effects from the nucleants he used.

I can see a need for developing nucleation of this sort, because with the air filled with silver iodide over the entire country, and if every-

body were engaged in seeding in a completely random manner it would prevent the growth of certain types of clouds so we are looking for types of things that will not produce harmful effects on the world's weather.

Senator CANNON. Might that also produce a ground contamination effect?

Dr. ST. AMAND. Ground contamination?

Senator CANNON. Yes. If this type of agent were introduced would that be detrimental to any types of crops on the ground?

Commander JORGENSON. No, sir. These would be natural ice crystals only.

Senator CANNON. There would be no other contamination?

Dr. ST. AMAND. From the use of the jet there would be nothing except ice.

Senator CANNON. I meant the other types of agents.

Dr. ST. AMAND. Silver iodide is sufficiently insoluble in water that it does not represent a real hazard, and small amounts are used. I don't regard this as being a serious source of trouble.

Now, in your fog work we have been extremely careful to pick agents that will not be either toxic or corrosive and we have gone down the list of chemicals that will produce the desired effects, and we have removed any of those that could possibly have deleterious side effects.

Senator CANNON. What is the stage of this jet program you are talking about? Are you actually doing some applied research in that area now?

Commander JORGENSON. We have the idea; we are trying to design the system at this moment.

Senator CANNON. So you are still in the basic research area on the equipment itself?

Commander JORGENSON. We have not yet built the equipment. We are trying to design it at the present time to fit the particular aircraft.

Dr. ST. AMAND. We have done it on a small scale with little bottles of compressed air and little pellet guns and so forth, so we know it works.

Commander JORGENSON. We have done it on a laboratory basis but we have not done it on an atmospheric basis.

Senator CANNON. Do either of you have anything to add?

Commander JORGENSON. No, sir.

Senator CANNON. Dr. St. Amand and Commander Jorgenson, we are very pleased to have you here with us. You have presented some very interesting information for the benefit of the committee.

Commander JORGENSON. Thank you very much.

Dr. ST. AMAND. Thank you.

Senator CANNON. Are there any other witnesses here who desire to be heard on the matter today?

(No response.)

Senator CANNON. If not, the hearings will be recessed and the next hearing will be in Elko, Nev., at 10 a.m., on the 10th of November at Ranch Inn Motel.

(Whereupon, the committee was recessed, to reconvene at 10 a.m., November 10, 1965, at Elko, Nev.)

# WEATHER MODIFICATION

WEDNESDAY, NOVEMBER 10, 1965

U.S. SENATE,
COMMITTEE ON COMMERCE,
*Elko, Nev.*

The committee met at 10 a.m. in the Corral Room of the Ranch Inn Motor Lodge in Elko, Nev., the Honorable Howard W. Cannon presiding.

Senator CANNON. The hearing will come to order. This morning we resume hearings on the subject of weather modification. We are specifically concerned with S. 23, introduced by Senator Anderson of New Mexico and cosponsored by myself and others, a bill designed to increase in substantial degree the annual average usable supply of water from rainfall and snowfall in arid areas under the direction of the National Science Foundation and the Secretary of the Interior.

The first hearing was held in Las Vegas, Nev. on November 5. Representatives and statements from the State government, the Naval Ordnance Station at China Lake, Calif., and the Desert Research Institute of the University of Nevada were heard. The testimony, in part, detailed the needs of Nevada and the prospects for successful weather modification, particularly in dealing with orographic clouds. The Desert Research Institute is presently conducting a cloud-seeding test here in Elko County. Twenty silver iodide generators are used to seed suitable storms. Precipitation measurements in two target areas are used to demonstrate the difference, if any, between the seeded and unseeded portions of the storms. It is a 5-year program. The importance of the program lies in the essential nature of adequate statistical information to determine the success or failure of seeding operations. The program here in Elko is particularly noteworthy because it was initiated by the local community. Private funds, raised locally, stimulated State and other groups, resulting in the present cloud-seeding program. Thus the program is doubly significant.

This hearing, as well as the one in Las Vegas, will provide the background for a series of subsequent hearings to be held on this subject.

At this time I would like to make a part of the record a statement submitted by Senator Alan Bible, the senior Senator of the State of Nevada, in support of S. 23. This will be made a part of the record.

(The statement referred to follows:)

STATEMENT OF SENATOR ALAN BIBLE TO THE SENATE COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE, LAS VEGAS, NEV., NOVEMBER 5, 1965

Mr. Chairman, first, let me congratulate you on the leadership you have provided in initiating hearings on S. 23, the bill to direct the Secretary of the Interior to institute a program to increase usable precipitation in five areas of the United States.

My interest in this program goes back to my early days in the Senate. In 1957, as a member of the Interstate and Foreign Commerce Committee, I chaired hearings in Washington, D.C., on S. 86, a bill to provide for an experimental research program in cloud modification. This bill vested the administration of the program in the National Science Foundation and it has continued to be active in developing the necessary basic research in this field.

On February 5, 1959, I again cosponsored legislation devised to increase usable precipitation in the Colorado River Basin. This was a 10-year program costing approximately $10 million, and would include engineering and meteorological studies as well as investigations of studies and devices to increase snowpack storage and water runoff. This bill was not favorably received by the Secretary of Commerce or the National Science Foundation, primarily on the grounds that the action was premature pending a solution of the scientific problems that were then facing the National Science Foundation.

In view of the lack of urgency indicated by the National Science Foundation, I proposed in 1964 that the Bureau of Reclamation appropriation be increased from $100,000 to $1,100,000 to implement a full-scale campaign to increase precipitation on the Colorado River.

Data supplied by the Bureau of Reclamation indicates the benefits of increased rainfall through weather modification could be tremendous. An additional inch of precipitation above Glen Canyon Dam would produce a runoff of 575,000 acre-feet. This extra amount of flow through Federal powerplants could boost income, on established power rates, by $2.5 million. Naturally, this additional water could be available for agricultural, municipal, and industrial uses. Allowing for losses in runoff, this added inch of precipitation would still provide 500,000 acre-feet of water for irrigation which, based on a 1962 water-crop benefit formula, would produce a gross crop income of $24.7 million. Municipal and industrial uses, of course, would increase the value of this extra precipitation even more.

These funds were utilized by the Bureau both as grants to universities, including the Desert Research Institute, and for a field program in the basin. Because of the effectiveness of the Bureau's program, the Appropriations Committee has approved funding this program for the next fiscal year in the sum of $2,980,000. This is but a step in the right direction. The legislation now before you, patterned after the saline water program, would prove whether or not weather control is presently within the grasp of our scientists.

As Senator Anderson stated during hearings held in Washington by the Interior Committee, on May 21, 1964, "It is readily apparent that it is vital to the public interest to reassess the position of weather modification research with a view toward paralleling Government-supported basic research with more extensive field applications of processes already known to be adapted to practical application.

"I would also like to point out that this should be only the first step in enactment of far-reaching studies of weather control.

"I can well recall the warning of Dr. John von Neumann, Atomic Energy Commission Commissioner, that weather manipulation, not the ICBM, would be the ultimate weapon for the protection of the free world * * *."

Again, my congratulations to my distinguished colleague for his initiative in calling hearings, and my pledge of complete cooperation in securing enactment of the bill.

Senator CANNON. The first witness today will be Mr. George Hardman, assistant director, State Department of Conservation and Natural Resources of the State of Nevada. Mr. Hardman, we are happy to have you. You may proceed.

## STATEMENT OF GEORGE HARDMAN, ASSISTANT DIRECTOR, STATE DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES OF THE STATE OF NEVADA

Mr. HARDMAN. I am George Hardman, assistant director of the department of conservation and natural resources. I reside in Carson City, Nev. Mr. Shamberger, who was director of the department until the 1st of January, has filed a statement with the committee at the Las Vegas hearing. Mr. DeRicco, who is now director of this

department, sends his regrets at not being able to be present himself, but prior commitments and the business of the department just make it impossible for him to be present. Therefore, I am representing the department here today.

I have very little to add to Mr. Shamberger's statement. The department is interested in cloud seeding and, of course, desires that this program should be continued. We have worked—we have received the funds from the legislature and from the counties and from private individuals. We have contracted with the Desert Research Institute to do the actual work in the field and to do the office work that is necessary in this kind of a program. We favor large programs. We don't favor the small individual private seedings because the results appear to be always in question. Therefore, we favor such large-scale programs as are now being conducted in Elko County and that will be supported by this bill, S. 23.

Senator CANNON. Do you feel that there has been enough research and development accomplished in the area now that we are ready to go ahead with a large-scale type of a program?

Mr. HARDMAN. I think we are ready at this stage now to go ahead with a pretty good sized program. This matter of the size of a research program was discussed on the plane as we were coming in this morning with Mr. Elliott, who has the actual operations here. The size of a research program is usually fixed by the budget. And with a cloud-seeding program we can seed as much territory or we can intensify the program as much as desired and the size of the budget will fix that.

Senator CANNON. What type of a budget does your department spend in this area now?

Mr. HARDMAN. We have a contract for about $40,000 a year. I say "we," that is the Desert Research Institute and our department, for the operations that are going on in the field. I don't know exactly how much is being spent by the Desert Research Institute on other types of work.

Senator CANNON. I was most interested in the extent of your efforts through your department?

Mr. HARDMAN. About $40,000 a year is being spent in seeding in the field operations.

Senator CANNON. Is there a proposal to increase or decrease or keep that program about the same in your next budgetary cycle or do you know at the present time?

Mr. HARDMAN. I don't know exactly what the plan would be. I think that it would be hoped that the Federal Government would take over this program in the field. Any results that you might get would be of a benefit to the country as a whole.

Senator CANNON. Now as I understand it the State of Nevada has a provision for licensing operators, is that correct?

Mr. HARDMAN. The law that was passed in 1960 provided for the licensing of operators.

Senator CANNON. Is that handled by your department?

Mr. HARDMAN. That is handled by our department.

Senator CANNON. And how many operators have you had occasion to license up to the present time?

Mr. HARDMAN. Only one.

Senator CANNON. Only one operator?

Mr. HARDMAN. Yes. That has been for research purposes.

Senator CANNON. Have you had other applicants or is this the only applicant?

Mr. HARDMAN. We have had no other applicants.

Senator CANNON. What type of requirements have you imposed as a prerequisite to receiving a license? Or have you actually spelled out in detail the requirements up to the present time?

Mr. HARDMAN. We haven't spelled those out. In general, however, we have recognized ability to do the job as indicated by the size of the organization, its successful operations at other locations, and its willingness to go along with the insurance provisions that we have asked.

Senator CANNON. Have you imposed as a prerequisite an insuring provision?

Mr. HARDMAN. Until this year, the State was immune to tort cases. That immunity has been dropped. Since then we have not changed our licensing procedures at all.

Senator CANNON. Do you require insurance to be carried by the operator for the protection of the operator and the State, jointly?

Mr. HARDMAN. For the protection of the operator and the State we will require insurance.

Senator CANNON. Does it cover only tort claims or does it cover the possibility of claims that might arise by, let's say, a person who might claim he had been deprived of water by the operator causing precipitation before the clouds got to his area?

Mr. HARDMAN. I can't answer that, Senator Cannon. I think maybe Mr. Elliott, when you have a chance to question him, can answer some of those questions. The State has no provision yet in our regulations for requiring any such thing.

Senator CANNON. What is your view on the extent of the Federal programs at this time? Is it your feeling that we would be justified in substantially increasing the Federal expenditures in this area at the present time?

Mr. HARDMAN. Well, this is a shorttime program the State has in mind. Five years is somewhat the limit. It is impossible to pick areas and be sure at the first shot. We think that this program should be continued at no smaller scale than we now have. We would like to see the scale increased a little bit.

Senator CANNON. Of course, what you say about the difficulty of producing results that are capable of definitive measurement is certainly true but we had a very fine example presented in the Las Vegas hearings by Desert Research Institute in the experiments they conducted in Washoe Valley around the Reno Airport. The results were certainly very well demonstrated there.

Mr. HARDMAN. We started this program at the beginning of a very dry spell. There were no clouds for the first 2 years, there was nothing to seed. It did give an opportunity, however, for the perfection of certain equipment which Mr. Elliott has and his workers and the Desert Research Institute have done pretty well. We haven't had 5 years, however, of good cloud-seeding weather.

Senator CANNON. Thank you very much, Mr. Hardman. We appreciate your appearance here and we, of course, are aware of the

fact that Mr. Shamberger, in appearing earlier, has had a lot of experience in your department and he certainly gave us the benefit of his experience.

Mr. HARDMAN. He was the boss.

Senator CANNON. The next witness will be Mr. Walter Wiseman, engineer, Control Data Corp., Las Vegas, Nev. Mr. Wiseman, we are happy to have you here. You may proceed as you see fit.

## STATEMENT OF WALTER J. WISEMAN, ENGINEER, CONTROL DATA CORP., LAS VEGAS, NEV.

Mr. WISEMAN. My name is Walter J. Wiseman, University of Nevada graduate, bachelor of science, electrical engineering. My vocational experience is systems oriented in the fields of communications and computers. At college, the engineering schools competed in a presentation to the students and public. My electrical engineering class based our presentation on developing two essential elements to Nevada's growth, or for that matter any similar arid area—that of power and water. Since that time, I have had a keen avocational interest in any means which can achieve these necessities.

I feel that stronger support of weather modification programs is commendable. Past demonstrations of harvesting water from the atmosphere, and other techniques of controlling severe weather phenomena, have gained a general consensus by science and engineering alike that control of weather is within our grasp. In fact, we already have a wealth of technology to apply in all aspects of instrumentation and observation systems to reduce previously gross trial methods to laboratory precision experimentation.

Control Data Corp. currently builds and equips laboratories for other scientific disciplines in our colleges, universities, and industry, mostly in buildings. But we also build them in much larger scope for controlled experiments in ordinance, rockets and missiles, and space exploration. The latter are highly capable instrumented ranges where a large variety of allied experimentation can be performed and closely measured for controlled, substantiated results. Weather modification needs this type of environment to grow and realize the potential promise it holds out to us.

One of the most promising areas, harvesting water, can perhaps best illustrate my point. It is perhaps apparent that the existing watersheds are the most desirable areas in which to stimulate more precipitation. They are the places where conditions are more favorable, and where water can be harvested without interfering with crop production or harvesting schedules. These watersheds have existing drainage systems of dams, reservoirs, and canals developed over many years of water planning with which to best utilize the water derived. However, to just produce more water for a watershed without a careful integration of the runoff systems capacity for control and storage would be to invite the disaster of subsequent natural floods. It is not just a matter of producing more water, but rather of developing a system which encompasses both the production and management of it.

An instrumented range with the ability to definitively measure conditions and parameters in the atmosphere as well as on the ground would yield a laboratory environment for this program of technique

development and practical application. Engineering a system of radar, aircraft, and other measuring or observation devices together with the telemetry, analysis and prognosis generating equipment would define the cost of this approach clearly. Such a range, or ranges, should be open to all experimentors to preserve the flexibility and competitive stimulation of diversity of scientific effort from many quarters. These laboratories could also be utilized for a host of other experimental work, such as clear air turbulence, severe storm warning and control, terminal weather forecasting, and integral watershed management in "test tube" fashion, as well as producing increased hydroelectric power and more usable water.

Thank you, Mr. Chairman, for the opportunity to appear before you today.

Senator CANNON. Thank you, Mr. Wiseman. I was interested in your statement, the last paragraph on page 1 of your statement. You make what to me is a very important point when you say that:

> Just to produce more water for a watershed without a careful integration of the runoff systems capacity for control and storage would be to invite the disaster of subsequent natural floods.

We had a rather dry period when they didn't have clouds really to operate with for seeding purposes. And yet this year we have had quite a bit of snowfall and rainfall and the conservation facilities in this area are getting pretty well filled up. I was told last night that the Rye Patch Dam, which the testimony in the record shows is a control dam at the lower end of the Humboldt before the water dumps into the Humboldt Sink, that Rye Patch Dam is almost full now. So it is obvious that if we are going to increase the water available through these means we are likewise going to have to have adequate conservation aids to take full benefit of the increase. This is the point, I take it, that your are making?

Mr. WISEMAN. Yes; right. In addition I guess the consensus that I derived from the testimony in Las Vegas was that instrumentation of the observation process was the most lacking area. This is why my testimony was pointed in this direction.

Senator CANNON. I understand you are engaged with a computer company at the present time.

Mr. WISEMAN. Yes.

Senator CANNON. To what extent, in your opinion, are computers used and if they are not used could they be used to a good advantage or are they necessary in this type of a program?

Mr. WISEMAN. Well they are used to a large extent by the military at this point in time with operational programs in being. The Fleet Numerical weather facilities at Monterey at the naval postgraduate school is perhaps one of the leading exponents and pioneers in the field. The development of programs that they have had down there have been rather pioneering and very successful and as a consequence of this the naval fleet weather centers have expanded their computer operations to handle the prognoses and analyses that Fleet Numerical does. Of course they are interested in the environment that the Navy operates in, that being the sea, and they are not particularly interested in what happens over a land mass.

Senator CANNON. You refer to an instrumented range as being desirable. A lot of the record shows that our measuring devices are

not adequate up to the present time. Does the State of Nevada offer any unique advantages for setting up such a range in your opinion?

Mr. WISEMAN. Yes, in many respects. From the standpoint of natural occurring conditions, it does. It has several ranges across the State which give the orographic rise and produces that type of cloud.

Senator CANNON. When you say several are you talking about mountain ranges?

Mr. WISEMAN. Mountain ranges, excuse me. The population is comparatively sparse so that weather modification could be carried on in many areas, in a controlled fashion without impinging on the personal rights of people. It is close to the west coast and a system here would be able to look into the Pacific area and the Gulf of Alaska area where most of our weather generates to take anticipatory action in preparing cloud-seeding programs. It has many comparatively small, by other standards, reservoirs and river systems developed but which, at the same time, demonstrate all of the general techniques in watershed management. It has in the Desert Research Institute, I believe, a substantial capability in the theoretical development and management and application of this program.

Senator CANNON. In your opinion should such an instrumented range, as you describe, encompass the entire Nation or would it be better to set up such a range in an area in the West that has the features that you defined earlier?

Mr. WISEMAN. From the standpoint of general coverage of the subject I believe that perhaps several ranges are in order. Perhaps one in the area of the West where we have rather unique conditions to this area. Perhaps one in the Southwest or Gulf States where they have unique conditions that don't occur in the West. But the concept behind establishing a range would be to do this in a "test tube fashion" for general application later on.

Senator CANNON. Of course the bill that we are now receiving testimony under, S. 23, envisions the establishment of a program in five areas of the country and so this seems to be somewhat consistent with what you are saying here now.

Mr. WISEMAN. Yes.

Senator CANNON. Do you think we are actually ready at this time to set up such an instrumented range, are we that far along in your opinion?

Mr. WISEMAN. Yes; I believe so. We have, as I said, a great many technological applications and advances to use at this point. The FAA radar system which is nationwide and could be used to great benefit in seeing the weather, seeing the precipitation, and gathering in the atmospheric information.

Senator CANNON. What would be some of the major components of an instrumented range that are not now available, let's say. You refer to a radar system here that is available.

Mr. WISEMAN. In actual fact the components exist, they just haven't been applied to this particular problem yet. But sensors on aircraft telemetered back through the FAA beacon system into a device which could analyze and provide a prognosis. And, of course, the operational equipment to provide practical application of cloud

seeding, the silver iodide generators or airplanes with dry ice and other nucleating agents.

Senator CANNON. Have you given enough thought to this to estimate the cost of, let's say, a range in Nevada sufficient to do the things you have been talking about?

Mr. WISEMAN. In brief fashion yes. It appears it would cost somewhere in the area of $5 to $6 million. This would be first cost, investment in hardware. This does'nt necessarily talk about the types of people and personnel that would be required.

Senator CANNON. That is independent of the maintenance and operations costs that would be involved in personnel and expense of operation and so on?

Mr. WISEMAN. Yes.

Senator CANNON. In your opinion, given the present state of weather modification, to what extent is the business community investing funds in operational weather modification programs or to what extent should they be interested?

Mr. WISEMAN. I think that could best be answered in pointing out that the airlines are initiating a program this year to do a practical program of clearing fog at airports. So they have evidently determined that the economics are favorable to making holes in clouds to land at airports.

Senator CANNON. That is a program similar to the one that was demonstrated by Desert Research Institute at the Las Vegas hearings?

Mr. WISEMAN. That is correct. Other companies like the water and power companies have been, for a number of years, utilizing spot cloud seeding to produce water and the economics have proved this operation for them. My company is extremely interested in it because we have computers installed at NCAR, at the Severe Storm Center, at the U.S. Weather Bureau, and at the Fleet Numerical and fleet center operations.

Senator CANNON. Thank you very much, Mr. Wiseman. We certainly appreciate your appearing here and giving us the benefit of your advice on this very important subject

Mr. WISEMAN. Thank you for the opportunity.

Senator CANNON. The next witness will be Mr. John Chisholm of the Desert Research Institute of the University of Nevada. Mr. Chisholm, we are happy to have you here and you may proceed.

## STATEMENT OF JOHN P. CHISHOLM, ACTING HEAD OF THE LABORATORY OF ATMOSPHERIC SCIENCES, DESERT RESEARCH INSTITUTE, UNIVERSITY OF NEVADA, RENO, NEV.

Mr. CHISHOLM. My name is John Chisholm. I am an engineer holding a master of science degree in electrical engineering. Currently I am the acting head of the laboratory of atmospheric sciences at the Desert Research Institute of the University of Nevada. My history is as follows:

I graduated from MIT in 1944, spent the next 7 years at the institution as an instructor. In 1950 I joined Bell Aircraft Corp. in Buffalo, N.Y., where I was responsible for the development of the Navy's automatic landing system for airplanes. I would like to describe the development of this system, as the overall problems

encountered are analogous to those involved in weather modification. Specifically the point I am trying to make is the concept of systems engineering as it applies to weather modification. This automatic landing system permits naval aircraft to land (without human intervention) on the moving deck of an aircraft carrier. It utilizes radars, computers, autopilots, data links, and a highly sophisticated computer to compute the control functions for the aircraft and to predict the motion of the aircraft carrier in confused seas.

The successful development of this system required a team composed of oceanographers, mathematicians, scientists, and engineers. The diverse talents required to produce a successful solution could only be found by combining the capabilities of personnel from many fields.

The oceanographers contributed in analyzing the motion of the sea and how such motion influenced the pitching and rolling of the aircraft carrier.

The mathematicians solved the complex equations utilized in the prediction of the ship motion.

The scientists developed the sophisticated radars and computers utilized in the control loop between the aircraft carrier and the aircraft.

The engineers implemented the concepts that were outlined by the work of the mathematicians, oceanographers, and scientists into a usable hardware. Their final contribution was the demonstration of this hardware under field conditions. The point I am trying to make is that my background has been heavily involved in systems engineering and it is my feeling that only by the application of such engineering concepts will the problems of weather modification be brought under scientific control.

The automatic landing system program was successful. In sea trials a twin jet fighter made 60 successful landings in the length of this room without the need for the pilot to touch the controls.

Returning to my qualifications, I formed the Sierra Research Corp. in Buffalo, N.Y., in 1957. The name Sierra stemmed from my desire to move the corporation to Reno, a city that I hold in high regard.

After 7 years of growth to 150 employees, I was unable to persuade the other owners to move so I resigned as president. Subsequently, I was appointed to a position in the Desert Research Institute. My decision to accept was founded on my high regard for Professor Mordy and belief that the systems concept, which I had successfully employed in the above-noted program, could be successfully utilized in the field of weather modification.

The systems concept underlies all major research and development programs in the United States today. It is exemplified by the successful development of intercontinental missiles and by the current space program. Fundamentally, it means gathering together a team whose backgrounds are of wide enough scope to encompass all facets of any problem. My experience has been that if you miss one facet you can be in trouble.

This does not mean just a team of scientists and engineers whose skills can direct a program. Although personnel are the obvious ingredients to initiate and supervise the program, progress depends upon the facilities for measurement and the technical assistants at all echelons to gather and reduce the data. The cost of such facilities

is high, especially during the startup phase of any group. Hence, adequate funding for weather modification, far above the current level, is necessary to assure some measure of success during the next half decade.

The Desert Research Institute of the University of Nevada has assembled a team with the necessary broadness of abilities to make significant contributions to the knowledge which will make weather modification a scientific reality.

Harold Klieforth, former director of the Sierra wave project, is an expert in synoptic meteorology, His talents lie in relating cloud forms to the large-scale weather patterns.

A vital next step is the understanding of the fundamental processes through which tiny cloud droplets attain sizes large enough to fall as precipitation. Roughly, it takes 1 million cloud droplets to make one raindrop. Professor Mordy, Dr. Berry, and Dr. Scott are experts in these processes. Their theoretical work involves both the physics and complex mathematics of the interaction of large numbers of these droplets.

The artificial stimulation of precipitation requires inserting the right nucleating agents into specific clouds. The study of these agents is a specialty of Dr. Hoffer and Mr. Warburton. Placing nucleating agents in a cloud at the right time and place, plus detailed measurements of the changes in the cloud, are complex problems in field engineering.

For example, positioning a seeding as well as an instrumented aircraft in turbulent clouds over mountainous terrain in winter is an extremely difficult job. Add to this the task of obtaining reliable measurements in the air and on the ground of the cloud and precipitation particles when steeply sloping 10,000-foot mountains lie beneath.

Any statistical analysis of the rainfall patterns and changes in these patterns due to seeding falls into the responsibility area of Mr. C. K. Stidd.

The administration of this program, in a coherent manner so that all personnel realize that they have a common goal and apply their diverse talents to achieving this goal, is my responsibility. And you will realize that the job without adequate tools becomes extremely difficult if not impossible. Fortunately, we have some of these tools and only lack the funds to procure the others.

Currently, the above-noted personnel with their well-qualified but inadequate supporting staff of engineers and technicians are headquartered in the new Water Resources Building of the Desert Research Institute. They constantly strive to design experiments and equipment which will permit the verification of the theoretical and laboratory experiments in the field.

For field operations in the Reno area we have: a well-instrumented aircraft, an instrumented mountain (Slide Mountain), and four radar systems situated around this mountain. These radar systems are used to position the aircraft and measure the radar reflectivity of the precipitation. The physical explanation of the formation of natural wintertime precipitation, and its modification, is the focus of this complex of personnel and equipment. The field program was conceived by and receives its scientific direction from the above noted scientists but is operated primarily by the engineering group associated with this program.

The program described above represents Desert Research Institute's effort to employ the system's concept to weather modification. Knowledge gained from this program, centered on one mountain, should provide the scientific and engineering basis for future programs covering large areas. It is believed that our Desert Research Institute program in Reno represents one of the few "systems" approaches in the country.

Supplementing our work in the Reno area is our project in this area (Elko). This program is directed by the Desert Research Institute and implemented by Mr. Elliott's organization.

Our present funding is $450,000 per year. The National Science Foundation supports the scientific effort, the Bureau of Reclamation, the engineering effort.

My personal opinion, based upon my first year's experience in this area, is that the funding for weather modification should increase tenfold within the next 5 to 10 years. The return to the country from such funding will be many times that amount.

In summary, the primary message that I wish to convey is that the Desert Research Institute's program in weather modification utilizes the systems concept, a concept that has evolved from the large-scale research and development programs conducted in this country in recent years. We believe that the application of this concept will achieve success.

Senator CANNON. Thank you for your very fine statement, Mr. Chisholm. You stated that you couldn't perform this job without adequate tools and that you had some of them and only lacked the funds to proceed with others. What are some of the specific tools that you are talking about?

Mr. CHISHOLM. Well, let me comment on the tools for one mountain experiment. Right now we are using a Twin-Beech aircraft which has a climb rate, when it has got a little bit of ice, of about 300 feet a minute. This climb rate in mountainous terrain is not the most satisfying thing in the world to the pilot or to his test engineers. What we desire is a better airplane. We have to have it in my opinion and the cost is a half million dollars. An airplane similar to what, for example, NCAR has would be satisfactory.

Senator CANNON. What is that?

Mr. CHISHOLM. A Queen Air. The radars we are using, although excellent and worth half a million dollars when new, are 15 years old and were designed before the Korean war. The radars that are better suited for this type of operation are what is known as doppler radars which are just coming into use. I could easily visualize a half million to a million dollars spent on radar suitable for this one mountain experiment.

At the present time when our airplane flies into these clouds, data is collected aboard that airplane on paper tape. A couple of hours later the paper tape is on the ground and scientists can reduce the records and say, "Two hours ago the temperature on top of that mountain in that cloud was minus 10°." The ideal situation, if you are talking about a laboratory in the sky, is to have the data that is in the airplane sent to the ground by radio and made immediately available to the scientist on the ground so that he will have a physical feel of the experiment that is going on. He can read the temperature and the

amount or number of snow crystals and he can change the experiment in the middle of it and not have to wait until days later after he has reduced the data. Specifically, airplanes, better radars, relaying of the data to the ground for the one mountain experiment all require funding.

Senator CANNON. What is your estimate of the cost of this relay equipment?

Mr. CHISHOLM. I would say that a hundred thousand dollars would provide excellent equipment. If now we extend this concept from the one mountain experiment to the Sierra Nevada Range, for example, we are talking not of one airplane or one or two doppler radars or one relay system, but many. And you can start multiplying numbers by 10 to 1. My feeling is that when you multiply the numbers 10 to 1 you multiply the returns by more than that.

Senator CANNON. Is your current program at the Desert Research Institute such that you can make capital investments subject to the funds that you have available for this type of thing or, for example, does your contract with the State limit you to operational type expenditures?

Mr. CHISHOLM. Our contracts are such that with the permission of the contracting officer, that is, the Bureau of Reclamation or the National Science Foundation, we can purchase capital equipment.

Senator CANNON. Have you made a presentation of your future needs or your present needs, let's say, to do a more efficient job? Have you made that type of a presentation to the National Science Foundation and the other departments involved?

Mr. CHISHOLM. No, sir; we have not. At the Desert Research Institute I am the one who can foresee how this money can be used because of my past experience in this large system. My opinion is that the people who are in this field don't realize how big the game is; they don't have a feeling for the money that should be made available or that is really required. Within the last few months I have been outlining in my own mind these requirements and the finances.

Senator CANNON. On about page 3 of your statement you said, "Hence, adequate funding far above the current level is necessary to assure some measure of success during the next half decade." Is that related to your statement on the last page where you said that the funding for weather modification should increase tenfold within the next 5 to 10 years?

Mr. CHISHOLM. That is correct, sir.

Senator CANNON. And when you are relating those terms, are you talking about the country's program in this area, or are you talking about Desert Research Institute's program?

Mr. CHISHOLM. I can only speak directly for the Desert Research Institute's program at this point. I would guesstimate that the figures for the country as a whole might be more than that because, for example, the East hasn't yet even begun to consider it. They don't have groups really organized for this work like the Desert Research Institute, that is they have to start from scratch. Perhaps when you look at the country as a whole, the funding ratio might be greater but that is speculation on my part, sir.

Senator CANNON. Is your present funding from the National Science Foundation on a year-to-year basis?

Mr. CHISHOLM. Our present funding from the National Science Foundation is for a 3-year period; our funds from them will be exhausted within 3 months. We are presently submitting new proposals to them for another 2-year continuance.

Senator CANNON. And what is the level for that proposal or are you in a position to say at this time?

Mr. CHISHOLM. The level of the funding that we are requesting is roughly $120,000 a year from the National Science Foundation.

Senator CANNON. You say that now you are proceeding on the basis of $450,000 a year. Are you getting that much from other sources?

Mr. CHISHOLM. Our expenditures over the last 6 months and projected into the next 6 months will roughly run $450,000 a year. Of this, approximately two-thirds will be the Bureau of Reclamation and roughly one-third will be from the National Science Foundation.

Senator CANNON. Do you think that this sort of a financing arrangement is appropriate and suitable to do the job?

Mr. CHISHOLM. There are two aspects of this funding arrangement that I could comment on. One, the sources. We are currently financed by the Bureau of Reclamation, an engineering organization, and the National Science Foundation, a scientific organization. I find such an arrangement very satisfying from the point of view of an engineer because I can communicate readily with the engineers of the Bureau of Reclamation. The more scientific types in our project find it more satisfying in the terms of the National Science Foundation. The funding level is another subject. Typically in the past, it is my feeling, and I am sure this is what has happened, the National Science Foundation and the Bureau of Reclamation have been able to get a certain amount of money and then you fit your operation to the money. A way of looking at this funding problem is to assume that you are in private industry and the Bureau of Reclamation comes to you with a request to bid on making certain studies in an area. If I were in private industry and the Bureau of Reclamation asked me to bid on the work that we are doing in Reno in an adequate manner I would start off with a $4 million capital investment and a several-million-dollar payroll per year. That is my feeling of the requirements in that area. So to restate myself, the source of funding is quite satisfactory. The type of funding on a 2- or 3-year basis from the National Science Foundation is quite satisfactory. The present uncertainty of the Bureau of Reclamation funding is very unsatisfactory. It is upsetting when I don't know what is going to happen to the Bureau funding next year. The total amount of funding is inadequate to really tackle the weather modification problem.

Senator CANNON. In Elko the Desert Research Institute installed a radar system as a part of the local program, but you have since withdrawn it. What is the explanation of that?

Mr. CHISHOLM. I think a way of explaining that withdrawal is to go back to the systems concept. The system concept, as outlined in my discussion earlier, is the bringing together of diverse talents to solve a complex problem. When the Desert Research Institute installed a radar in Elko there was not one electrical engineer on the program. It was thought that a radar was necessary for meteorological studies, so a radar was placed in Elko. When I became associated with the program I asked, "Why a radar in Elko?" They

said, "To gather meteorological data." My background has included the FAA and large scale military systems and I said, "I can go to the FAA in Salt Lake City and I can get better radar coverage there for the Elko area than you are getting with your radar on Doby Summit." They didn't believe me so I went to Elko and Salt Lake City and obtained information on precipitation in the Elko area by photographing a PPI presentation of the FAA and correlating the observed precipitation simultaneously with a ground observer in Elko whom I controlled by telephone. The actual photographing was done in the Salt Lake City ARTCC Center since the output of the Battle Mountain radar is microwaved to Salt Lake City. By using a Polaroid camera we were able to get this information. I was able to convince the people in Desert Research Institute to discontinue the Elko radar facility and we are currently getting better radar coverage than we were getting before. In place of the radar equipment we have installed a radiosonde at Elko. For less money we are getting better radar coverage as well as radiosonde coverage and we are able to do this over a wider area. This is one minor aspect of the systems concept; that is, bringing together people with diverse talents.

Senator CANNON. Are there other areas where the FAA system could be used in weather modification programs?

Mr. CHISHOLM. Yes. These reports discuss this matter. I would like to make them a part of the record if I may.

Senator CANNON. They will be received and made a part of the record.

(The reports referred to follow:)

LETTER PROGRESS REPORT NO. 3, MARCH 31, 1965—BUREAU OF RECLAMATION CONTRACT NO. 14-06-D-5401; NATIONAL SCIENCE FOUNDATION GRANT NO. GP 941

(Submitted by the Desert Research Institute of the University of Nevada)

INTRODUCTION

This is the third of a series of monthly letter progress reports outlining the activities of the Desert Research Institute on the above noted Bureau of Reclamation contract.

These monthly letter reports will be supplemented at various intervals by technical reports detailing a specific aspect of the program.

The format of these letter reports coincides with the work plan recently accepted by the Bureau.

*Work plan A. Acquisition of meteorological and hydrological data*

The acquisition radar (10 centimeters) has been added to the extensively modified M-33 system previously installed and checked out at the Truckee-Taho Airport. The GMD-1A radiosonde set at this location has been used for seven releases during the month of March.

Personnel from the Weather Bureau worked with DRI personnel in launching balloons in the Mount Rose area and in helping to set up a GMD system at the Elko Airport. One radiosonde release for checkout purposes was made at the Elko Airport during the last week in March. The computer program to reduce the GMD radar numerically which was started last month is almost complete and is currently undergoing final checkout.

The instrumentation of the DRI Twin Beech has progressed to the point that the following are operational.

(*a*) Johnson-Williams liquid water content meter;
(*b*) Rosemount temperature probe;
(*c*) Universal turbulence meter;
(*d*) Compass follower;
(*e*) Crossfell rate of climb indicator;
(*f*) Pressure altitude; and
(*g*) Barnes infrared radiometer.

In addition an excellent intercom system has been installed and FM radios have been installed at the university, Truckee-Taho Airport, and the aircraft, so that good communications net has been established. At the present time recording in the aircraft is done on the direct-writing oscillograph.

During the month of March four flights, March 6, 22, 29, and 30, were made in the aircraft for the purposes of gathering data with respect to cloud systems over the Mount Rose complex. In addition, one flight was made to and from Elko, Nev., with all the instrumentation working for the purposes of checking out the instruments.

A 50-level monometer has been constructed and is in working order. Steel needles are again used for the contacts in the mercury, since the sharp point gives good definition in level, and steel (iron) is about the only reasonable conductor which does not amalgamate with mercury. In addition, the process of accurately locating the contacts was quite quick and simple, using the steel needles. It appears, based on tests with the present model, that considerably greater resolution can be obtained. However, if more than the 50 levels are to be recorded, a more sophisticated switching and coding scheme will have to be used. The 50-contact stepping relay being used is at about the limit of its capability.

Present plans are to connect the manometer to one of the available pressure pillows to test the overall system. The output pulses are still being recorded on a strip chart recorder. However, on order is a high-speed decimal counter from Abrams Co., which is expected to give the level directly as a decimal output. Also on order is a pair of CB radio transceivers. When these arrive, tests can proceed on the overall telemetry system.

*Work plan B. Perform field experiments in cloud nucleation in the Elko and Reno area*

*Elko.*—The existing cloud-seeding program is continuing in the Elko area. No significant design changes have occurred in this program during the reporting interval. As noted in section A, a radiosonde has been installed at Elko. This will greatly aid in the statistical analysis of seeding results.

*Mount Rose.*—No seeding experiments have been conducted.

*Work plan C. Investigate the feasibility of a weather surveillance radar network in the Western United States*

Considerable effort has been expended on this phase of the program during this report period. The background relating to this effort is as follows:

The Weather Bureau Research Station, Las Vegas, Nev., during 1964, conducted a study of the feasibility of using existing radar networks in the Western United States to track tetroons (constant altitude balloons) to determine airflow patterns from the Nevada Test Site of the Atomic Energy Commission.

Their study indicated that the existing FAA radar network, figure A, could be utilized for this purpose. In this connection an operational program of tracking tetroons by this technique has just been implemented (March 15, 1965).

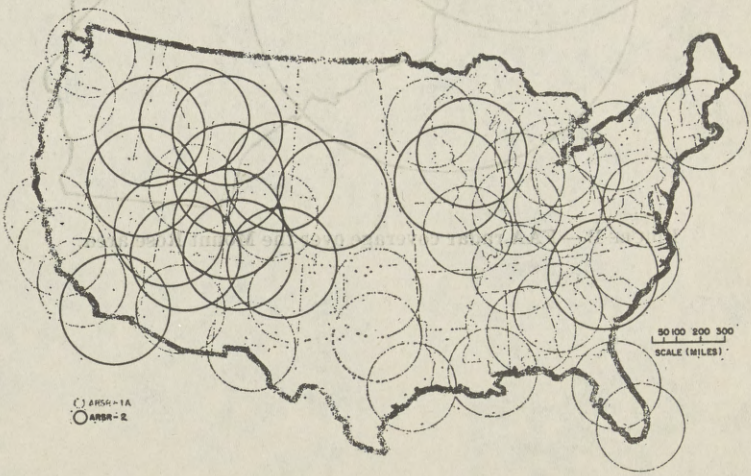



FIGURE A.—FAA radar coverage.

During the course of this study it became clear that this FAA radar network also provided excellent precipitation detection capabilities. Specifically the FAA radars have the same or better precipitation detection performance as the WSR–57, the standard meteorological radar of the Weather Bureau. This conclusion was verified by a separate study performed by Weather Bureau personnel associated with the severe storms project in Oklahoma.

The use of such a weather detecting radar network is of obvious interest to the DRI in connection with the program covered by these reports. For this reason the matter has been under current study, as discussed below.

The FAA radar network is divided into air route traffic control centers (ARTCC) with radars in the coverage area of each center being microwaved to a central location.

Figures B and C show the centers of particular interest to this project, those of Salt Lake City, Utah, and Fremont, Calif. With these two centers, coverage over the two areas of interest, Mount Rose and Elko, is obtained.

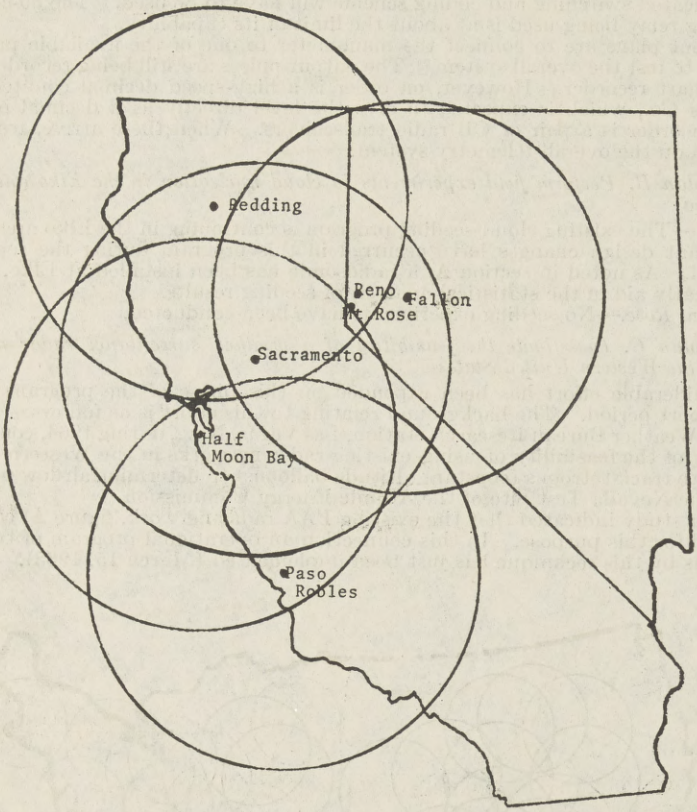



**FIGURE B.—FAA radar coverage over the Mount Rose area.**

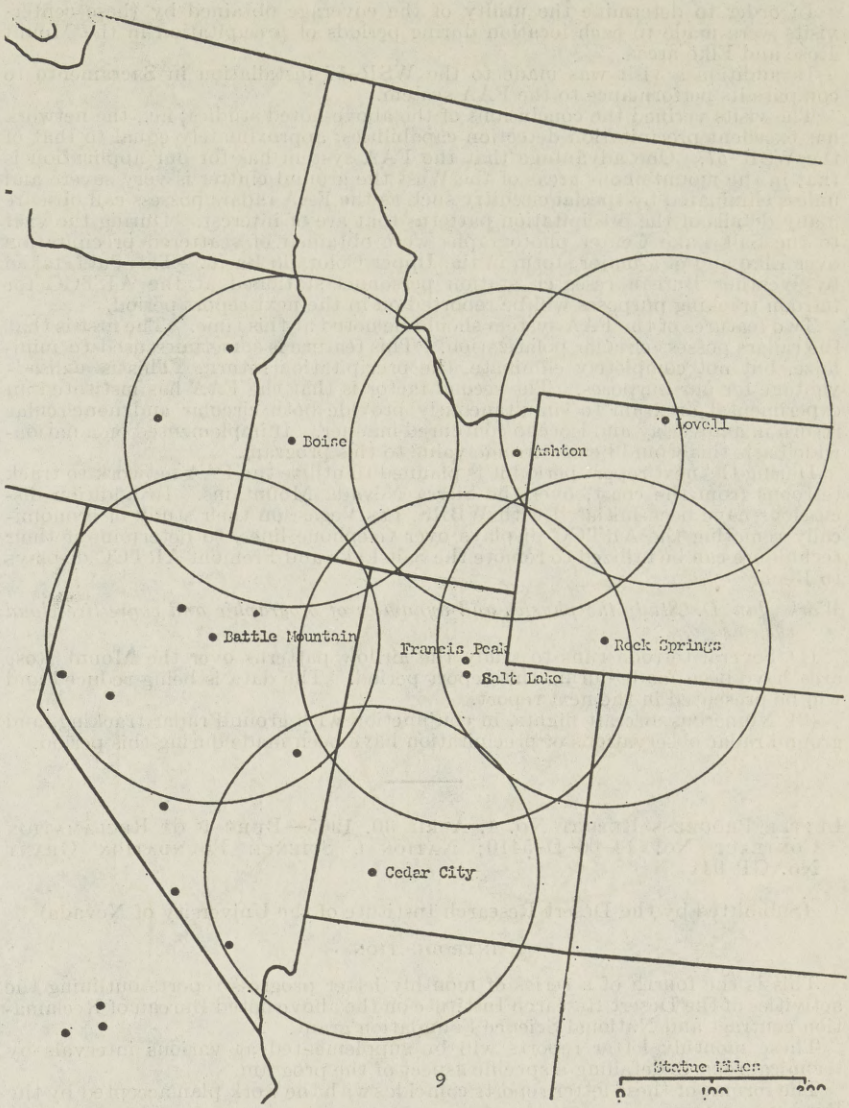



FIGURE C.—Salt Lake City ARTCC coverage.

In order to determine the utility of the coverage obtained by these centers visits were made to each location during periods of precipitation in the Mount Rose and Elko areas.

In addition a visit was made to the WSR–57 installation in Sacramento to compare its performance to the FAA system.

The visits verified the conclusions of the above-noted studies; i.e., the network has excellent precipitation detection capabilities, approximately equal to that of the WSR–57. One advantage that the FAA system has for our application is that in the mountainous areas of the West the ground clutter is very severe and unless eliminated by special circuitry such as the FAA radars possess can obscure many details of the precipitation patterns that are of interest. During the visit to the Salt Lake Center photographs were obtained of scattered precipitation over Elko and of a major storm in the Upper Colorado Basin. This data, taken by Weather Bureau research station personnel stationed at the ARTCC for tetroon tracking purposes will be reported on in the next report period.

Two features of the FAA system should be noted at this time. The first is that the radars possess circular polarization. This feature is sometimes used to minimize, but not completely eliminate, the precipitation return. This is a disadvantage for our purposes. The second factor is that the FAA has instituted an experimental program to simultaneously provide both circular and noncircular return in an overlay and isoecho contoured manner. If implemented on a nationwide basis this would be of extreme value to this program.

During the next report period it is planned to utilize the FAA network to track tetroons from the coast, over the Sierra Nevada Mountains. In addition discussions have been initiated with WBRS, Las Vegas, on their study of economically remoting the ARTCC displays over telephone lines, to determine if their techniques can be utilized to remote the Salt Lake and Fremont ARTCC displays to Reno.

*Work plan D. Study the physics and dynamics of orographic and convective cloud systems*

(1) Several tetroon runs to study the airflow patterns over the Mount Rose area have been made during this report period. The data is being reduced and will be presented in the next report.

(2) Numerous aircraft flights, in conjunction with ground radar tracking, and ground radar observations of precipitation have been made during this period.

---

## Letter Progress Report No. 4, April 30, 1965—Bureau of Reclamation Contract No. 14–06–D–5410; National Science Foundation Grant No. GP 941

(Submitted by the Desert Research Institute of the University of Nevada)

### INTRODUCTION

This is the fourth of a series of monthly letter progress reports outlining the activities of the Desert Research Institute on the above noted Bureau of Reclamation contract and National Science Foundation grant.

These monthly letter reports will be supplemented at various intervals by technical reports detailing a specific aspect of the program.

The format of these letter reports coincides with the work plan accepted by the Bureau.

*Work plan A. Acquisition of meteorological and hydrological data*

The GMD 1–A radiosonde set located at the Truckee-Tahoe Airport has been used for seven releases during the month of April. An additional $x$ band M–33 radar has been placed in operation in the Reno area, east of Mount Rose. The computer program to reduce the GMD data numercially was completed and is being used operationally.

During the month of April three flights, April 6, 7, and 28 were made in the aircraft for the purposes of gathering data with respect to cloud systems over the Mount Rose complex.

New engines with a 12–1 blower ratio have been installed in the Twin Beach test aircraft. A test flight to 24,000 feet with this new configuration has been

achieved, as contrasted to the previous altitude performance of 19,000 feet. This greater altitude capability permits us to utilize the majority of the wave clouds that frequently occur over the Mount Rose area. These wave clouds provide ideal "atmospheric laboratory" conditions due to their stationary configuration in space.

*Work plan B. Perform field experiments in cloud nucleation in the Elko and Reno area*

*Elko.*—The existing cloud-seeding program is continuing in the Elko area. No significant design changes have occurred in this program during the reporting interval. The radiosonde has been installed at Elko. This will greatly aid in the statistical analysis of seeding results.

*Mount Rose.*—No seeding experiments have been conducted.

*Work plan C. Investigate the feasibility of a weather surveillance radar network in the Western United States*

As noted in Letter Progress Report No. 3, personnel of the Weather Bureau Research Station, Las Vegas, Nev., obtained information on precipitation in the Elko area by photographing a PPI presentation of the FAA Battle Mountain radar. The actual photographing was done in the Salt Lake ARTCC Center since the output of the Battle Mountain radar is microwaved to Salt Lake.

The data was obtained by using a Polaroid camera to photograph a Bright Display. A Bright Display is a TV-type presentation of radar data stored on a storage tube. The technique is as follows:

The radar output is read into one side of a storage tube and stored there for a period up to 6 minutes (as determined by the operator). The stored data is scanned and displayed on what are essentially conventional TV receivers.

As noted previously one of the major advantages of the FAA system is the use of MTI (moving target indication) to eliminate ground clutter. This is especially advantageous in the mountainous areas of the West.

A second advantage of the FAA system is the use of video mapping. This presents easy identification of the areas of interest by correlating the video maps with airways charts.

Both the above features, the use of MTI and video mapping can be noted in the enclosed photographs figures A through F.

59-528—66—pt. 1——5

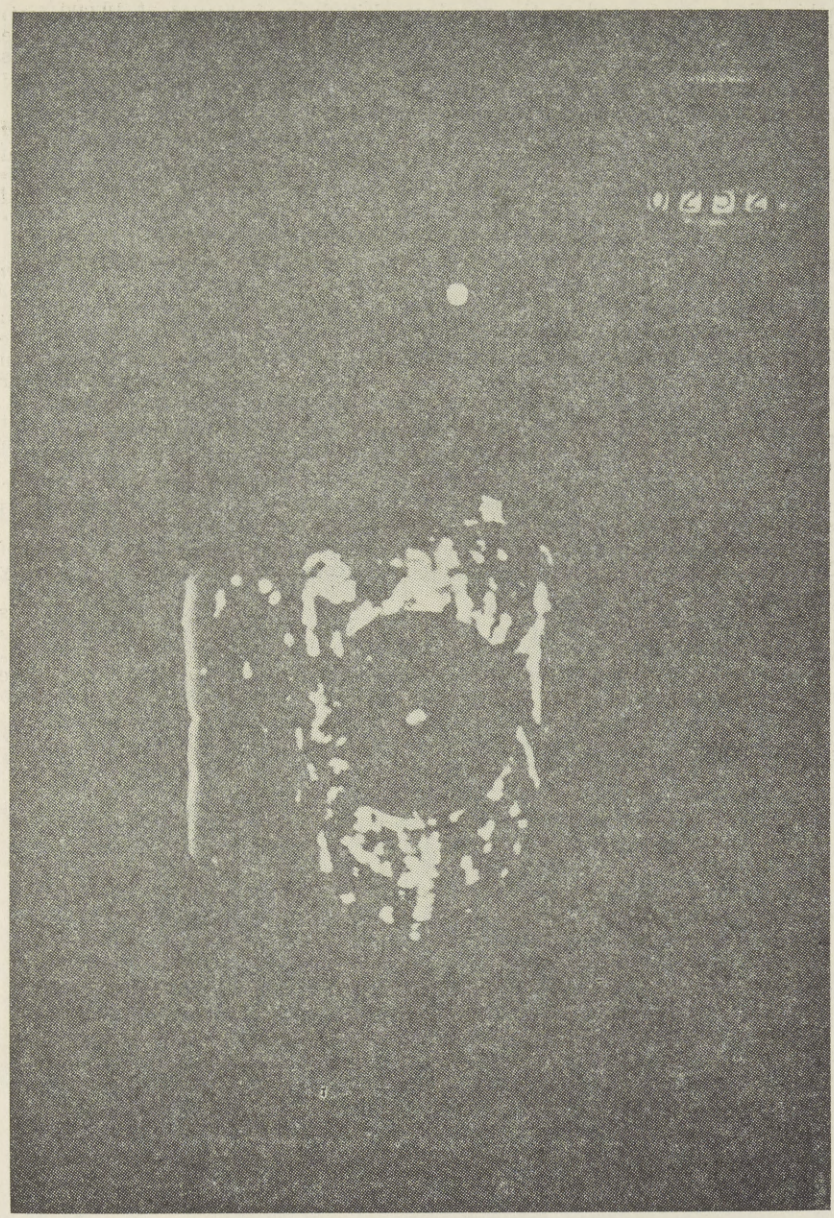


FIGURE A.—Photograph of Battle Mountain radar with MTI to 50 miles.

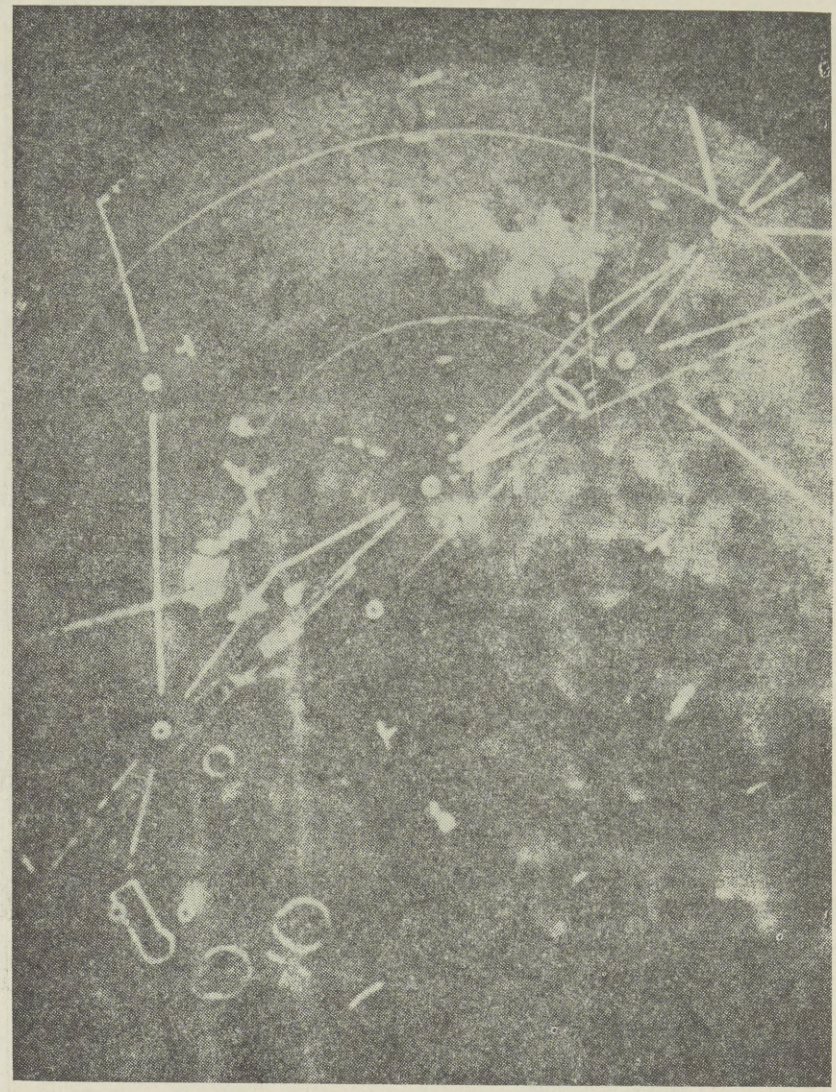


FIGURE B.—Battle Mountain radar with MTI to edge of presentation.

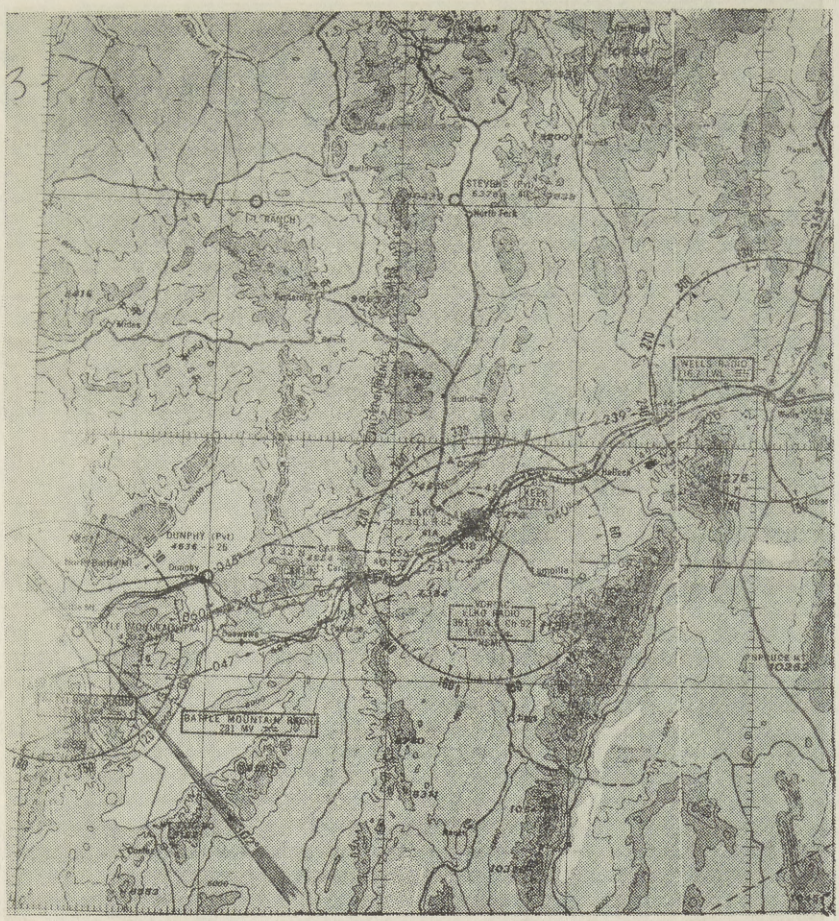



FIGURE C.—Airways map of Elko area.

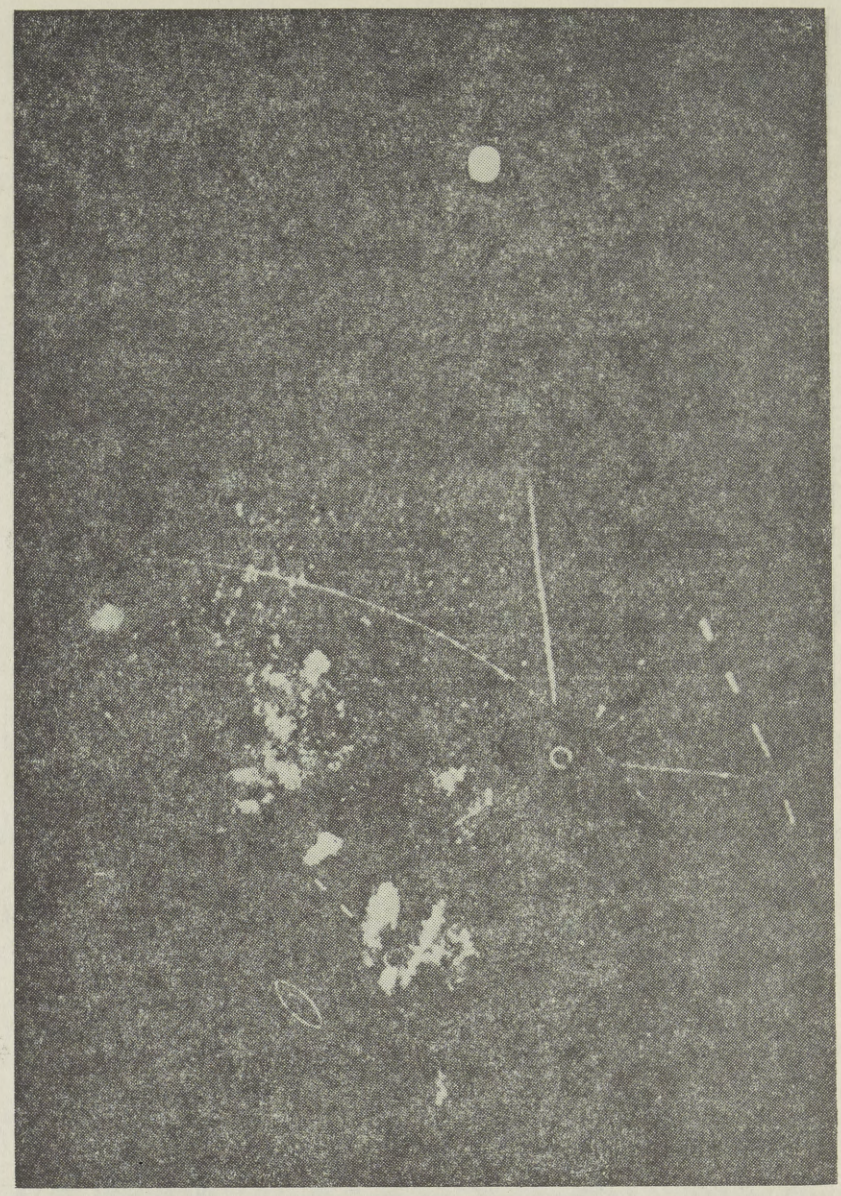


FIGURE D.—Detailed precipitation patterns in the Elko area.

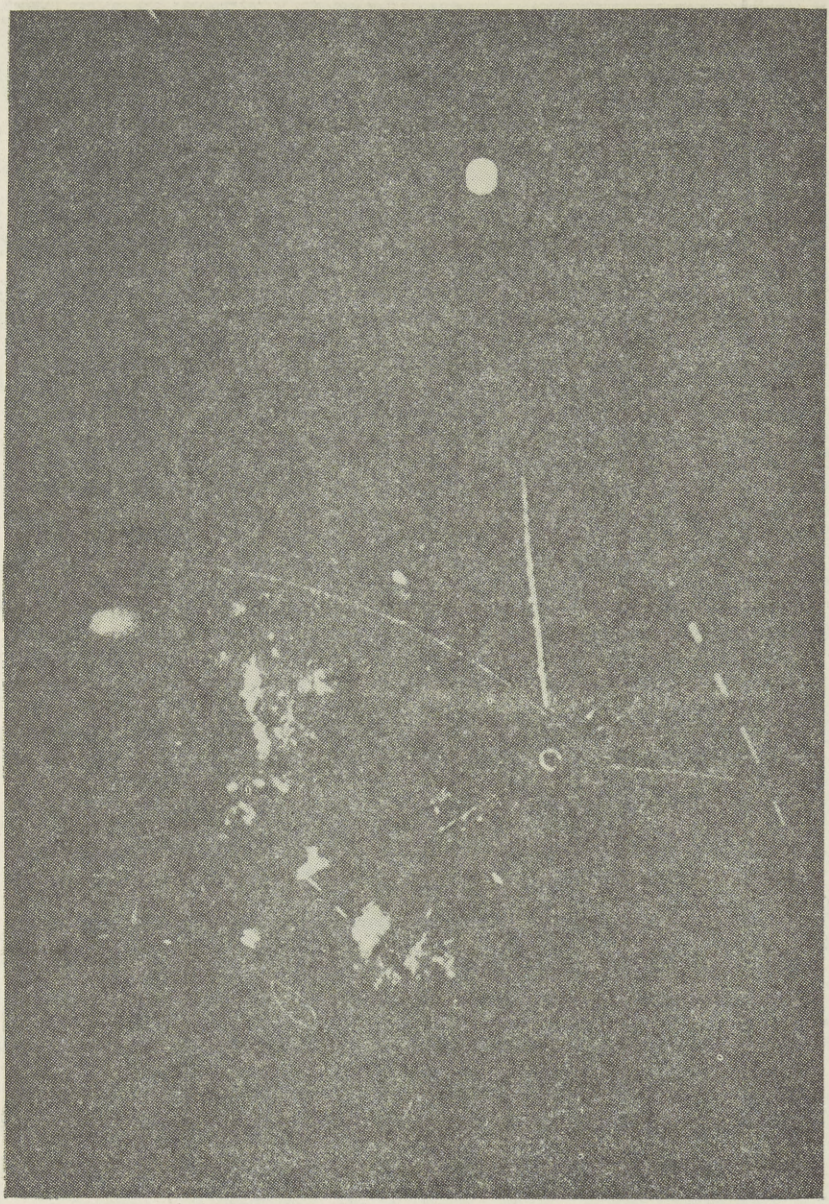


FIGURE E.—Detailed precipitation patterns in the Elko area.

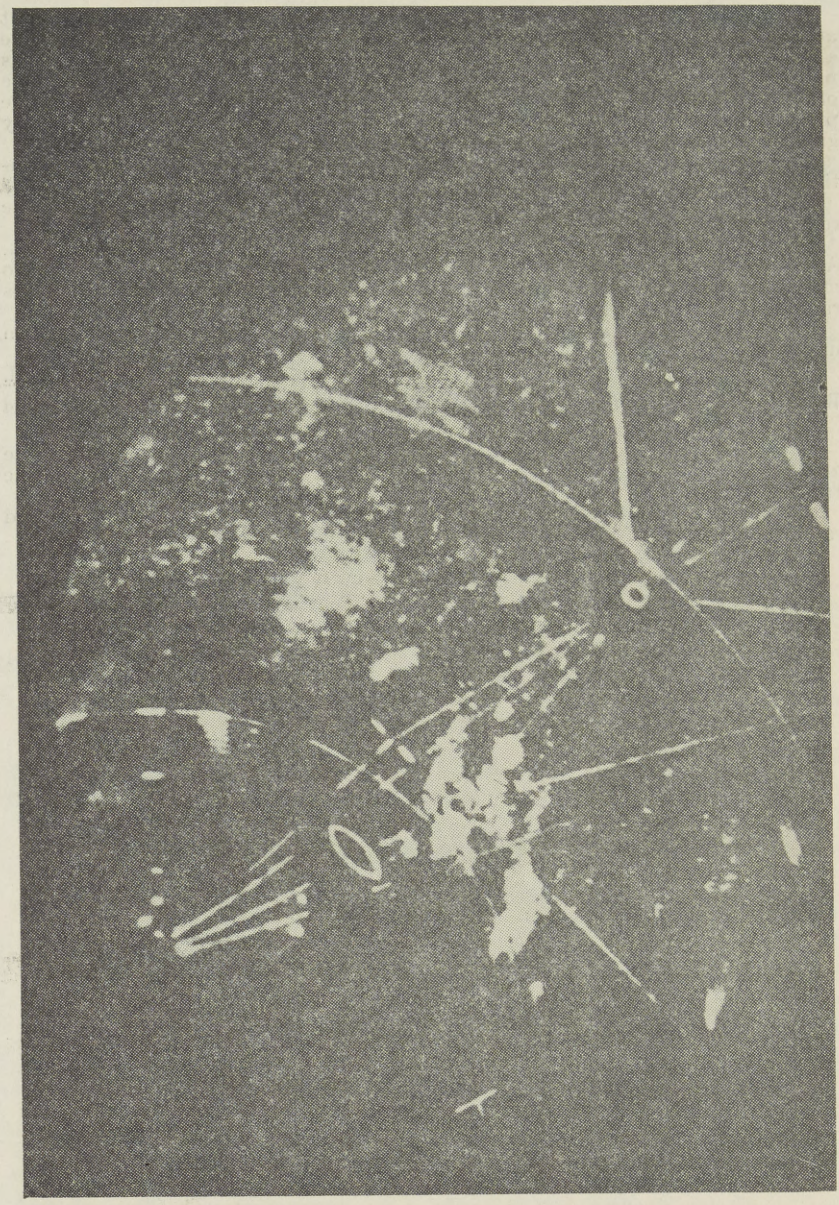


FIGURE F.—Detailed precipitation patterns in the Elko area.

In reviewing these photographs it should be realized that they represent a first attempt at such photography, in which changes were made in both exposure time and scale factors used. For this reason the scale factor and exposure of the various photographs are not uniform. Figures A and B show the radar output to a range of about 120 miles. In figure A, MTI is utilized to a range of 50 miles. Some precipitation within the 50-mile circle is discernible. Beyond 50 miles the heavy ground clutter makes the detection of precipitation rather difficult.

In figure B, MTI is utilized to the edge of the presentation and so the precipitation is readily discernible at all ranges.

The video map of figure B presents the exact location of precipitation to be readily identified, by using the airways chart of figure C.

Figures D, E, and F show the precipitation in the Elko area in more detail. Again the location of the precipitation can be obtained by reference to the video map which shows the location of the Carlin fan marker and the Elko and Wells radio.

Figure G shows the location of the Elko target areas with respect to the terrain under discussion.

As additional photographs of interest become available they will be presented.

*Work plan D. Study the physics and dynamics of orographic and convective cloud systems*

(1) Several tetroon runs to study the airflow patterns over the Mount Rose area have been made during this report period. The data was reduced and one track is presented below.

(2) Three aircraft flights, in conjunction with ground radar tracking, and ground radar observations of precipitation have been made during this period.

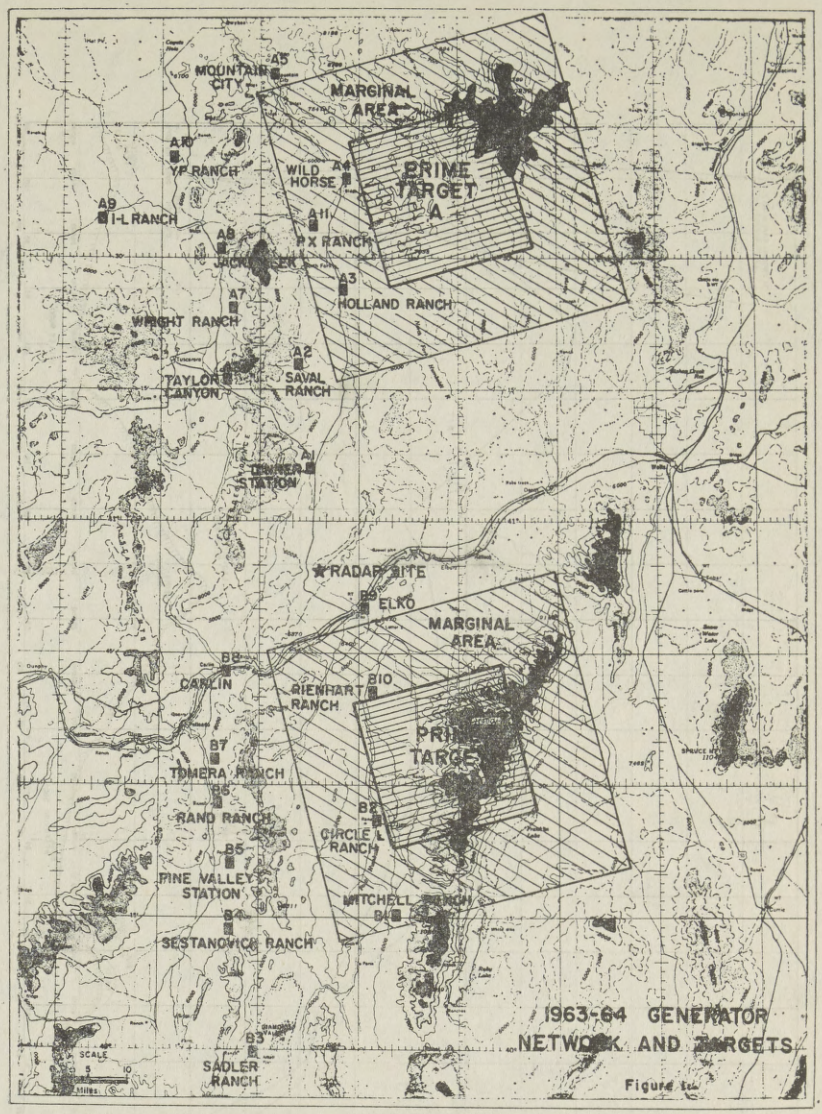
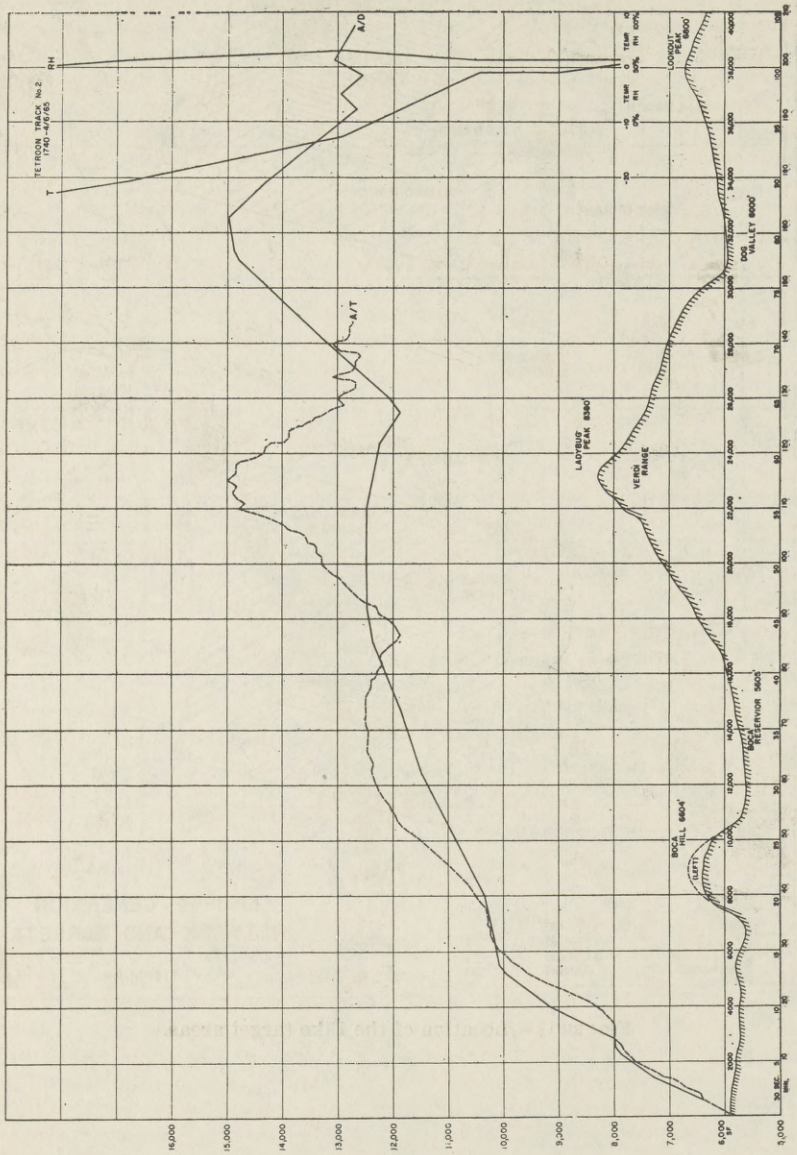



FIGURE G.—Location of the Elko target areas.


TETROON TRACK No.2
1740-4/8/65
RH
T
A/D
A/T
LADYBUG PEAK 8380'
VERDI RANGE
DOG VALLEY 8000'
LOOKOUT PEAK 8600'
BOCA RESERVOIR 5600'
BOCA HILL 6604'
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000

Mr. CHISHOLM. This outlines the radar coverage that is available through the FAA system. In addition to the radar coverage through the FAA system, there are other very interesting aspects. Specifically, Loren Crow, special assistant to Mr. White of the Weather Bureau, came up with the idea that the air traffic control beacon in all commercial transports could be used to extract meteorological data from the airplane, relay it to the radar site, thence to the ARTCC, and thence to computers. If you go through the numbers here you will find that 100 times more sounding data could be obtained in this manner than is presently being obtained. In the opinion of some people in weather modification, of which I am one, this data could play a vital role when tied in automatically to computers in the general area of automatically telling you where to do the seeding, et cetera. In addition to the weather radar coverage of the FAA system and the concept of extracting data from transponders in transport airplanes it is possible to release balloons and track them on the FAA system. This is a concept that was developed in the Las Vegas Research Station of the Weather Bureau. These three areas alone can make a significant contribution to meteorology in general and weather modification in particular in my opinion.

Senator CANNON. Do you think there would be any difficult problem of coordinating this type of an effort if you have these additional agencies involved?

Mr. CHISHOLM. Yes, there would be problems. I think when you try to coordinate with any agency there are problems. We have proceeded on an informal basis to discuss these problems. How successful we will be is a good question.

Senator CANNON. Do you have a suggested method on how this might be handled effectively?

Mr. CHISHOLM. I would prefer not to comment at this time, sir. It is a question on which I am not an expert.

Senator CANNON. As a former businessman having returned to the academic life do you think that weather modification, as such, makes economic sense?

Mr. CHISHOLM. I can answer that question by sort of categorizing various fields in weather modification, and in each separate field I can ask three questions. (1) Can you modify the weather? (2) Can you make money modifying the weather? (3) Do you understand how you are modifying the weather? Let us take one obvious case, that of fog dispersal at airports. There is no question that you can modify and get rid of the fog at airports if the fog is supercooled. There is no question that fog dispersal makes economic sense. It is now being done by airlines because it is money in their pocket. There is no question that they understand the processes involved.

So in the area of fog dispersal the answers to the three questions: Can you do it? Does it make money? And do you understand it? are "Yes." The next most easy area to discuss in weather modification is that of the so-called wintertime orographic precipitation processes. The question of can you modify the weather has been controversial up to quite recently. It is now, I believe, generally agreed that you can increase the precipitation from wintertime orographic processes. Mr. Elliott can perhaps comment on that. The question: Can you make money at it? is perhaps best answered

by the fact that Pacific Gas & Electric, and other people, claim informally a substantial return on their money just from power alone. The question of whether you understand what you are doing is still very controversial. The actual processes that go on in these clouds in the winter over the mountains is very little understood. The answers to the questions as applied to wintertime orographic seeding are you can do it, you can make money, but you really don't know what you are doing. In the third area, the so-called convective storms, you can't get agreement that you can produce significant precipitation increases, and hence you can't get agreement that you will make money because you don't know whether you are producing an increase. However, judging by the fact that 10 years ago fog seeding was only advocated by a few people and now it is a money-making proposition, my feeling is that in 10 years the seeding of convective clouds will be accepted as being economically feasible. When you talk about weather modification on a larger scale than that it gets outside the area I have been working in.

Senator CANNON. Your comments are rather interesting particularly when you go back to what we thought 10 years ago. I had some experiences in the United Kingdom during the war where we tried to burn off the fog. As a matter of fact we did burn it off in a number of instances. Of course it was quite an expensive process but we saved a lot of men and a lot of airplanes by being able to burn out a foggy area so that they could land. And at that time this idea was unbelievable when they first brought it over. I think many of us thought that they were crazy. But I had occasion to use it and I was mighty happy to have it.

Thank you very much, Mr. Chisholm, for the ideas you have given us. They will be very helpful to the committee when they consider this problem.

Our next witness will be Mr. Robert D. Elliott, president of North American Weather Consultants. Mr. Elliott, we are happy to have you here with us today and you may proceed.

## STATEMENT OF ROBERT D. ELLIOTT, PRESIDENT, NORTH AMERICAN WEATHER CONSULTANTS, SANTA BARBARA, CALIF.

Mr. ELLIOTT. Mr. Chairman, I have a prepared statement which I would like to read if I may.

I have been a professional meteorologist for 28 years and hold a bachelor's degree in physics and a master's degree in meteorology from the California Institute of Technology. My experience has been primarily in the application of meteorological knowledge in the private sphere. During the war I served as a naval aerological officer. In 1950 I was cofounder of a company which has specialized in cloud seeding, weather forecasting, and meteorological studies over the past 15 years; North American Weather Consultants. I might add that in the realm of cloud seeding we have conducted projects in eight States. We normally have from 4 to 12 per year and many of them are long duration projects for utility companies. One of them is now starting its 16th year in the High Sierras.

During the course of my professional work with North American Weather Consultants, my coworkers and I have planned, supervised,

and analyzed a variety of weather modification projects ranging from research projects designed primarily to gain knowledge through operational projects to increase water supplies. At present, North American Weather Consultants is conducting the operational phase of the Nevada Atmospheric Research project here in Elko County. In the city of Elko we maintain a meteorological office staffed by a professional meteorologist and assistants. Weather information is received via weather teletype and local sources so that the weather situation is continuously monitored and cloud-seeding operations can be directed during storms.

At this point, I should like to outline the history of this project and its goals and this is a brief outline. During the 1950's a number of commercial cloud-seeding projects had been conducted in the Elko area. Among the leaders—that is, leaders and residents in this general area—who were interested in employing cloud seeding as a means of alleviating water shortages, there grew the feeling that more research effort toward determining specific effects in this area was in order. At that time the concept of the randomized cloud-seeding test was new, and it was accepted by them as a basis for research. A project designed in this fashion requires that one should forego seeding in about half of the seedable storms in order to obtain a background of nonseeded storms that can be compared to the seeded storms.

The storms to be seeded are selected randomly, such as by flipping a coin. When this is done, it is possible to instrument the area with rain gages and other observational devices to detect the differences between seeded and nonseeded storms. In the absence of randomization it is necessary to employ as a basis for comparison data from historical storms. But there is usually a very limited historical network of rain gages and no supplementary observations of physical variables, so that a much less satisfactory basis for the evaluation of results is provided.

The feeling of water users in this area was that the test program should be supported by whatever funds could be found locally or at the State level, and, accordingly, public meetings were held in the fall of 1960, at which a general type of proposal was presented to the public. The proposal committee was headed by Hugh Shamberger of the Nevada State Department of Conservation and Natural Resources. Testimony was presented at that meeting by Prof. Wendell A. Mordy, of the Desert Research Institute, Dr. Vincent J. Schaefer, the discoverer of cloud seeding, and myself, as well as by many citizens of Elko and adjoining counties.

It was not until the fall of 1961 that a project actually got underway. Financial support of this project came from the State of Nevada, from Elko and adjoining counties, and from private parties and irrigation districts scattered throughout northeastern Nevada and adjoining areas in Idaho and Oregon. Later on, additional support was provided by the National Science Foundation and the Bureau of Reclamation. Overall supervision of the project was by the Desert Research Institute and the operational phases were conducted by North American Weather Consultants.

The first year, 1961–62, did not contain all of the elements of the final scientific design that was put into effect in the 1962–63 season and is continuing at present. The first year, 1961–62, was random-

ized, but with only one target area. Much useful information was gathered from this first year that aided in the final design of the project. In the final design there are two targets, one area being in the upwind slopes of the Jarbidge Mountains some 45 miles to the north of Elko, and the other area being on the upwind slopes of the Ruby Mountains, approximately 20 miles southeast of the city of Elko.

Each of these target areas has installed in it five specially designed heated recording gages. At suitable distances upwind of each target area is a network of 10 silver iodide smoke generators strategically located so that the area can be targeted under varying wind and air mass conditions. The mode of operation is that when the field meteorologist in Elko determines that seedable conditions exist, he calls the Desert Research Institute and receives instructions either to seed the northern target or the southern target, the other one being used as a comparison area. The selection is made on a random basis so that the field meteorologist has no idea which will be seeded prior to his call. Thereafter, the seeding continues in the selected target area for the duration of the storm or for 18 hours. After 18 hours, if the storm continues, a new decision must be made since the succeeding 18 hours will be counted as a new unit of observation.

In this way there is being built up a sample of seeded and nonseeded cases in the two adjoining areas. It is the goal of the project to obtain a sufficiently large sample of seeded and nonseeded storms in order to be 95 percent sure of the reality of any seeding effect detected. It has been estimated that this can be achieved within a 5-year period provided all data are collected in good form. It is our policy to make no statements as to preliminary results. I might say, and add, that in the first year in which we did not have the full design there were an abundant number of storms. In the next year when we started the full design, that is the 1962–63 season, it was very dry and we didn't get the expected number of storms. 1963–64 was better and this last year, 1964–65, was again rather dry.

In addition to the use of precipitation as data for the evaluation, supplementary observations are being made of the wind flow and air mass structure in this general region which will be employed to sharpen the statistical analysis and increase our assurance as to the results. Mr. Chisholm mentioned some of the observations which are being made. These are balloon observations where we sound the atmosphere and get the temperature and moisture structure aloft, and the wind pattern. This considerably sharpens the analysis and was one of the things that we determined was needed after our tests in the Santa Barbara area during the 1957 and 1960 period.

I would now like to present some general observations concerning weather modification activities. In any field program, whether research oriented or operations oriented, an interdisciplinary approach is required. The three basic elements are: (1) cloud physics, (2) synoptic meteorology, and, (3) engineering.

In our field operations it is necessary to have a basic understanding of the cloud physics mechanisms including the entire role of microphysics in the production of rain by natural or artificial means.

Synoptic meteorology is the science of the air motions and atmospheric processes which form the background of the cloud physics

processes. There is obviously an interaction between the cloud physics and synoptic meteorological aspects which has unfortunately in the past been largely overlooked or ignored by those concerned with the more theoretical aspects of cloud physics. However, this is something which could not be ignored by those engaged in actual operations where it was necessary to insure that proper targeting of the intended area of effect was made under varying wind flow and air mass conditions. It necessitates the close monitoring of the current weather conditions. It is also essential to the evaluation of the results that the behavior on the synoptic meteorological scale be measured in the general seeding area. I can elaborate a little on that point. We are concerned with the behavior of submicroscopic particles that are a millionth of an inch in diameter, that is the silver iodide smoke particles, and their interaction with the cloud droplets which are a hundred times as large, and their interaction with larger scale motions, convective motions in the storms. And finally, the effects of large-scale processes, such as fronts and convection lines, that pass through the area. They all interact with each other and we have to comprehend the entire range of scales before we really know what we are doing.

The engineering aspects involve the development of appropriate silver iodide dispersal systems and logistic support thereof. Also involved is extra instrumentation for observing precipitation and other weather elements under adverse climatic conditions. Generators that can be reliably operated by radio control on remote mountain peaks is one facet of this engineering aspect which we in North American Weather Consultants have developed through the last decade.

With prospects of increased weather modification activity there arises the possibility of interference between projects. This has been minimal in the past, but it is anticipated that legal provision should be made for negotiating compromises where it arises.

It is being accepted now that both operational and research type programs can coexist, and will feed information to each other which will result in a steady improvement in the state of the art. I might add here that the cost of the research-oriented project is much, much greater than that of the operations-oriented project. The reason is we have sufficient knowledge to perform certain types of operations-type projects, in other words we can do them. But in order to improve the state of the art we do have to learn more and this means that we need to have more knowledge. Likewise, it seems probable that various Federal agencies can make different contributions to the advancement of this field. It therefore would appear that a pluralistic approach is in order, and that there is no need for a "weather czar" to regulate all weather modification activities in the Nation.

More stringent regulation covering qualification of cloud seeders is in order, but the exact method for doing this is still an open question.

Thank you, Senator Cannon, for permitting me to present this testimony.

Senator CANNON. Thank you, Mr. Elliott, for your fine presentation. Do you feel that Nevada offers an above-average site for conducting large-scale atmospheric tests and experiments?

Mr. ELLIOTT. I think it is a remarkably fine area in which to do this, for several reasons. One is it is sparsely populated and you

don't have this problem of conflicting interests in the weather. There are many regions over the country where there are various agricultural activities which have varying requirements at a particular season. It might be important to get more precipitation for say the wheatgrowers where the cherrygrowers don't want any because it splits their cherries. This was the case in Washington State. And the farther east you go the more problems of this type you run into. But here in Nevada you are just down to a rockbottom minimum of problems and as far as precipitation increases are concerned there seems to be no limit to what would be acceptable. That is perhaps not recognized as being an important point but it is extremely important.

Another point is that you have very good visibility conditions and good flying conditions and a fairly minimal density of aircraft over the State. There are areas where there is very little air traffic, which means that you can do a lot of aerial sampling without running into problems. The north/south orientation of the mountain ranges, there is one range after another across the State, presents a beautiful orographic barrier for testing the effects of seeding of orographic systems and for studying the orographic system uninfluenced by cloud seeding. Those are the important points I think that favor Nevada over any other State.

Senator CANNON. What is your estimate of the size of the business community involved in operational weather modification programs such as you are engaged in?

Mr. ELLIOTT. Well I would say that with our 5 to 12 projects a year we have pretty well covered the business interests in the West with respect to cloud seeding to increase snow in the high mountain areas, snow that would be subsequently used for hydroelectric generation. We also do some work at lower levels, lower elevations, but still mountain areas, such as the Los Angeles County Flood Control District. These organizations all have staffs of engineers and technically trained people who are able to comprehend what we are doing and are satisfied that they are making a good calculated risk in investing in weather modification.

On the other hand I would say that we are not satisfying, by any manner of means, the potential market, should we put it that way, the potential market as far as farm and ranch operations are concerned. And the reason is that those organizations do not have the technical staffs which the power companies do. And there is a question in their minds as to just what they are getting and they are unable to organized a sustained program that goes on year after year. I think this is entirely understandable. Now I had not, until several years ago, actually realized what the potential water benefits were as far as farming was concerned, and I am speaking now of irrigation farming. But it appears that the best authorities estimate benefits of $50 to $75 an acre-foot. This is not always paid for by the farmer himself but the ultimate benefit in crops which he could raise with this acre-foot of water is that amount. Now the benefits to the power companies range from $3 to as high as $20 an acre-foot in the high head plants, so that it appears that something is being overlooked here, and I feel that this is where the Federal Government can play a role.

Senator CANNON. As a matter of fact, it would appear that the Federal Government would be the only one that could handle that type of a program?

Mr. ELLIOTT. Well, we have certainly tried and I think Elko County exemplifies the situation where we, and at least one other group, did some seeding from time to time but no sustained program was forthcoming. Yet there was a lot of interest and there were capable leaders in this area who recognized that something, perhaps a more stable base, was needed. And hence this cooperative research program was organized which involved our particular capabilities in the operational field and the Desert Research Institute's capabilities in the atmospheric sciences field and the State in the organizational field.

Senator CANNON. Were your first efforts in this area operational-type efforts rather than research and development?

Mr. ELLIOTT. Yes; that is correct.

Senator CANNON. What results did you have there?

Mr. ELLIOTT. Well, using the historical data as a basis for evaulation we felt that we had good results. But on a 1-year project you can't say with much certainty that you are getting anything. As a matter of fact, on the commercial projects which have been evaluated, the 10-year project in the Kings River area in California, the Sierras, and the 16-year project, only 14 years have been evaluated so far, of the San Joaquin project provide the best evidence of the effectiveness of orographic cloud seeding. They show statistically significant results when you accept the historical background. Now there are some statisticians who feel that dependence on historical data is unacceptable and that you do have to have a randomized cloud seeding project, and we recognize the need for some projects of this type.

Senator CANNON. Your San Joaquin project is an operational project rather than a research project?

Mr. ELLIOTT. Yes, sir; that is right.

Senator CANNON. Do you have any comparative figures or percentage figures that you can give us on that project?

Mr. ELLIOTT. Well, that project was around a 7-percent increase according to some independent studies that have been made. There are different ways of evaluating it to get that order or magnitude of increase. And I think that throughout the High Sierras this is the sort of thing that you get, which may not sound large but economically it is extremely important. On the other hand, along the California coast and in Santa Barbara County and the San Gabriel Basin east of Los Angeles, we have some rather convincing evidence of increases on the order of 50 to 100 percent in the primary part of the storm; that is, in the 7 hours during which the heaviest precipitation occurs. And we are convinced that that area is particularly favorable for cloud-seeding effects, probably because there is a rich source of water in the air which comes right off the ocean. When you get inland, where your base elevation is 5,000 feet or more, you do not have this rich source of water, and I think that we can expect the effects to be less marked in the Nevada area although I do have the feeling they will be higher than in the Sierras.

Senator CANNON. What percentage of your operation is operational versus research?

Mr. ELLIOTT. Well, about 80 percent is what I would term operational. Under research we have had the Santa Barbara randomized cloud-seeding project and this project in Elko County. And we have also conducted, under a National Science Foundation grant to our research affiliate Aerometric Research, Inc., a project in the Santa Barbara area to study the details of storm structure. This involved no seeding; however, it did provide background information for developing ideas on how to do a better job in cloud seeding.

Senator CANNON. In your opinion and based on your long experience in this field, would you say that seeding in one area is likely to reduce the rainfall in another from the same cloud system?

Mr. ELLIOTT. Our experience has been that this is not the case at all and that what actually happens is the effect trails off as you go downwind from the area. There is some discussion at present that there may be a shadow effect in convective systems—that is, summer systems—in Missouri and in the eastern part of the country. However, in the West we haven't detected anything of this type.

Senator CANNON. What you are saying then is actually a cloud system can be made, under certain circumstances, to produce a net increase?

Mr. ELLIOTT. That is right. And I think this is a very rational thing to conclude on the basis of the physics, of the gross scale physics of the thing, because when moist air is driven up a mountain slope you get condensation due to the lifting and cooling. This condensation is in the form of cloud droplets which do not drop out. There is a certain amount of natural nucleation and a certain amount that falls out as precipitation and some of it goes on over the mountain and evaporates to the lee. In some careful measurements which we made on this storm study project which I have mentioned in the Santa Barbara area, we computed that 75 percent of the cloud water that formed through condensation over two orographic barriers in southern California, 75 percent of it evaporated to the lee of the mountain range. Now if you are seeding you are actually recapturing a certain amount of that cloud water which would evaporate anyway downwind. We would have no benefit from that anyway without seeding.

Senator CANNON. Would you comment on the legal liability aspect of this operational weather modification?

Mr. ELLIOTT. Well, I guess it is no secret that we were sued for $13 million for allegedly causing the December flood in 1955 on the Feather and Yuba Rivers. At that time we were conducting operations for the Pacific Gas & Electric Co. and they were, of course, also sued. In order to make their point the plaintiffs had to claim that we had missed our target, which was the Almanor Basin, which was fully protected by dams so that there was no runoff from that area. And that some of our effects had occurred down to the south on the Feather and Yuba Rivers. Actually we were not seeding during that particular storm but they claimed that in prior seedings we had built up the snowpack in the southern area. However, they were unable to make their claims good and the judge decided that we had had no effect outside of our intended target area. As a consequence of this some of the insurance companies got rather tough. They had, even up to that time, been tough to the extent that it was almost impossible to get insurance for the direct effects of cloud seeding. But their general liability rates went up after that for some of the

larger utility companies and this had a very adverse effect on our cloud-seeding business. However, in the last 2 years we have been able to get insurance covering the direct effects of cloud seeding and this covers all of our clients including the State of Nevada.

Senator CANNON. What type of liability coverage do you get?

Mr. ELLIOTT. It covers in addition to the standard coverage, which is normally required, the direct effects of cloud seeding. On special instances and in one special instance we have gotten coverage up to a million dollars.

Senator CANNON. It covers against flood or damage of that nature?

Mr. ELLIOTT. Yes, sir. Claims for flooding or producing droughts or what have you.

Senator CANNON. Have you had any lawsuits on the basis that you may have deprived someone of rainfall that they otherwise would have received?

Mr. ELLIOTT. No, sir; we have not.

Senator CANNON. Have you had any such charges made by anyone, not in the form of lawsuits?

Mr. ELLIOTT. No; we have never had, except for a few facetious remarks from time to time.

Senator CANNON. Does this business of weather modification make good economic sense to you?

Mr. ELLIOTT. It certainly does. I feel that it has made such good sense that the commercial operations—that is, the ones that have been conducted by qualified people—have sustained the interest and increased the knowledge of orographic seeding and if they hadn't been in existence we wouldn't be sitting here now talking about this. It would be a dead issue.

Senator CANNON. Has your business increased as you gained experience in this field?

Mr. ELLIOTT. It increased up to the time of the suit and then it dropped very sharply and now we think it is coming back. But as I have already said, I feel that we have pretty well saturated the field with respect to seeding for hydroelectric water resources but not as far as the farmer and the rancher are concerned.

Senator CANNON. That lawsuit put you in the unusual position of trying to claim that you didn't affect that which you were out trying to do; is that it?

Mr. ELLIOTT. Well not exactly. Fortunately it put us in the position of claiming that we were hitting our target area and not slopping over.

Senator CANNON. And the target area had actually increased in precipitation and snowpack?

Mr. ELLIOTT. Oh, yes; but it was safely behind dams and no water was let out except for the standard allotted waters.

Senator CANNON. Can you think of anything else that you would like to add, Mr. Elliott, that would be helpful to us?

Mr. ELLIOTT. No; I have nothing else. I would certainly be happy to show you our field office here in Elko if you do have time.

Senator CANNON. I would be very much interested in seeing it while we are here. If you have nothing further to add at this time, we thank you very much for appearing.

Are there any other witnesses that would like to be heard this morning? If not, the hearings will stand in recess and I will arrange with you, Mr. Elliott, about when we can visit your operation.

larger utility companies and this had a very adverse effect on our cloud-seeding business. However, in the last 2 years we have been able to get insurance covering the direct effects of cloud seeding and this covers all of our clients including the State of Nevada.

Senator CANNON. What type of liability coverage do you get?

Mr. ELLIOTT. It covers, in addition to the standard coverage, which is normally required, the direct effects of cloud seeding. On special instances and in one special instance we have protection up to 10 million dollars.

Senator CANNON. It covers against what or damage of what nature?

Mr. ELLIOTT. Yes, sir. Claims for damage or proximate damage what have you.

Senator CANNON. Have you had any lawsuits on the basis that you may have deployed someone or initiated any other activity would have received?

Mr. ELLIOTT. No, sir, we have not.

Senator CANNON. Have you had any such claims, actually in any case, in the form of lawsuits?

Mr. ELLIOTT. No; we have never had, except for a few instances remarks from time to time.

Senator CANNON. Does this business of weather modification take good economic sense to you?

Mr. ELLIOTT. It certainly does. I feel that it has made good sense that the commercial operations—that is, the ones that have been conducted by qualified people—have stimulated the interest and increased the knowledge of geographic seeding and if they hadn't been in existence we wouldn't be sitting here now talking about this. It would be a dead issue.

Senator CANNON. Has your business increased as your general experience in this field?

Mr. ELLIOTT. It increased up to the time of the 80's and then it dropped very sharply and now we think it is coming back. But as I have already said, I feel that we have pretty well satisfied the field with respect to seeding for hydroelectric water resources but not as far as the farmer and the rancher are concerned.

Senator CANNON. That leaves out your in the original position of trying to claim that you didn't affect that which you were out trying to do; is that it?

Mr. ELLIOTT. Well, not exactly. Fortunately, it puts us in the position of claiming that we were hitting our target area and not dropping it.

Senator CANNON. And the target area that actually increased in precipitation and snowpack?

Mr. ELLIOTT. Oh, yes; but it was solely behind a mountain and we were let out except for the standard allotted water.

Senator CANNON. Can you think of anything else that you would like to add, Mr. Elliott, that would be helpful to us?

Mr. ELLIOTT. No; I have a feeling that I should get back to my office and office here in Elko. I know the boys there.

Senator CANNON. I would be very much obliged if you would do this for us. If you have any other information to indicate the success of your operations.

Mr. ELLIOTT. Thank you very much, Senator, and I appreciate the time you have given us.

# WEATHER MODIFICATION

MONDAY, FEBRUARY 21, 1966

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

The committee met at 10:09 a.m. in room 5110, New Senate Office Building, Hon. Howard W. Cannon presiding.

Senator CANNON. The committee will come to order.

This is the third in a series of hearings held by the Committee on Commerce on the subject of weather modification. The first hearing was held in Las Vegas, Nev., on November 5, 1965. The second hearing was held in Elko, Nev., on November 10, 1965. At those hearings representatives from State government, universities, the Navy, and commercial operators were heard. Since the hearings in November, three things have brought the subject into sharper focus. The first is the report of the Panel on Weather and Climate Modification of the National Academy of Sciences. The second is the report of the Special Commission on Weather Modification of the National Science Foundation. The third is S. 2916, a bill to reorganize certain details of the administration of the weather modification program.

The two reports have both optimistic and pessimistic tones. An optimistic note is sounded by the National Science Foundation when they say that "weather and climate modification is becoming a reality." The National Science Foundation states "that a rational exploration of weather and climate modification could be one of the important developments in the atmospheric sciences during the present decade."

A pessimistic note is sounded when one reviews the shortcomings of the present programs. In summary, the problems are both scientific and administrative:

(*a*) Frustration of the attempt in Public Law 85–510 to centralize responsibility;

(*b*) A 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 and goals; and

(*e*) A failure to study inadvertent weather modification, and the social, economic, legal, and international implications of weather and climate modification.

In recent times, three dates are important for this subject. In 1946 dry ice and silver iodide were successfully used to modify clouds. In 1957–58 the Advisory Committee on Weather Modification reported a possible 10 to 15 percent increase in precipitation from seeded clouds

and Public Law 85–510 was passed giving the Natioal Science Foundation significant authority in this field.

The third date is the present. It is important because of the two reports already mentioned. It is important, too, because an opportunity exists to take stock of the present situation, to correct the deficiencies, and to enlarge upon the successes. Nineteen hundred and sixty-six will be the year in which opportunity was seized or lost. The reports are in and action is awaited.

Weather modification is not a new subject. Urban construction, air pollution, and so on, are a continuing experiment in weather modification. What is new is the attempt to perform controlled weather modification. What is new is the effort to separate the science and the fiction.

Charles Dudley Warner of Hartford, Conn., said, "Everybody talks about the weather, but nobody does anything about it." In defense of these hearings, we are here to talk about doing something about the weather.

The first witnesses today are from the National Science Foundation. Before we start with the witnesses I would like to include in the record, a statement from Dr. Wendell A. Mordy, director of the Desert Research Institute of the University of Nevada.

(The bill follows:)

[S. 2916, 89th Cong., 2d sess.]

A BILL To provide for a weather modification program to be carried out by the Secretary of Commerce

*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 "Weather Modification Act of 1966".

WEATHER MODIFICATION PROGRAM

SEC. 2. The Secretary of Commerce (hereinafter referred to as the "Secretary") is authorized to carry out a program of applied research, development, and experimentation in the field of weather modification and climate control, giving particular attention to areas that have experienced floods, drought, hail, lightning, fog, tornadoes, hurricanes, or other weather phenomena.

DUTIES OF SECRETARY

SEC. 3. In order to carry out the provisions of this Act the Secretary is authorized to—

(1) conduct applied research, either directly or by grant, contract, or cooperative agreement with public or private agencies or institutions, including but not limited to cooperative programs with any State through such instrumentalities as may be designated by the Governor of such State, in the field of weather modification and climate control;

(2) develop such testing techniques as he deems advisable;

(3) issue regulations, after notice and opportunity for hearing, affecting any operations of commercial enterprises engaged in such field which conflict with or impede any activities conducted under this Act, encourage compliance with such regulations by such enterprises, and report to the Congress not later than one year after the effective date of this Act recommendations for additional legislation concerning the enforcement of such regulations;

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

(5) 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;

(6) accept and make use of property, equipment, and personnel of other agencies of the Federal Government loaned to the Department of Commerce, with the approval of the Director of the Bureau of the Budget, and such other agencies are authorized to loan, without reimbursement, such property, equipment, and personnel to such Department;

(7) consult with meteorologists and scientists in private life and with agencies of the Federal Government interested in or affected by research and experimentation in the field of weather modification and climate control;

(8) initiate studies, in cooperation with the Federal Council for Science and Technology, on the coordination of activities in such field by agencies of the Federal Government, make recommendations encouraging such coordination to such agencies, and report to the Congress not later than one year after the effective date of this Act recommendations for such additional legislation as he deems advisable to carry out such coordination; and

(9) report annually to the President and to the Congress on the administration of this Act.

HEARINGS; DOCUMENTARY EVIDENCE

SEC. 4. (a) The Secretary, or any employee of the Department of Commerce designated by him, may for the purpose of carrying out the provisions of this Act hold such hearings and sit and act at such times and places and take such testimony as he deems advisable. The Secretary or any employee of such Department designated by him may administer oaths or affirmations to witnesses appearing before the Secretary or such employee.

(b)(1) The Secretary may obtain by regulation, subpena, 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 carry out the provisions of this Act, 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 subpena 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, subpena, or other document issued with respect thereto, such person furnishes such Department 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.

(3) Any person who willfully performs any act prohibited, or willfully fails to perform any act required, by the above provisions of this subsection, or any regulation issued thereunder, shall upon conviction be fined not more than $500.

(4) Information contained in any statement, report, record, or other document furnished pursuant to this subsection shall be available for public inspection, except (A) information authorized or required by statute to be withheld and (B) information classified in accordance with law to protect the national security. The foregoing sentence shall not be interpreted to 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 Secretary may disclose information described in such section 1905, furnished pursuant to this subsection, whenever he determines that the withholding thereof would be contrary to the purposes of this Act.

INTERNATIONAL COOPERATION

SEC. 5. (a) The Secretary is authorized to cooperate in any international activities relating to weather modification and climate control consistent with the provisions of this Act. The authority to cooperate in international weather modification and climate control 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 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, 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.

TRANSFER AUTHORITY

SEC. 6. (a) So much of the personnel, property, records, obligations, commitments, and unexpended balances of appropriations, allocations, and other funds of the National Science Foundation, which the Director of the Bureau of the Budget determines is used primarily with respect to applied research, development, or experimentation in the field of weather modification are transferred to the Department of Commerce.

(b) Any transfer of personnel pursuant to this Act shall be without change in classification or compensation, except that this requirement shall not operate to prevent the adjustment of classification or compensation to conform to the duties to which such transferred personnel may be assigned. All orders, rules, regulations, permits, or other privileges made, issued, or granted by any officer or agency in connection with any personnel, property, or funds transferred under this Act, and in effect at the time of the transfer, shall continue in effect to the same extent as if such transfer had not occurred, until modified, superseded, or repealed. No suit, action, or other proceeding lawfully commenced by or against any agency or any officer of the United States acting in his official capacity shall abate by reason of any transfer made pursunt to this Act, but the court, on motion or supplemental petition filed at any time within twelve months after such transfer takes effect, showing a necessity for a survival of such suit, action, or other proceeding to obtain a settlement of the questions involved, may allow the same to be maintained by or against the appropriate agency or officer of the United States.

AMENDMENTS TO NATIONAL SCIENCE FOUNDATION ACT OF 1960

SEC. 7. (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.

APPROPRIATIONS AUTHORIZED

SEC. 8. There are authorized to be appropriated such sums as may be necessary to carry out the provisions of this Act.

EFEECTIVE DATE

SEC. 9. This Act shall take effect on the date of its enactment except that sections 6 and 7 shall take effect ninety days thereafter.

(The statement follows:)

UNIVERSITY OF NEVADA,
DESERT RESEARCH INSITIUTE,
*Reno, Nev., February 17, 1966.*

Senator HOWARD CANNON,
*Senate Office Building,*
*Washington, D.C.*

DEAR SENATOR CANNON: It is my understanding that on February 21, 1966, you are chairing the Commerce Committee hearing on the Magnuson bill. I would appreciate your including in the testimony, the enclosed policy state-

ment of the Weather Control Research Association. The Desert Research Institute is a corporation member of this organization.

The W.C.R.A. is composed of groups and individuals who are working to develop the economic basis for weather modification as well as doing scientific research in this field. The governmental, industrial, and private representation among its members are scientists and engineers who enjoy a high degree of respect in the scientific community.

The Weather Control Research Association represents a majority of those who have been in the practice of weather modification over the past 15 years. While we recognize the desirability of Government support and regulation of weather modification activities, we are convinced that the contributions being made by private and independent groups are vital to programs in weather modification. We are apprehensive that a single Government operating agency with full responsibility for the development of weather modification will tend slowly to build toward stifling Federal bureaucracy and control. At this stage of development, it is important to maintain independence and debate and diversity of approach in solving the many problems ahead.

The D.R.I., therefore, supports this enclosed policy statement. We would like the role of nongovernmental agencies to be spelled out in any major weather modification law, with an independent board or commission established to insure compliance with this intent.

Any help you can give us in bringing these views to the attention of the committee will be appreciated.

Sincerely,

WENDELL A. MORDY, *Director.*

STATEMENT OF POSITION OF THE WEATHER CONTROL RESEARCH ASSOCIATION WITH RESPECT TO FEDERAL LEGISLATION ON NATIONAL WEATHER MODIFICATION PROGRAMS AS ADOPTED BY ITS EXECUTIVE AND POLICY COMMITTEES ON FEBRUARY 14, 1966

The Weather Control Research Association has been in existence since 1951. It is composed of people interested in all phases of weather modification. Private and government organizations are about equally represented. Our members come from private utilities, public utilities, water supply agencies, irrigation districts, universities, research institutes, State governments, local governments, Federal agencies, private weather consulting firms, and private industries active in weather research, and cloud seeding operations.

The field projects and research efforts of people represented within this organization have provided the basis for the optimism expressed in the recent National Academy of Sciences report "Weather and Climate Modification Problems and Prospects."

*1. Regulation and licensing*

In the broad field of weather modification, we feel it is urgent that a separate, regulatory or licensing Commission should be established, independent of any operational or coordinating Government groups. The reason for this is that mission-oriented agencies overregulate those projects which are in competition with their own activities. This separate regulatory board should be adequately funded to provide realistic monitoring of the effects of weather-modification activities.

*2. Utilization of private manpower in both planning and operations*

It is important that manpower in the private field, where many years of experience have been accumulated, be used in hearings on legislation and in the planning and the formulation of any national programs.

It is also important that experienced individuals be utilized fully in carrying out the programs.

These points are stressed because a great many new people will be needed to carry out the contemplated, large-scale weather modification programs. If past mistakes and wasted effort are to be avoided, however, we must continue to draw heavily on the experience of the people who have actually developed our present knowledge and refinements of technique.

*3. Utilization and encouragement of private industry and local government*

The Federal policy should encourage industries, utilities, local government, and private water users to continue the valuable work which has produced positive results in the past. This group has much to offer based on their long ex-

perience in this field. Industry will rise to the occasion if given the continued opportunity to develop broad imaginative programs in weather modification.

*4. Legal aspects*

We recognize the need for and encourage the passage of Federal laws designed to strengthen, encourage, and promote scientific field research and operational programs performed by professional level persons and groups. Such laws should afford protection to the public from unqualified cloud seeders acting without regard for the best interests of the community, and, at the same time, these laws should afford protection to legitimate operators by defining liability and by the provision that litigation be handled uniformly at the Federal level.

The conflicting provisions of present State and local regulations now unjustly harass weather modification activities and only Federal action can resolve this problem.

The Weather Control Research Association is greatly encouraged by the recent findings of the National Academy of Science and the National Science Foundation. We appreciate the effort in Congress to realize the values to be derived from weather modification and we stand ready to help if called upon.

WEATHER CONTROL RESEARCH ASSOCIATION MEMBERS ARE DRAWN FROM THE FOLLOWING ORGANIZATIONS

*1. Universities and nonprofit research institutes*

National Center for Atmospheric Research
New York State University
Rand Corp.
San Fernando Valley State College
San Jose State College
South Dakota Institute of Atmospheric Sciences
Stanford Research Institute
University of Nevada, Desert Research Institute
University of Wyoming, Natural Resources Research Institute

*2. Public utilities, power and water companies and districts*

Bear Valley Mutual Water Co.
Buena Vista Water Storage District
California Electric Power Co.
California-Oregon Power Co.
East Bay Municipal Utility District
Fenescal Water Co.
Irrigation Districts Association of California
King's River Conservation District
Los Angeles County Flood Control District
Los Angeles Department of Water & Power
Metropolitan Water District of Southern California
Pacific Gas & Electric Co.
San Bernardino Municipal Water District
Southern California Edison Co.
Washington Water and Power Co.
Western Municipal Water District of Riverside County

*3. Private meteorological firms*

Atmospherics, Inc.
Eugene Bollay Associates
K R C Service Corp.
Meteorology Research, Inc.
North American Weather Consultants
Wallace Howell Associates, Inc.
Weather Modification Co., San Jose

*4. Governmental agencies*

California Department of Water Resources
California Division of Forestry
Illinois State Water Survey
U.S. Bureau of Reclamation
U.S. Forestry Service
U.S. National Park Service
U.S. Naval Ordnance Test Station
U.S. Navy
U.S. Weather Bureau

*5. Foreign*

Bureau D'Amenagement de l'Est due Quebec Inc.
Hebrew University of Jerusalem
Research Council of Alberta Canada

*6. Other*

Bronson, Bronson, and McKinnon (Law)
California Federation of Women's Clubs
Farm Credit Banks of Berkeley
Kern County Land Co.
Leeds; Hill & Jewitt, Inc. (Cons. Engr.)
Lockheed Aircraft Corp.

Senator CANNON. The first witness today is Dr. Leland J. Haworth, Director of the National Science Foundation.

Senator Dominick?

Senator DOMINICK. Mr. Chairman, I don't want to hold up this hearing, but I do want to say to my very good friends, Dr. Roberts and Dr. Chamberlain and my other Colorado constituents, that I am pleased they are here. I know that what they are going to present to the committee will be of immense value. I have to go to another committee meeting about 10:30, so if I am not here when they start their presentation I hope that they will understand. I will be back as soon as I can. I just want to express my gratitude that they have come so far on such an important matter and their testimony will be a great help to us.

Senator CANNON. Doctor, you may proceed.

## STATEMENT OF DR. LELAND J. HAWORTH, DIRECTOR, NATIONAL SCIENCE FOUNDATION; ACCOMPANIED BY DR. ADRIAN CHAMBERLAIN, VICE PRESIDENT, COLORADO STATE UNIVERSITY, CHAIRMAN, NATIONAL SCIENCE FOUNDATION SPECIAL COMMISSION ON WEATHER MODIFICATION; DR. WALTER ORR ROBERTS, DIRECTOR, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH; DR. A. RICHARD KASSANDER, PROFESSOR OF METEOROLOGY, DIRECTOR OF THE INSTITUTE OF ATMOSPHERIC SCIENCES, UNIVERSITY OF ARIZONA, CHAIRMAN OF THE BOARD OF TRUSTEES, UNIVERSITY CORP. FOR ATMOSPHERIC RESEARCH; DR. EDWARD TODD, SPECIAL ASSISTANT TO THE ASSOCIATE DIRECTOR (RESEARCH), NATIONAL SCIENCE FOUNDATION; DR. EARL DROESSLER, HEAD, ATMOSPHERIC SCIENCES SECTION, NATIONAL SCIENCE FOUNDATION; AND DR. HORACE R. BYERS, DEAN OF SCHOOL OF GEO-SCIENCES, TEXAS A. & M. UNIVERSITY

Dr. HAWORTH. With your permission, I would like to introduce the others sitting with me.

Senator CANNON. Fine.

Dr. HAWORTH. On my left is Dr. Richard Kassander, of the University of Arizona, who is the chairman of the board of trustees, University Corp. for Atmospheric Research. He will be one of the witnesses.

Next is Dr. Adrian Chamberlain, Colorado State University, who was Chairman of the National Science Foundation Special Commission that prepared the report you mentioned.

On my right is Dr. Walter Roberts, Director of the National Center for Atmospheric Research. Both Dr. Chamberlain and Dr. Roberts will be witnesses.

Still further to the right is Dr. Earl Droessler, head of our Atmospheric Sciences Section.

And further down is Dr. Edward Todd, who is the special assistant to the Associate Director for Research of the Foundation.

The last two named will not formally testify.

Also, in the audience is Dr. Horace R. Byers, dean of the School of Geosciences at Texas A. & M. University, who is Chairman of the National Science Foundation Advisory Committee on Weather Modification, and was formerly chairman of the University Corp. for Atmospheric Research board.

Thank you, Mr. Chairman.

Mr. Chairman and members of the committee——

Senator CANNON. Would Dr. Byers raise his hand so we will have him identified, too?

Dr. HAWORTH. That is Dr. Byers.

Mr. Chairman and members of the committee, I am happy to have the opportunity to speak to you this morning. In the next 20 minutes or so I will outline the development of the National Science Foundation's support of research in weather modification and allied fields, and conclude with some recommendations concerning the Federal weather modification program for the coming years. I will not dwell extensively upon a description of the current state of our ability to modify weather and climate. As you are aware, the Foundation has just released a report which you have already mentioned, entitled "Weather and Climate Modification" which was prepared at the request of the Foundation by a Special Commission appointed in June 1964 to examine the physical, biological, legal, social, and political aspects of the field. Dr. Adrian Chamberlain, vice president of Colorado State University, who served most capably as the Chairman of that Commission will speak to you later this morning. The Commission relied very heavily on the National Academy of Sciences Panel on Weather and Climate Modification for its analysis and evaluation of the current state of weather and climate modification from the point of view of the physical sciences. I understand that your committee will hear from representatives of that Panel later in the week.

Following Dr. Chamberlain's remarks, Dr. Walter Orr Roberts, director of the National Center for Atmospheric Research, will discuss some of the current opportunities for research progress in the atmospheric sciences and relate them to our needs for modification of the weather. He will also describe some of the activities of his laboratory which are directly related to weather modification objectives, especially with universities and other Government agencies such as the Bureau of Reclamation, ESSA, and NASA. Dr. A. Richard Kassander, chairman of the board of the University Corp. for Atmospheric Research, will comment on the university-based atmospheric science community and its contribution to weather modification studies.

It was some 20 years ago that General Electric Co. scientists, Irving Langmuir and Vincent Schaefer, modified clouds by seeding them

with dry ice pellets. Not long afterward Bernard Vonnegut, a co-worker, demonstrated that a smoke of silver iodide crystals would accomplish the same results. This was the beginning of modern American weather and climate modification through cloud seeding.

The 1946 demonstration that clouds might be modified and rain produced by scientific means arose out of World War II investigations of fog particles by Langmuir and Schaefer. The military possibilities of this discovery led the armed services to support a broad theoretical, laboratory and field program in cloud modification from 1947 to 1952, known as Project Cirrus. Civilian implications were investigated by the cloud physics project of the U.S. Weather Bureau and the National Advisory Committee for Aeronautics from 1948 until 1951. The Department of Defense followed the termination of Project Cirrus in 1952 with a 5-year cloud nucleation project.

Whether or not the multi-million-dollar rainmaking activities of the late 1940's and early 1950's grew out of the obvious interest of the Federal Government in weather and climate modification research or from coincidental severe drought conditions in many parts of the Nation, large cloud seeding operations became a fact of life. Soon $3 to $5 million a year was being spent by water users, particularly in the West, for commercial cloud seeding, and about 10 percent of the land area of the United States had become the target of cloud-seeding attempts. There was also considerable activity in other countries.

The drought that then held sway in many parts of the country, the claims of some of the rainmakers, and criticism from portions of the scientific community led the Congress to create an Advisory Committee on Weather Control to study and evaluate public and private experiments in weather modification.

In its final report in 1957 the Advisory Committee on Weather Control found, on the basis of statistical evaluations, that cloud seeding in the mountainous areas of the western United States, of storms occurring during the cool, moist winter and spring months produced an average increased precipitation of 10 to 15 percent from seeded storms with a satisfactory degree of probability that the increase was not the result of natural variations in the amount of precipitation. On the basis of its physical evaluations the committee found that seeding from the ground with silver iodide is a valid technique for seeding clouds. The advisory committee then recommended that the development of weather modification must rest on a foundation of fundamental knowledge that can be obtained only through scientific research into all the physical and chemical processes in the atmosphere. The committee also recommended that encouragement be given the widest possible competent research in meteorology and related fields, such research to be undertaken by Government agencies, universities, industry, and other organizations; that the Government sponsor meteorological research more vigorously than before; that the administration of Government-sponsored research provide freedom and latitude for choosing methods and goals with the emphasis to be put on sponsoring talented men as well as their specific projects; and that the National Science Foundation be designated to promote and support research in the needed fields and to coordinate research projects.

These recommendations together with the 1957 report of the American Meteorological Society and the 1958 Third Report of the Committee on Meteorology of the National Academy of Sciences emphasized the need for: fundamental knowledge; research; experimentation; education and training in meteorology and related fields; information assembly and dissemination; and increased Federal support to universities for basic research in the atmospheric sciences.

The result of these recommendations was the passage by the Congress of Public Law 85–510, signed by the President on July 11, 1958, which in pertinent part authorized and directed the National Science Foundation to "initiate and support a program of study, research, and evaluation in the field of weather modification * * *."

Beginning even before the issuance of its report, the conclusions of the Advisory Committee on Weather Control had come under direct attack by several elements of the scientific community, primarily the statisticians. The validity of its data was brought into question and the correctness of its conclusions was seriously questioned. By the time Public Law 85–510 was passed, about the only aspect of weather modification upon which general agreement could be reached within the scientific community was that basic research and a great deal of it was needed.

The bright hopes sparked by the experimental research of Langmuir and Schaefer in 1946–47 had failed to bring forth the anticipated results, and it now was necessary to put the infant art of cloud modification on a sound scientific basis. It was at this point that the National Science Foundation, in fiscal year 1959, began its task of lending credibility to a field of effort which had been plagued with lack of technical and scientific understanding by approaching the leading meteorologists and other scientists in the United States of America and abroad to undertake scientific investigations which would open the doors to knowledge. The previous years of arguments, adverse publicity, and sometimes downright quackery, had taken their toll, and NSF found a reluctance on the part of established researchers to enter the field and risk the possibility of being called a "rainmaker."

In the years following, the NSF pursued a vigorous campaign to enlist new capabilities and talent from both the academic and professional community. These efforts were influential in the formation of new academic arrangements such as the Desert Research Institute at the University of Nevada, the Department of Atmospheric Sciences at the Colorado State University, the Cloud Physics Laboratory of the University of Washington, the Institute of Atmospheric Sciences at the South Dakota School of Mines and Technology, the Annual Yellowstone Field Expeditions of the State University of New York, the Langmuir Mountain Observatory of the New Mexico Institute of Mining and Technology, and the Showers Project Group of the Pennsylvania State University.

From this ever-increasing willingness of the academic community to perform research in weather modification have emerged new and valuable meteorological research talents. These were supplemented by the talents of chemists, physicists, and mathematicians who were needed to round out the scientific team and find answers for many

obscure atmospheric problems. In the past 6 years, the NSF-supported effort in research specifically directed at weather modification problems has risen from $1.1 million in fiscal year 1959 to $2 million in fiscal year 1966 and an estimated requirement of $3 million in fiscal year 1967. In addition, and very importantly, the support of general basic research in the atmospheric sciences, much of which contributes to the fundamental understanding necessary for success in weather modification has risen from approximately $3 million in fiscal year 1959 to a total, including NCAR, of $20 million in fiscal year 1966.

Senator DOMINICK. I wonder if I might ask a question, Mr. Chairman?

Senator CANNON. Yes.

Senator DOMINICK. Could you tell the committee what the budget request for fiscal 1967 is, for weather modification, on behalf of NSF?

Dr. HAWORTH. $3 million.

Senator DOMINICK. This has been included in the President's suggested budget?

Dr. HAWORTH. Yes, sir. And as I say, that does not include much work that really is very closely related. It represents the line item labeled "Weather modification" in the budget. For example, none of NCAR's work is in the $3 million.

Senator CANNON. That $3 million is the figure you stated just earlier when you said that it ranged from $1.1 million in 1959 to $2 million in 1956, and $3 million in 1967?

Dr. HAWORTH. Yes, sir.

Senator CANNON. You may proceed.

Dr. HAWORTH. For example, much of NCAR's work actually bears very directly on weather modification. In the 7 years of sponsorship of weather modification research, NSF grantees have learned much which will be useful for weather modification. The University of Chicago Project Whitetop, for instance, has demonstrated the importance of the warm rain coalescence process in many supercooled convective cloud systems which formerly were thought to depend entirely on the Bergeron-Findeisen ice process. In addition, radar studies of seeded clouds have tentatively indicated about 5 to 10 percent rainfall increases in the nearby target areas with decreases of about the same size (rainshadow effect) downwind from the target area, the latter phenomenon being, however, quite uncertain.

Chemical research at Lehigh University and the University of Arizona has revealed that the nucleating ability of silver iodide is a surface phenomenon not associated with the lattice structure of AgI as previously thought, but is strongly influenced by trace impurities. Strangely enough, ultrapure silver iodide has been found to be an extremely poor ice nucleator and to exhibit no photosensitivity in sunlight. At Colorado State University, an intensive investigation has revealed that there is a carryover and redistribution of silver iodide ice nuclei from one day to the next. This results in a persistent buildup in observed ice nuclei concentration on days when no seeding is performed.

Research carried on at the New Mexico Institute of Mining and Technology has pointed out the significant role of freezing upon the

generation of electrical fields in clouds. The influence of electrical fields upon the coagulation of cloud particles has suggested the possibility of modifying clouds through artificial changes in the potentials which occur when the droplets freeze. These possibilities are also being investigated by scientists at the Arthur D. Little Co. and others.

Another noteworthy development has been the discovery of an entirely new class of nucleating materials by a researcher at the University of Wisconsin. These materials are of the type which strongly absorb heat when they go into solution in water. One such substance is common urea, such as used in fertilizer. When ground into particles of between 1 micron and 20 microns in size, urea has been shown to be effective in producing ice crystals from micron-sized cloud droplets at temperatures as high as 6° C. above freezing, which is roughly 10° F. above freezing.

Research at the State University of New York, University of Washington, and the University of Chicago has brought out the fact that supercooled water droplets will freeze at a warmer temperature when the nucleant is introduced externally to the droplet surface than when the nucleant is embedded in the droplet initially during the cooling process. The difference in freezing temperature may be as high as 15 to 30 degrees Fahrenheit, and indicates the desirability of introducing the nucleant by rocket or mortar shell high up in the cloud to take advantage of this effect.

As the Foundation's programs grew it became obvious that a central research facility in the atmospheric sciences with the capability of staging meaningful experiments and large-scale laboratory efforts was necessary to stimulate the field of atmospheric sciences and to serve as a central focus for the efforts of the university community. This led the Foundation, with the advice and encouragement of the National Academy of Sciences, to support the request of the University Committee (now Corporation) for Atmospheric Research that a National Center for Atmospheric Research be formed. Dr. Roberts will speak to you later about its programs. At this point I want to say only that the Foundation is pleased with its performance and believes that Dr. Roberts can be proud at having built NCAR so quickly and so well.

The Foundation's program in weather modification does not stand alone. Their mission requirements have caused many other Federal agencies to mount strong programs and, to properly round out the picture, I would like to mention very briefly some of their present activities.

The Department of Commerce, the Environmental Science Services Administration (ESSA) carries on a research program in weather modification. The work includes—

(*a*) Experiments on tropical clouds and hurricanes conducted with the Navy on Project Stormfury.

(*b*) Development of theoretical models of the atmosphere capable of reproducing the natural processes which produce the weather.

Within the Department of Defense all three services have strong interests. The program of the Air Force is directed mainly toward a study of the life cycle of clouds and their electrical properties utilizing ground radar and highly instrumented, cloud-physics aircraft. The

Air Force also has undertaken a comprehensive field research program to understand the natural life cycle and variability of warm fog. The Army program of research in weather modification has emphasized three areas: the basic study of cloud physics mechanisms, the basic understanding of precipitation phenomena, and the basic concepts of cloud modification. The efforts by the Navy in weather modification, including both laboratory and field work, are centered around studies of warm fog, trade winds, cumulus clouds, the hurricanes. The latter involves joint work with the Weather Bureau on Project Stormfury.

The Department of the Interior's interest in weather modification is concerned with the atmospheric water resources of the Nation and the possibility of stimulating additional precipitation and runoff to the river basins which feed the Bureau of Reclamation reservoirs. The Bureau program is founded in part on the continuation of a number of programs initially developed under Foundation sponsorship.

In the Department of Agriculture the primary effort is the continuation of the Forest Service's Project Skyfire. The project has two long-range objectives:

(*a*) To obtain a better understanding of the occurrence and characteristics of lightning storms and lightning fires in the northern Rocky Mountain region; and

(*b*) To investigate the possibility of preventing or reducing the number of fires caused by lightning by applying techniques of weather modification.

The Foundation has helped in the support of this program for several years.

The Foundation's responsibility has been not only to support weather modification research, but to present an overview of the state of knowledge and effort in the field. Its annual reports to the President and the Congress—now seven in number—have given this overview by describing the total national efforts in the field. Additionally, the third annual report presented for the first time the highlights of weather modification activities around the world. The seventh one has some of that in it, too. The Foundation promoted the exchange of information about plans and programs of the various Federal agencies and effectively provided for cooperation and coordination at the working level through various mechanisms, including the Annual Interagency Conference on Weather Modification, where much of the current Federal interest in weather modification has been kindled.

Your perusal of the reports of the National Academy of Sciences Panel on Weather and Climate Modification and of the Foundation's Special Commission, I am sure indicated to you that the scientific community generally feels that the field of weather modification presents a great opportunity for progress. Research supported by NSF and the other Government agencies has produced increased knowledge sufficient to convince leading scientists that there are indeed great opportunities here. In the words of the Academy Panel:

> An earlier era of speculation has gradually been superseded by the present period, in which rational and systematic exploration of modification potentialities has become possible.

The Foundation is proud that its programs of the past few years have also served to reduce the manpower limitations that heretofore existed, although even now the number of scientists available is not as

large as we would like. There are, however, very strong limitations on basic knowledge even in those fields where we know enough to be optimistic concerning our chances for success in the development of engineering methods and there are, of course, technology limitations which developments of the postwar era in instrumentation, flight capabilities, and data processing have done a great deal to minimize. The large computers, of course, are very important in this respect. Three of the major developments are the weather satellites, the use of radar for observing clouds, and the use of computers to simulate atmospheric phenomena. The advent of large computers, particularly, has immeasurably brightened the prospects for rapid progress in climatic research. The fundamental way in which these machines have changed our approach to atmospheric studies and the prospects for progress has been emphasized by both the Academy Panel and the Special Commission.

Additionally they point out that certain areas of weather and climate modification require, for their adequate exploitation, an immediate increase in applied research and in the development of technology. The problems of the clearing of fog, and the enhancement of precipitation are two of these. The Foundation is in hearty agreement. It is none too soon for us to increase our efforts in applying our knowledge to the further development of these techniques.

At the same time, both groups have made it abundantly clear that our fundamental knowledge and understanding are still woefully incomplete, and that there are hazards, particularly in the biological field, whose magnitude is but dimly seen. Both groups have also pointed out the potentially serious problems associated with inadvertent modification of weather and climate as an undesired and largely unforeseen consequence of man's habitation of this earth. In all too many areas, the exact nature, magnitude and time scale of these problems is distressingly obscure, but in those few places where the veil has been lifted, both the National Academy and the Special Commission have found cause for serious concern. With this concern, and with their expressed recommendation of the need for a stepped-up program of basic and applied research in weather and climate modification and on the natural causes of climate change, the Foundation is also in hearty agreement.

Whatever the course of events, the Foundation feels that its own research activities must receive increased emphasis. As the committee is well aware, the NSF's authority is limited as a consequence of its creation as a scientific research and education oriented agency. It would be quite inappropriate for the Foundation to carry its weather modification activities into extensive development of technology or to the conduct of large field operations for the express purpose of enhancing precipitation. Here, I am distinguishing between an operation designed to increase precipitation in order to have more water as compared to experiments to see what can be done. Likewise, regulation through licensing, or other means, of weather modification research or commercial operations is not an appropriate role for the Foundation, and we do not feel that the Foundation should go further in developing such activities. To repeat, however, the Foundation is strongly of the opinion that its research and education efforts both directly and indirectly supporting weather modification should increase.

Senator CANNON. Are you thereby increasing your funding level to permit you to do more?

Dr. HAWORTH. Yes. That is a requirement to do more, yes.

Senator CANNON. What level are you talking about? What do you envision?

Dr. HAWORTH. I think we should continue to grow at something like the rate we have been growing during the last 2 or 3 years.

Senator CANNON. That doesn't quite support your statement if you say we continue to grow at about the same level that we have. Did you say "go" or "grow"?

Dr. HAWORTH. Grow.

Senator CANNON. What would you then envision, for example, in the 1968 budget?

Dr. HAWORTH. I don't think I figured that out exactly. It should go up by fiscal year 1970, say, to perhaps more than double what we are hoping for in 1967.

Senator CANNON. All right.

Dr. HAWORTH. Of course, it has to be in competition with all the other needs for funds.

Senator CANNON. I understand. I was just trying to get into proper focus the type of growth you were talking about.

Dr. HAWORTH. This is for the underlying research.

The necessity for indirect or related research on weather modification deserves some comment. There are many scientists including members of the Foundation staff and the National Science Board who have become increasingly convinced that the changing character of man's interaction with his environment will constitute the central scientific problem for the next generation or two.

The Foundation is vitally concerned with developing and shaping the role it must have in this general problem area in order properly to serve the coming needs of society. Study of the problems of human interaction with the environment requires a broad range of scientific skills—physical sciences (oceanography, meteorology, geophysics, geology, geochemistry), social sciences (anthropology, social psychology), engineering (transportation, sanitary engineering, systems engineering), biological sciences (ecology, systematic biology), and so forth, not all of which are directly related to weather modification.

The magnitude of environmental problems is growing at an amazing rate, as is the number of thoughtful citizens, both scientists and others, who are becoming alarmed at the prospects before us. It is my feeling that the National Science Foundation has sufficient breadth and contact with the broad academic scientific community to bring all fields of science to bear upon developing an improved understanding of environmental problems, including weather modification. The Foundation also has great resources in the fields of science education and science information which it can bring to bear on the problem.

So great is my own concern with developing the Foundation role and stance in this problem area that I have recently established an Environmental Sciences Division within the Foundation, which is of equal organizational rank with the older research divisions, such as the Mathematical and Physicial Sciences Division, the Biological and Medical Sciences Division, the Engineering Division, and the Social Sciences Division.

To sum up, I agree with the reports you have read that, in addition to increasing our basic research activities, it is now time for enhanced Federal support of applied research and engineering development aimed toward economically beneficial operation in several areas of weather modification.

My recommendations are as follows:

1. The National Science Foundation must continue to have the authority and expanding resources to support a broad program of underlying research in weather and climate modification at universities and colleges and other appropriate institutions, particularly NCAR.

2. Other Federal agencies should be encouraged to undertake such research and development activities in weather modification as may be required for the effective discharge of their specific missions. Examples are: suppression of lightning by the Department of Agriculture, fog dispersion by the Federal Aviation Agency, rainfall augmentation by the Department of Interior, and severe storm suppression by the Department of Commerce.

3. With the advance of weather modification capabilities to a point calling for experimental and developmental activities going beyond the scope of the National Science Foundation, another agency should be assigned major responsibility for the overall progress of the field. Because of its broad interest in the atmosphere, and its capabilities including extensive field organizations, I believe that the Environmental Science Services Administration is the logical agency to assume this major responsibility.

I might say, Mr. Chairman, that serious consideration is being given in the administration to a reorganization plan that would transfer to ESSA much of the responsibility that was given to the NSF, by the 1958 congressional action, leaving, however, the National Science Foundation's authority and responsibility to continue to do the underlying research.

In discharging such responsibility ESSA should give emphasis to large-scale field experiments and to research on the broad question of climatic change and modification and should consider the establishment of a substantial laboratory for weather and climate modification activities. This agency should also undertake necessary data collection, dissemination, and evaluation. It should in addition bear principal but not sole responsibility for international arrangements and programs relating to weather modification, working of course with the Department of State. ESSA is particularly appropriate for this role because of its activities in other aspects of worldwide meteorology, including the world weather watch.

The discharge of these general responsibilities should be in addition to ESSA's present specific programs. In consonance with recommendation 2 above, this assignment should not preclude other agencies from engaging in activities appropriate to their specific missions.

4. The responsibility for insuring adequate coordination for the Federal Government rests with the Office of Science and Technology. Among the objectives of such coordination are the most rational use of the resources of funds and manpower devoted to the various agency programs in relation to each other and a unity of overall governmental policy in this field.

5. A single agency, or subagency, not having responsibilities for research and development or for operations in weather modification should be given the necessary authority to monitor weather modification operations and to exercise such regulation as may be necessary to protect the integrity of Federal programs.

Dr. Chamberlain will discuss the Commission's recommendations on these matters.

6. Study should be given to the provision of appropriate compensation to the public for damages arising from Federal weather modification activities and protection for Government grantees and contractors.

I thank you for the opportunity to discuss briefly this very complex and important problem. I will be glad to try to answer any questions you may have.

Thank you, Mr. Chairman.

Senator CANNON. Thank you, Doctor, for a very fine statement.

I have a number of questions relating to organization, proposed organization, the funding, and so on. Perhaps it would be well to hold those until after we have heard from the entire panel.

Dr. HAWORTH. I would greatly appreciate that.

Senator CANNON. Very well.

The next witness I presume will be Dr. Chamberlain.

Senator Hart, do you agree with going ahead with the panel statements?

Senator HART. Yes, I do.

## STATEMENT OF DR. ADRIAN CHAMBERLAIN, VICE PRESIDENT, COLORADO STATE UNIVERSITY; CHAIRMAN, NATIONAL SCIENCE FOUNDATION SPECIAL COMMISSION ON WEATHER MODIFICATION

Dr. CHAMBERLAIN. Gentlemen, it is a pleasure to discuss with you the results of the work of the National Science Foundation Special Commission on Weather Modification as you consider S. 2916.

The Commission was chartered to make recommendations to the National Science Foundation and to provide a response for a committee of the Federal Council on Science and Technology. The assignment included consideration of the physical, legal, social, biological and political aspects of weather and climate modification.

Man's growing knowledge of the natural environment has given him an increasing awareness of the changes taking place in his earthly habitat. Fortunately, his increasing knowledge has also indicated some possible means of deliberate modification of the environment.

This knowledge may make it possible, hopefully, for him to plan for conservation and development of the environment for the benefit of man. He is at last learning he cannot consider himself free to heedlessly exploit the air, water, land and growing things of the earth.

The central issue of public policy considered by the Commission was: Do the scientific and engineering possibilities of meaningful deliberate weather and climate modification seem sufficiently promising of social benefits to indicate the time has arrived for the Nation to direct substantially larger resources of money and manpower to the many facets of the field?

The Commission concluded the answer is: Yes; for reasons of scientific, human, biological, legal, and international need. Such a national program will require a budget increase of at least $40 million to $50 million per year by 1970 over the fiscal year 1966 level for weather and climate modification activities.

## SCIENTIFIC PROSPECTS

The Commission feels the study of weather and climate modification is ready to pass from being considered a speculative field to one ready for a rapid expansion of carefully planned research and development.

Many interesting and potentially valuable opportunities are becoming evident that will attract many of the Nation's best minds to the field if fiscal resources are made available to support the intellectual talent of industry, academic institutions, and Government agencies.

The atmosphere can be viewed as a complex system in which ascertainable changes in air motion will take place in response to identifiable forces. If the forces are altered, in principle the motion of the air can be influenced.

Therefore, in principle, meaningful modification of the weather and climate should be feasible if one can demonstrate the capability to alter these forces so as to produce predictable consequences.

In a practical sense, it is necessary to establish only beyond reasonable doubt that the cause and effect are related. Aside from intellectual curiosity, this has been the central problem of weather modification research.

Progress has been made. That seeding (the cause) can dissipate supercooled fog (the effect) has been so clearly demonstrated it is moving to the operational phase for some airports.

On a larger scale, there is evidence, though somewhat ambiguous, to support the view that precipitation from some types of clouds can be increased by the order of 10 percent by seeding. The question of corresponding decreases outside the target area is unresolved.

Hail and lightning research is beginning to show some promise. A program of large, carefully instrumented and statistically designed field experiments is needed. These will take a great deal of money.

The study of the energy levels of atmospheric subsystems such as tornadoes, hurricanes, and extratropical cyclones leads to the conclusion that it is not practical to think of altering these subsystems by direct application of energy. Yet the study of instabilities in the atmosphere indicates at least four kinds of instabilities may be susceptible to man's effort to "trigger" national reactions. These instabilities—(1) phase instability of water, (2) colloidal instability of cloud particles, (3) convective instability of the atmosphere, and (4) baroclinic instability of the large scale circulation—will all require a great deal of theoretical, laboratory and field research.

I am sure that as your scientific testimony is presented, that there will be further elaboration on these particular instabilities.

Improved prediction of weather phenomena may be as important in many cases as modification in terms of social and economic benefits. For this end and others a global observation network will be necessary. Numerical stimulation studies need to be expanded.

The Commission was greatly concerned about the inadvertent modification of weather and climate underway due to the activities of

man. Air pollution from our cities is an example. This is a problem of grave importance. Little is understood of the weather and climate modification being induced by this means.

Nonatmospheric means of modifying weather and climate need to receive increased attention. The atmosphere interacts with the expanses of earth and sea. Man's ability to induce large-scale alterations of the land and sea continues to increase. The possible consequences of such alteration on weather and climate need a great deal of study.

To illustrate this, conversation is taking place with regard to pouring oil over the seas, thereby setting the air-sea interaction which might potentially, at least from a speculative point of view, influence hurricanes, as an example of nonatmospheric means.

The Commission concludes the scientific and engineering prospects of meaningful progress in weather modification are sufficiently attractive that a great deal more manpower should be drawn into the field. This expansion of activity will require talent from several disciplines.

Also required will be a great increase in the logistics support for field and laboratory research and operations. The results of increased intellectual concentration on the field would be important not only to those interested in precipitation augmentation, but also the entire field of atmospheric resources.

## BIOLOGICAL RELATIONSHIPS

Anything that has a significant effect upon plants and animals is of primary concern to man. Plants and animals are the foundation of his existence.

Modifying weather and climate may initiate changes in the abundance of certain plants and animals. It may also induce instabilities in numerous biological populations—including those that prey on man and challenge his existence.

Thus, a national program of weather and climate modification must include support for a substantial research program in ecology and related biological sciences.

The present state of knowledge is very inadequate for making good predictions of the biological consequences of specific weather modification projects except under limited conditions.

The ecological system of agricultural fields is well enough understood that reasonably good predictions can be made. But in a more complex system such as that of large uncultivated watersheds containing many species of interacting plants and animals it is not now possible to make quantitative predictions.

Living things are adapted to the weather that prevails. Any change in the weather will be generally deleterious to them. Weather and climate modification over large areas of a few hundred square miles or larger for long periods of time is likely to induce a decreased stability of biologic communities. This instability would manifest itself as an increase in pests, weeds, and pathogens.

It is extremely necessary and important that a national weather modification program involving large areas for field experiments have fiscal support for ecological studies by numerical stimulation and field study.

To obtain a net benefit from a biological point of view will require much better knowledge than now available of the interactions of weather and organisms. Such research is expensive. Such studies span many years for obtaining meaningful conclusions.

The largest social credit item for weather modification is likely to be an increase in primary plant production of the drier parts of the land surface.

### STATISTICS

As is well known, a controversy among statisticians over the validity of the conclusions of early research did not encourage weather modification research during the late fifties. The situation is better now.

The current central question on the role of statistics in weather and climate modification research is not whether to use statistics but how to use it in the early design through to the analysis of the research data.

The national program in weather and climate modification needs to provide for support of statisticians to work on all facets of physical, engineering, and biological studies in the field. Furthermore, support is needed for basic statistical methodology research.

### HUMAN EFFECTS

Sound public policy in the face of uncertainty about the techniques of weather modification requires that research also be initiated on the social and economic effects. Such research is needed to fully exploit what may be an historic opportunity to improve the environment for society, and at the same time be prepared to avoid activities which might be detrimental to man.

So intricate are the interlocking motivations in human behavior that subtle changes may be initiated by weather modification and not even be detected.

Some beneficial changes, such as bountiful crops and their impact on the economy, can be readily followed. But because the organization of society is so complex it is not evident whether the quality of life may be enhanced or degraded by every possibility of weather and climate modification.

It seems clear, for example, that the power and motion of severe storms provide some of the most exhilarating opportunities that the human mind experiences. Would it be of social benefit to completely control weather and remove these phenomena from the realm of human experience? How could one put a value on such a possible degradation of the quality of the life experience?

From an economic point of view many effects of precipitation augmentation for crops, hydroelectric power, et cetera, can be fairly readily measured. But other effects might not be so simple to evaluate.

For example, what would be the economic, social, and political problems of shifting a hurricane so it hit North Carolina instead of Florida? To learn how to deal with such problems in advance of the technological capability, in the face of large uncertainty about the ability to modify weather, will require a great deal of effort.

Several areas of potential conflict of interest are already recognizable. Public policy should seek to provide a means to reconcile con-

flicts equitably. It should seek to prevent victimization, either by people who mistakenly think they are gaining benefits or of individuals who are unaware of damages being inflicted on them.

Conflicts may arise between those trying to conduct experiments and those wishing to carry out operational projects for utility or agricultural clients.

A national program on weather and climate modification should include support for research on the social and economic consequences of alternatives. For example, it might be more profitable to pursue research in crop genetics to improve drought resistant crops than to augment precipitation.

Further, if weather modification includes serious pests and weed problems, the costs of these might overshadow the benefits of increased crop production. Because the answers to such questions are not known, research is needed.

Research is needed on the basic relationships between weather characteristics and human behavior. The decisionmaking process of man in the face of uncertainty needs further study. The social effects of inadvertent weather and climate modification, such as air pollution, need further investigation. The social consequences of commercial operations and field experimentation need to be studied.

The providing of indemnification against damages for federally supported work would encourage more academic, industrial, and private scientists and engineers to seek support for research and development work.

## LAW

A demonstrated capability to modify weather and climate over areas of substantial size presents legal problems of great difficulty. Yet even before such an ability is assured the law is involved on at least two counts: (1) the rules over responsibilities and liabilities of weather and climate modification to other members of the public, and (2) regulation by Government.

It does not seem possible to recommend, without a great deal of further study, appropriate rules of law to govern "property rights in weather." Easy analogies to the law regarding water, land, air space, et cetera, do not seem adequate for the problems of weather modification.

The liability of weather modifiers with respect to those claiming injury to their person or property, for example, need to be decided on their own merit. The few court cases to date do not give much basis for predicting how the law will develop.

Some 22 States have enacted laws regulating weather modification. Most of these States require licenses. Effective January 1, 1966, the National Science Foundation increased its recordkeeping requirement and imposed on all operators a requirement of advance notice to it of any activity. This information is an aid to the Federal research and development effort.

The Commission concluded that Federal legislation should be enacted adequate to—the first is essential preemption by the Federal Government—

(1) Delay or halt all activities, public or private—that is the power to do this—in actual or potential conflict with weather

and climate modification programs of the Federal Government, whether these programs are conducted for the Federal Government by its own agencies, or by its public or private grantees or contractors.

(2) Immunize Federal agents, grantees, and contractors engaged in weather and climate modification from State and local government interference.

(3) Provide to Federal grantees and contractors indemnification or other protection against liability to the public for damage caused by Federal programs of weather and climate modification.

These recommendations are restricted in scope because it is felt that regulation should be only the minimum necessary for permitting accomplishment of immediate national goals.

As knowledge develops more comprehensive regulation will be required. And since weather transverses national boundaries, study needs to be made of international legal problems.

### INTERNATIONAL

As weather and climate modification research and development continue to expand, some form of international collaboration will be essential in the planning and carrying out of operations which may affect localities of other countries and continents far distant from the scene of the operation. Such events have a bearing on the political relationships among nations.

With weather modification still in its infancy, it provides an inviting opportunity to encourage multinational interest in mutual cooperation among the people of rival nations.

Weather and climate modification might well serve as an avenue to widening the areas of common interest among nations, thereby helping in accomplishment of the objectives of easing tensions. In the process the field of weather modification may be able to contribute significantly in the growing international food crisis.

The international aspects of weather modification require careful study of the biological, social, economic, and political factors. The results of study of these fields in the United States may not be directly applicable to many of the developing countries where the social institutions, biological environment, and political system are different.

Now is the time to start the steps, in concert with other nations, to explore the international institutional mechanisms that may be appropriate to foster international cooperation.

To provide an appropriate public policy setting for weather and climate modification, the Commission feels the Nation should enunciate policy containing these two points:

(1) It is the purpose of the United States, with normal and due regard to its own basic interest, to pursue its efforts in weather and climate modification for peaceful ends and for the constructive improvement of human life throughout the world.

(2) The United States, recognizing the interests and concerns of other countries, welcomes and solicits their cooperation, directly and through international arrangements, for the mutual achievement of human well-being.

### FISCAL NEEDS

The Commission concluded that weather and climate modification research and development activities of the Federal Government should be increased by $40 to $50 million per year by 1970, excluding any national laboratory type capability which might be initiated.

These figures were derived by estimating the program needs which should be increased from the fiscal year 1966 level of $7.2 million of agency budgets, excluding logistical support provided by the Department of Defense. About half of the increase will be needed for basic research, including such things as much larger computer capability. Much increased support is necessary for conducting carefully designed and adequately instrumented field experiments.

The budget increases should definitely include funds for the physical sciences, statistics, engineering, the social and biological sciences, and the law.

No estimate beyond 1970 was made by the Commission. It was felt the level of funding for the 1970–80 period could be much better estimated after a couple more years of experience. The field is capable of going ahead so rapidly that long-range cost estimates would probably have little validity.

### ORGANIZATION OF GOVERNMENT

The field of weather and climate modification needs to have the services of government, private industry and academic institutions. It must be able to accommodate participation by the individual scientist who only needs pencil and paper to the large complex organization necessary for a massive field experiment. The following factors enter into analysis of the organizational needs:

(1) There is need to bridge the organization gap between laboratory research and large-scale field experiments; this gap can exist even in the basic research aspects. There is need for organizational arrangements for enough applied research to develop the field, while preserving scientific objectivity in the basic research effort. The economic, political, and spectacular aspects of weather and climate modification operations must not be permitted to crowd out the basic research.

(2) There is need for biological and social science research to go hand in hand with the physical science and engineering research in support of the missions of all agencies, contractors, or grantees concerned with weather modification. There is need to preserve diversity in the research effort, but there is the need also to establish a Federal organizational mechanism for accomplishing what cannot be done through diverse research activities.

(3) Responsibility should be clearly assigned for the formulation of arrangements for appropriate scientific cooperation with the governments of other nations.

(4) Adequate enforcement power needs to be provided an administering agency so as to insure the filing of information relative to all weather modification field experiments and all commercial operations. The agency assigned regulatory functions should have a regional or field office establishment.

(5) The conduct of research and development in this field should be kept insulated from activities involving the regulation of weather

modification operations, but at the same time the two types of activity should be sufficiently proximate organizationally to assure immediate access to data derived from the operations being regulated.

Based on these considerations, plus the fact several Federal agencies have missions—such as Department of Defense—that require weather modification knowledge, the Commission concluded a pluralistic organization for assignment of responsibility would best insure progress of an expanded national program.

The suggested assignment of responsibilities can be summarized as follows:

(1) The mission of developing and testing techniques for modifying weather and climate should be assigned to an existing or new agency in the executive branch of the Federal Government. The mission should include support and conduct of research and development and such operational activities as are needed for the furtherance of the technology of weather and climate modification.

Substantial authority to contract for services should be provided. This agency should have major but not exclusive responsibility, in collaboration with the State Department, for formulating and implementing programs of weather and climate modification involving international cooperation.

(2) The National Science Foundation should continue and expand its support of research in the atmospheric sciences, including its program directed at providing a satisfactory scientific basis for weather and climate modification. This should be carried on primarily at universities and colleges.

The National Science Foundation program has been the major source of funding for development om manpower for weather modification activities. The National Science Foundation should be given increases in funds for expanding this support since the manpower needs will continue to grow.

The National Science Foundation should continue maintenance of the National Center for Atmospheric Research as a facility for the conduct of basic research on a scale beyond that feasible for individual university investigators. The degree of continuing and special attention given by the Foundation to support of the physical sciences, engineering, and biological sciences and the social sciences aspects of weather and climate modification should be reviewed from time to time in the light of the progress of the overall national program.

(3) Federal agencies should undertake such operational activities as may be required for the effective discharge of their mission. Also, pursuant to Executive Order 10521, Federal agencies should be free to conduct and support such research and development as may be required in the discharge of their missions.

The Commission also felt that a national laboratory type of capability is needed for an expanded interdisciplinary program encompassing all the relevant disciplines. Yet it is not clear that creation of a national laboratory per se is the answer. The President's Special Assistant for Science and Technology could perhaps be called on to initiate appropriate feasibility studies.

Insofar as the nature of a regulatory agency is concerned, care must be taken to insure access of all agencies to the information generated,

while at the same time keeping regulation organizationally separated from research and development.

Whether the regulatory function needs to be divorced completely from the operating agencies, or can be assigned to a separate branch or subagency of an existing agency, will depend largely on the extent of activity and the degree of regulation required.

As to the jurisdiction of a regulatory agency over other Federal agencies, to the extent regulation involves requirements of notice, reports, licensing of activities, et cetera, there seem to be good reasons why all agencies should be subject thereto. In addition, the regulatory agency should be given power to resolve minor conflicts between agencies, such as the timing of particular experiments.

The Commission recommends that the Office of Science and Technology consider establishment of a special mechanism for the coordination of weather and climate modification policies and programs. Such an entity could not only serve to resolve major conflicts but could serve to promote unity in policy and deployment of funds and manpower with optimum effectiveness.

Both the executive branch and the Congress may wish to have available scientific and public policy advice from a group of knowledgeable people from outside the Federal Government. This need might well be met by the appointment of a standing committee in the National Academy of Sciences, in cooperation with the National Academy of Engineering. The group should include persons with experience in the physical, biological and social sciences and engineering.

## SUMMARY

In closing the Special Commission on Weather Modification was made up of 11 men from several disciplines. They were provided background data by numerous individuals and groups such as—

(1) Panel on Weather and Climate Modification of the National Academy of Sciences;

(2) Study Committee of the Ecological Society of America;

(3) University of Minnesota conferences on statistics and weather modification;

(4) Participants in the University of Chicago Symposium on Economics and Social Aspects of Weather Modification; and the

(5) Southern Methodist University study of certain legal aspects in weather and climate modification.

In summary, the Commission feels the time has arrived for the United States to initiate a much expanded interdisciplinary research and development program in weather and climate modification. This program should be adequately organized and funded. Provision should be made for participation by individuals, educational institutions, private firms, the several levels of government and foreign countries. Regulation should be kept to a minimum consistent with available knowledge.

To be able to deliberately modify our environment in a predictable manner may be our salvation as a society on this planet.

Thank you, Mr. Chairman.

Senator CANNON. Thank you, Dr. Chamberlain.

We will now hear from Dr. Roberts.

## STATEMENT OF DR. WALTER ORR ROBERTS, DIRECTOR, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Dr. ROBERTS. Mr. Chairman, referring to your opening remarks, I'm glad to join in the determination, now widely shared, to do something about the weather.

Dr. Haworth and Dr. Chamberlain have given you very comprehensive statements, and our time is short to cover the many, many things that I would like to say. Consequently, I have prepared a written statement amplifying quite a few points that I propose to touch on only in summary in my oral satement.

Perhaps you will find it appropriate to include my written statement in the record of the hearing. Of course I shall be glad to amplify any points you ask about it either now or at a later time.

Senator CANNON. The written statement will be included in the record of the hearing. You may proceed to summarize it, if you wish.

(The document referred to follows:)

### STATEMENT OF WALTER ORR ROBERTS, DIRECTOR, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Mr. Chairman and members of the committee, my name is Walter Orr Roberts, and I am director of the National Center for Atmospheric Research (NCAR) in Boulder, Colo. As you may know, NCAR is a basic research laboratory in the atmospheric sciences, and is operated under contract with the National Science Foundation by a nonprofit corporation composed of 21 American universities, from MIT and Florida State on the east, to the University of Hawaii on the west, and from the University of Texas to the University of Alaska.

The work of our laboratory in many areas of the atmospheric sciences is interesting and important. Though I will be happy to answer any questions you may have about it, I have restricted this written statement to a more general view of the prospects and challenges of atmospheric modification. As an appendix, I have attached a brief outline of the work at NCAR most closely related to atmospheric modification of various kinds. You can see that it is a very significant part of our program.

Specifically, I shall discuss the following general questions:

1. The magnitude of the prospects for practical benefit in applications of the atmospheric sciences. This is a field that has, in my opinion, as much promise for the benefit of mankind as the peaceful uses of atomic energy, and it is similar to atomic energy in its scientific and technological complexity. Its state, however, is not too far beyond where atomic energy research was when Hahn and Meitner had observed fission, but practical atomic bombs or working atomic powerplants were but an idea and a hope. Perhaps we can be said to be at the place in progress analogous to where our atomic scientists were when the first atomic pile began to chain react at Stagg Field in Chicago.

2. The need for new concepts in planning and management of applied research and engineering projects in weather modification. We are beyond the scale of a laboratory science though much related laboratory science is still needed. We have reached a stage where skilled planning and management are required to solve complex logistic and scientific planning problems for new pilot operations in the natural environment.

3. The need for new realism about our national research objectives if atmospheric modification is to yield its maximum payoff. If we are to attain the maximum possible mastery of our atmospheric environment—such as may ultimately be achieved through large-scale weather or climate modification—we must be prepared for a long-range program in basic research, organized in such a way that there is a constant feedback to and from efforts in applied research.

4. The need for wise planning to increase the reservoir of highly skilled atmospheric scientists to carry on the work in coming decades. This means an increasingly vigorous program of research and education in the universities.

5. The need to recognize the implications of where we are. The weather modification techniques available today are extremely rudimentary. To mount a

large program in applied research and development in weather modification without an equally vigorous push in basic research will guarantee in advance that we will not attain all—or even most—of the benefits possible. In the words of the song, "You can't have one without the other."

Conversely, we must see to it that new advances in research are promptly put to work for the benefit of mankind. Government laboratories, private corporations, and the universities must cooperate effectively, and perhaps more deliberately than in the past, to assure close and productive coupling of basic research advances to practical weather modification goals.

### THE NECESSITY FOR ACTION

It is heartening to me that the Congress should be so deeply interested in the prospects for modifying the atmosphere for the benefit of man. I personally feel a great sense of urgency of getting on with the job with all the determination and wisdom we can muster; for no matter how determined and wise we are, it will be a matter of years or decades before we have come anywhere near close to reaping what now seem to be the probable ultimate benefits.

Not only are these ultimate benefits of great value, but there are many potential rewards on the way.

Though there are serious gaps in our knowledge of why the atmosphere behaves as it does, we do know enough about its processes to start immediately, for example, on a balanced, long-range national program to help solve one of the Nation's most pressing present problems: a national water shortage. And this will be an ever more pressing future problem, with the need for increased water usage in an expanding world technology and in an exploding world population.

I am not an expert on population nor on the relationships between population, food-producing techniques, and the need for arable land; but it doesn't take an expert to see that whatever can reasonably be done to increase the amount of fresh water available for agriculture and industry should be done, in order to head off inevitable problems of the future.

Secretary Udall, in a speech before the annual meeting of the American Meteorological Society in Denver last month, spoke of the need to tap "the rivers in the sky." Ten years ago, this would have been Buck Rogers talk. Even today, this is a statement of determination to reach a goal that we still do not know how to reach, for it involves basic knowledge not yet attained and technology we have not yet mastered. Yet, as you run your finger along the cutting edge of the new research, you are compelled to realize that there is promising evidence that we can, even today, tap this atmospheric water reservoir, albeit to a relatively small degree and under very special circumstances. And we can do it only very clumsily and very inefficiently, with yet unreliable, unpredictable, and partially ambiguous results. But we can do it.

I use the words clumsy, inefficient, unreliable, unpredictable, and ambiguous not in criticism of current efforts, which are being carried out with considerable ingenuity, devotion, and patience. These words merely describe where we are, in relation to the potential I can see for modification of weather, climate, and the atmosphere.

To describe in another way where we are today, let me say that in my opinion our current knowledge allows us to realize but a small fraction of the ultimate potential in the field of weather modification. Today we talk about the probability of increasing the yield from clouds over a watershed by a few percent. This seems technologically possible from the basic knowledge we now have. But we cannot be content with this. Not only is much more than this likely to be possible, but it can be flatly stated that the know-how we have today—the ability to increase rainfall in favorable locations by a few percent—won't solve the really big water resource problems this Nation and the world will face in coming decades. We can and must do more.

A glance through the summary volume of the National Academy of Sciences' Report on Weather and Climate Modification makes this clear. The way to major benefits in weather modification is in large part still blocked by major problems, each of which will require years of hard work by teams of the most skilled researchers we can find.

Weather modification, moreover, involves far more challenging total prospects than cloud modification to increase precipitation. We must not overlook the possibilities that the large-scale features of the atmosphere—the paths of jet

streams, hurricanes, squall lines—may ultimately prove subject to man's deliberate influences.

If this sounds even today like Buck Rogers, many of us, myself included, feel that it is an objective more likely to be achieved than the goal, for example, of increasing by 50 percent the water yield of the Upper Colorado River Basin through cloud modification. Even if our sights are set solely on the objectives of increasing the water resources of drought-stricken or normally arid regions, the attack via modification of the large-scale circulation features of the atmosphere may ultimately prove the most promising.

Moreover, to weather "modification" let me also add the word "demodification." The dramatic rise of air pollution over the past 20 years has made it clear that the atmospheric sciences must be applied to conserving as well as developing this precious resource. We have experimentally established that it is all too easy to alter the atmosphere significantly by excessive sewerage of gaseous and smoky wastes. And over and beyond their adverse medical, economic, and esthetic effects, these wastes may be having climatic or other large-scale weather influences as yet undetected, though perhaps major, because of the still rudimentary state of atmospheric science.

The atmosphere is a totally essential resource of mankind. It begins at our feet, and stretches continuously to the farthest star. We live in it, breathe it, are protected from natural space radiation and meteorites by it. It is the only major source of manufacture of fresh water for the earth. An average drop of water distills from the oceans and rides aloft on the winds—on the average but 10 or 15 days before falling to earth as life-giving moisture. Without the atmosphere, our planet would be as barren as the hostile and lifeless surface of the moon, as improbable an abode of intelligent man as the poisonous vapors of Saturn or Jupiter.

The problem we face is to conquer the mysteries of our atmosphere, and through knowledge to bring about the mastery of the atmosphere—for the benefit of all mankind.

We are, I am firmly convinced, dealing with a field that is, as I mentioned above, similar to atomic energy, not only in terms of its ultimate usefulness, but also in terms of its scientific and technological complexity and in terms of the manpower and time required to realize its potential. In cost, weather modification or control techniques may perhaps prove less expensive to develop than techniques for the peaceful use of atomic energy. But they will not be accomplished with the present timid efforts, short-term funding and tentative manpower commitments.

If we are to think in terms of ultimate as well as immediate benefits, we will have to think more realistically, not only about the substantial sums of money that must be invested over a period of many years, but in a number of other ways as well. For we are talking about modifying a physical system—the weather—that has global dimensions and is as intricate a system as any that exists in nature. Money begets activity, but only through a comprehensive national program will activity bring the results we seek.

## PLANNING AND MANAGEMENT

We must be more daring and more persevering in our concepts of the planning, management, and logistic requirements involved in basic research, practical experimentation, engineering development, and operations in atmospheric modification.

In one of the most impressive sections of its report, the National Academy of Sciences Panel states flatly that "the present fragmentation of effort in weather modification research and development" has led to a situation where "many of the fragments are below critical size or quality needed for effective work." [1] It further states that the present situation doesn't provide proper mechanisms either for setting priorities among large, costly projects, or for planning and managing their scientific and logistic complexities once a project is chosen. We cannot progress adequately until this situation is righted.

## SOME IMMINENT PROSPECTS

The need for a new mode of management and planning becomes clearer if we discuss in some detail the three kinds of weather modification which, in my

[1] "Weather and Climate Modification. Problems and Prospects," final report of the Panel on Weather and Climate Modification, NAS–NRC Publication 1350, Washington, D.C., 1966, vol. 1, p. 21.

opinion, are among those having the brightest prospects in the next few years. In each of these, the logistics are difficult and expensive. In each of them, developments in engineering and in scientific research will have to be closely coupled, because as engineering advances are made, the need for specific pieces of basic knowledge will achieve critical significance. And progress in each of them will carry with it a whole series of political, economic, and legal questions.

*Orographic precipitation.*—This occurs in regions where a mountain barrier uplifts and thus cools the air flowing across it. It now appears certain that in some mountainous regions, winter snowpack can be increased at least a few percent by seeding of all appropriate winter storms with silver iodide. Having said this, we have said a good deal of all we know today. We know that it happens, and we have some theories to explain why. But there are enormous holes in our knowledge. If we are looking for the best possible design to produce the greatest possible result, we have almost certainly not yet understood the factors that will allow us to specify such a design.

Without a doubt, we are thus still in the Model-T era of cloud seeding. We do not yet understand the life cycles of mountain clouds well enough to know the best time and place to insert the silver iodide. We are not yet sure of where to place our generators so that the silver iodide will get to the right part of the cloud, assuming we knew where that was. We do not yet know adequately the abundance of natural seeding nuclei in given cloud systems. The design of seeding generators is still rudimentary and empirical; engineering and research wisdom must be put to this problem. The best generator depends on what size, concentration and character of silver iodide particles you wish to generate, and our knowledge of these winter-storms clouds is not yet sufficient to answer any of these questions with certainty. And so on.

At each step of the way, it is necessary to conduct extensive experiments, studies, and tests to see what the results do to our theories about these storms. But we now know what things to tackle first, and this is a great step forward.

*Hail suppression.*—The Russians have already conducted large field programs in their wheat-growing country which is as plagued with hail as are our American High Plains. The Russian hail-suppression system, briefly, is this: They, like us, have an empirical understanding of the kind of cloud that is likely to produce hail. If such a cloud appears, they fire away at it with rockets or artillery shells loaded with silver iodide, or they use plane-borne seeders, on the theory that the silver iodide will induce the formation of many small hailstones rather than a few large ones, and that most of the small hailstones will melt before reaching the ground. They have claimed 100-percent success in some field efforts—that is, during an entire season they say that no hail damage occurred in certain areas where storms with large hail occur many times during a normal season. Similar experiments in other countries have produced less straightforward results.

The first step in a U.S. national hail suppression program (and a very sound plan is now being organized), is to try to understand the phenomena involved in hail, and the thunderstorm that produces it. But to probe and understand hailstorms is a gigantic undertaking, requiring not only the talents of many scientists, but also a high degree of organization, backed up by engineering skill and expensive equipment—aircraft, radars, new kinds of measuring devices—all spread over a large area and, if feasible, mobile as well. NCAR, for example, needs a jet airplane to carry thunderstorm-probing "dropsondes" above the crests of hail-producing storms, something a propeller plane cannot do. This scale of operation is not a venture for a single university scientist, or two or three. It requires skilled organization involving dozens of creative scientists and several times that number of technicians to back them up.

As I will discuss in further detail later, the scientific talent needed for such undertaking is scattered across the country, mainly in the universities, and it is critically important that our attack on hail suppression be organized in such a way as to use this talent and at the same time not impair the primary goals of these university scientists; namely, to train a new generation of still more numerous and talented scientists.

*Air pollution.*—When we speak of modifying the atmosphere, we often overlook the fact that man is already modifying his atmosphere by spewing into it great amounts of fossil-fuel exhaust and other contaminants. Indeed, we may be touching off processes that will have significant long-range effects on the climate of entire regions. It is essential, before we go through many more years

of this constant increase in pollution, that we understand its full impact on the air we breathe and the climate in which we live.

The atmosphere, whether we like this or not, is a complex system. It is, indeed, a great arena in which many processes are simultaneously taking place, each of them interacting and feeding back on other processes. To trace the full cycle of inserting various gases and particles in the air from our industrial and urban centers is thus a fiendishly complex problem, requiring research in the laboratory, extensive measurements in the field, and the applications of advanced mathematical and computer techniques.

This is one area in which substantial progress has been made in the last 5 years, under the leadership of the Public Health Service, and with active collaboration from other agencies. It is essential that this progress continue into the more complex and costly stages of applications to come.

This brief sampling indicates the size and complexity of the problems that lie in the road to practical benefits. It is also important to note that the idea of weather modification, even in the short run, implies something far broader than increasing precipitation. To view atmospheric modification only as a means of adding to our water supply would be to sell its prospects tragically short. Thus I urge, when you consider what the proper role in weather modification is for the Federal Government and how it should be pursued, that you look at it in an appropriately broad context.

### THE ROLE OF BASIC RESEARCH

Looking to the future, we must also be realistic in our conception of what is needed in weather and weather modification research. The kinds of research we will carry on in the future require the best technological support we can muster. For example, a worldwide observing system now being planned by ESSA—the world weather watch—will make it possible for the first time for us to describe the atmosphere as the global entity it actually is (for, as you know, storm systems are linked and interact on one another all the way around the globe). This observing system will probably require two artificial satellites, thousands of free-floating weather balloons of a remarkable new type that NCAR is now experimenting on, and other remote sensing devices to bring the now-unobserved 80 percent of earth under adequate weather observation.

But this is not the only requirement for effective long-term progress in both weather prediction and weather modification. Another is vastly enlarged computing capabilities. We must have computers with 100 times the speed and capacity of the largest computer available today, and we need to have its intricate computing programs written in such a way as to exploit the most advanced knowledge of how the wind and weather systems behave. Both are today in sight. And with both in operation we will be in a very favorable position to do weather modification experiments—in a computer—with very exciting potential consequences.

Let's consider for a moment some of the possible large-scale weather modification schemes that have been suggested in recent years by various scientists. The late Harry Wexler, distinguished chief scientist of the Weather Bureau, suggested that if lampblack were spread on the polar icecap, it might change the radiative balance in polar regions and thus warm the surface, increase the melting of ice, and through this affect the delicate ice versus water equilibrium of the Arctic Sea. This, in turn, one can speculate, might well result in a more frequent occurrence of the kinds of outbreak of polar air that trigger winter cold waves and blizzards in temperate latitudes and also bring spring rains to promote crop growth.

Another scheme proposed several years ago was to build a dam across the Bering Strait between Alaska and Siberia, in order to regulate the flow of cold Arctic waters into the warmer North Pacific, and ultimately through temperature effects to modify the evaporation, temperature, and winds in that region. The original proposal, advanced by the U.S.S.R., was designed to lengthen the growing seasons of eastern Siberia and western Canada, and thus to increase wheat production in both Canada and the U.S.S.R.

A more modest idea, of which I was the author, speculated about the possibility of creating layers of artificial cirrus clouds (not unlike those that sometimes form on jet airplane contrails) over the Gulf of Alaska, which might act as atmospheric "blankets" at a critical altitude and thus pump heat into the wind systems. The effect might be to deepen winter storm systems and divert them further south. A storm that would otherwise travel eastward along the

Canadian border might, in my notion, be influenced to dip deeper into the central Great Plains and bring moisture to winter crops. There is some insecure but very intriguing evidence that the extremely small amounts of energy involved in the aurora borealis may, on certain winter occasions, do just this. If so, the energy to trigger such a sequence of events is almost certainly within man's capability to release under his control.

There are troubles with such ideas. Many of them are almost ridiculously costly. A dam across the Bering Strait might cost $50 billion. And we cannot, at present, tell at all securely whether or not it would bring any benefits. Perhaps even more important, we cannot, at present, even determine that such ideas, if tried out in reality, would not backfire, producing harmful efforts, possibly even irreversible ones, not only in their immediate regions but all around the globe. A minor disturbance in the Gulf of Alaska today can amplify to a major storm in the Mississippi Valley on Saturday, and a week from today it may become a cold wave that will freeze a substantial part of the orange crop in Florida.

It would thus be obviously irresponsible to test such schemes in nature before we can understand in detail what their full effect will be, and why. It would be politically unfeasible as well. You are all aware of the uproar that occurs when one farmer who has hired a cloud seeder is accused by his neighbors of "stealing" their rain. I saw this when, some years ago, I served as chairman of the Weather Control Commission for the State of Colorado. It's easy to imagine, such disputes magnified to an international scale.

In short, to try such schemes on partial knowledge would entail risks that only the most desperate would try. It is a part of our job in the atmospheric sciences to see to it that we never reach that point of desperation.

### PUTTING THE ATMOSPHERE IN A COMPUTER

Fortunately, we are now in the process of developing, at NCAR and elsewhere in this country, a way of simulating such weather modification experiments. We hope to take the supercomputer I mentioned previously, and insert in it a "mathematical model" of the global atmosphere. Such models now exist in rudimentary form, and work is progressing in making them suitably realistic, though this is no simple job. In fact, the late John von Neumann, the father of the modern electronic computer, said that such models of weather represented "without doubt the most complicated series of interrelated problems not only that we know of, but that we can imagine." He felt the entire science of computers could be justified by the weather experiments they would permit. Great progress has been made in the last 10 years, and I expect that workable models of this character are not too many years in the future.

Using future world weather watch data, together with a realistic "mathematical model," in a supercomputer, we will simulate, I believe, large-scale weather modification experiments without risk, without political problems, at token costs; and much more rapidly than in nature. We will be able to compare costs and benefits, and understand the full effects. From such research, we will be able to determine which kinds of weather modification will be likely to produce significant benefits. And this knowledge will spur the development of the necessary technology and engineering for application in the real atmosphere.

A group in our NCAR laboratory is already at work on a study of the requirements for the supercomputer. Various prototype components of the world weather watch are already under test. In a few days NCAR will start launching 100 experimental globe-circling, constant-level balloons from New Zealand in a first realistic test of the balloons for a global weather system for the 1970's.

I should also point out that the world weather watch, the supercomputer, and the mathematical model are all essential to improved methods of long-range prediction. It is easy to see that this must be so; for to predict the total effect of a proposed weather modification scheme, we must be able also to predict what would happen if we were simply to do nothing, and let nature take its course. In short, progress in weather modification must go hand in hand with progress in weather prediction—that is, in the understanding of what the weather will do unmodified.

There are other areas of research where long-term efforts of great logistic complexity must be mounted—for example, in the study of the birth, life, and death of hurricanes. All such studies thrust us into new realms of great magnitude, where the ways we have become accustomed to doing things will no longer be sufficient.

### MANPOWER PLANNING

We must also be forceful in our efforts to attract to the atmospheric sciences and to train a larger share of the young and brilliant scientific talent of this Nation, so that the current handful of scientists—not more than a couple of thousand at the Ph. D. level in the whole world today—grows by tenfold in the next generation. Any lesser growth, I believe, will seriously affect our ability to get the job done. Indeed, the greatest obstacle to rapid progress in the atmospheric sciences today is the manpower shortage. I am sure Dr. White, who has been vigorously and very effectively recruiting people for the expanded programs of ESSA, will testify to the painfully short supply of highly trained atmospheric scientists now available.

We must therefore mix balance with our boldness. We must put enough manpower into efforts that will yield relatively short-term results, such as further refinements in cloud-seeding techniques, and into relevant research with a longer reach. We must also stimulate more effectively the talent that is best used in achieving long-range goals in the training of the next generation of scientists.

Once more, this means an expansion of university research and education, without which any applied research effort will fail its long-term goals.

We must look directly, also, to forging far more effective links between the university community and those agencies having an interest in applications. A very substantial part of the atmospheric research talent today resides in the universities. In order to keep it available to train the next generation, it is essential that most of this research talent stay in the universities. But it must not be in ivory tower isolation there.

One of the major goals of NCAR is to help create new ties between universities and the interested Government agencies, for the mutual benefit of both. The "user" agencies, in our approach, will get a better access to research advice and the university scientists will get research opportunities that otherwise would be beyond their reach. For example, NCAR is now serving as a link between NASA and the universities in the field of development of the "synchronous satellite" for measurements in tropical meteorology—a field of vast promise.

Next winter, NASA plans to launch the first synchronous satellite for meteorology, and it will be perched continuously over a single region of the tropics. It will use an ESSA camera, designed by Dr. Verner E. Suomi of the University of Wisconsin, to provide the first continuous observations of cloud development in the tropics. The life cycles of giant tropical cumulus clouds, in their aggregate effect, have a great influence on the general circulation of the global atmosphere.

But if the satellite data are to yield a better understanding of fundamental atmospheric processes, they must be linked to auxiliary observations using ships, land stations, balloons, aircraft, etc. NCAR, with NASA and ESSA help, held a meeting January 28 on this subject, and will conduct a workshop early next summer, in order to enlist the interest of university scientists and to define what auxiliary observations would be most helpful to their research.

Such mechanisms for enlisting the cooperation of university scientists are essential to the healthy future of the atmospheric sciences. Any reorganization of the Federal Government's effort in this field must take full account of the need to keep research and education in the universities strong and growing.

### CONCLUSION

In closing, I should like to return once more to discussing where we are today in pursuit of atmospheric modification. Our knowledge is rudimentary. We have attained enough knowledge, however, to know how we should behave in order to realize some practical benefits, and we should move as quickly as possible to do so. The knowledge required for major benefits to mankind, however, is not yet within our grasp. This can be attained only through a national program in the atmospheric sciences that is strong in both basic and applied research, more effectively organized than it is now, and it should be linked more directly to national goals than our atmospheric research effort is today. The ultimate payoff will, I am convinced, be hundreds of times what is now within reach.

At this stage of the game, the line between basic and applied research in atmospheric modification is nearly impossible to draw. Indeed, it will always be difficult to distinguish unambiguously between basic and applied research in

the environmental sciences, of which atmospheric science is a major component. It is, in my opinion, logical to assign major responsibility for the Federal Government's program in applied research and development in weather modification to a single agency. And the concept of weather modification encompassed must be as broad as the one I have used throughout my testimony. But I am not sure the time will ever come to erect a solid wall of demarcation between the sponsorship of applied research on the one hand and of basic research on the other. Even the scientist himself often doesn't know when he crosses the line. To try to draw it administratively, under such circumstances, will confuse rather than clarify the situation, will hinder rather than promote effective use of new knowledge, and will do nothing to enhance the quality of the basic research carried on at the universities or in NCAR.

Consequently, it is my firm conviction that the Congress should not withdraw the National Science Foundation's authorization to sponsor applied research in atmospheric modification. NSF's role should extend, in this field, to the point of demonstrations of the principles of application, though not to actual operational uses of new techniques or methods.

It would be, in my view, unwise to inhibit scientific groups under NSF sponsorship from proceeding from discovery all the way to demonstration of the principles of the discovery's relevance to application. After all, demonstration of relevance in solving practical problems is what the practical world wants and needs from science. It is essential to take all reasonable measures to stimulate just such coupling of research to man's needs.

APPENDIX TO STATEMENT BY DR. WALTER ORR ROBERTS, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH, BOULDER, COLO.

The following table shows various activities at NCAR (left column) and the potential applications (some of them, of course, not yet under, or ready for, development) to which the results of those activities may prove valuable (right column):

| ACTIVITY AT NCAR | AREA OF POTENTIAL APPLICATION |
|---|---|
| I. Research programs: | |
| A. The general circulation: | |
| 1. Numerical models of the general circulation | Developing improved prediction methods.<br>Computer simulation of large-scale weather modification experiments.<br>Probing the causes of climatic change and possible climate-modification schemes. |
| 2. Influence of cloud processes on large-scale circulations, with emphasis on the tropics | Impact of rain augmentation efforts on larger storm systems.<br>Prediction and modification (how the tropics influence the behavior of the global atmosphere). |
| 3. Turbulence observations and theory | Prediction and modification (how the oceans and land surfaces exchange energy with the atmosphere). |
| B. Physics of clouds and precipitation: | |
| 1. Dynamics of thunderstorms and rain showers | Hail suppression.<br>Augmenting precipitation. |
| 2. Cloud condensation studies | Rain "suppression" (i.e., moving rain inland). |
| 3. Thunderstorm electrification | Electrical effects on rainfall (potential modification method). |
| 4. Worldwide freezing nuclei measurements | Cloud seeding (background knowledge of levels of natural nuclei on which artificial nuclei would be superimposed). |
| 5. Cloud-seeding "carry-over" effect of iodine bonding with terpenes from trees | Cloud seeding. |
| 6. Effect of shock waves on ice formation | Hail suppression. |

| ACTIVITY AT NCAR | AREA OF POTENTIAL APPLICATION |
|---|---|
| I. Research programs—Continued | |
| C. Life cycles of trace gases and aerosols: | |
| 1. Worldwide measures of trace gases and aerosol distribution to determine "chemical climatology" of the atmosphere | Air pollution.<br>Prediction of climatic change. |
| 2. Studies of atmospheric isotope distribution | Inadvertent modification. |
| 3. Chemical reactions in the stratosphere | Inadvertent modification. |
| 4. Chemical sampling of tropical atmosphere | Corrosion-prevention techniques. |
| D. Solar activity studies (solar particle emissions; solar plasma ejections; ultraviolet and X-ray bursts from sun; coronal variation analysis and theory; flare physics; solar radio noise generation) | Improved prediction of possible influences of Sun on Earth's weather.<br>Prediction of solar events during manned space flight.<br>Improved prediction for radio communication. |
| II. Facility programs: | |
| A. Superpressure balloon development | Economically feasible element of a three-dimensional global weather observing system (the world weather watch).<br>Safer balloon sounding devices for weather observations. |
| B. Mathematical modeling and computing techniques | Improved prediction methods.<br>Computer simulation of large-scale weather and climate modification schemes (see IA). |
| C. Weather radar development | Clear-air turbulence prediction.<br>Precipitation augmentation.<br>Hail suppression.<br>Storm-avoidance techniques for aircraft. |
| D. Boundary-layer sensing development | Precipitation augmentation.<br>Air pollution. |
| E. Program on applications analysis (analysis of knowledge-gaps hindering applications; identifying new applications possible with currently available knowledge) | Project-by-project basis. |

Dr. ROBERTS. Thank you.

Let me start with a few words about NCAR, although I am aware your committee knows a good deal about our research laboratory. With resident staff and visitors from all over the world we do basic research on all aspects of the atmosphere. Our management corporation has 21 university members ranging the length and the breadth of the United States from MIT to Hawaii, from Alaska to Florida State University.

Our participating group is truly international in its composition, and all universities, members or otherwise, universities and colleges, have free access—have access to our facilities.

I have attached an appendix to my written statement showing specifically the parts of the research programs of NCAR that relate directly to fundamental questions of weather and climate modification. It is a very substantial fraction of all of our work.

At NCAR we studied the atmosphere which in our concept and in truth stretches continuously from our feet to the atmospheres of the most distant stars. How and why does it change? How does it change naturally, and can we push it to change more, less, faster, or more favorably?

My written testimony goes into some detail on five particular questions relevant to your interests in the committee today which I shall simply mention here. They are, first, the prospects for practical benefit and application of atmospheric science rival in importance atomic energy and medicine but are still at a very early stage—we are still at a very early stage of knowledge about their application.

The time is now at hand to plan the complex logistic and public protection matters demanded by imminent pilot modification operations in the natural environment, which we should now do.

Maximum benefit will demand a long-range realistically planned, large-scale and costly national effort involving enhanced applied research and development guided by heightened basic research effort.

The shortage of adequately trained scientists and engineers requires a deliberate attack by the universities.

And fifth, to push applications alone in the light of the primitive state of basic knowledge today, will guarantee in advance that we will not attain all or even most of the possible benefits. However, closer cooperation of an applications-oriented nature is required of the universities, government laboratories, and private corporations.

The job is so big that it demands the resources of all who are capable and interested.

Secretary Udall recently spoke of tapping the rivers of the sky for water. Ten years ago this would have been Buck Rogers' talk. Today it is a statement of firm purpose and not a present possibility. But as you run your finger along the cutting edge of research today you realize that we can almost surely, even now, tap this river of the sky, albeit to a relatively small degree and only under special circumstances, and we can do it only very clumsily, inefficiently, with yet unreliable results, unpredictable and with sometimes ambiguous results.

Moreover, we can increase the water resources of even the most favorable regions only by amounts estimated from a few percent to around perhaps 15 percent. This clearly is of great importance but it will still not solve the major water resource problems of this Nation and of the world either now or in the coming decades.

We can, I am confident, do very much more than this, and we must.

Weather modification involves far more challenging total prospects than just cloud modification to increase precipitation. We must not overlook the possibilities that large-scale features of the atmosphere—the paths of jet streams, hurricanes, the location of squall lines—may ultimately prove subject to man's deliberate influence. If this sounds fanciful, many of us, myself included, feel that it is an objective more likely to be achieved than the goal, for example, of increasing by 50 percent the water yield of the Upper Colorado River Basin through cloud modification.

Moreover, to weather modification let me add the word "demodification." The dramatic rise of air pollution over the past 20 years has made it clear that the atmospheric sciences must be applied to conserving as well as developing this precious resource. Modern cities have experimentally established that it is all too easy to alter the atmosphere significantly by excessive sewerage and gaseous and dusty and smoky wastes.

Over and beyond the adverse medical, economic, and esthetic effects of these things, these wastes may be having climatic or other large-scale weather influences as yet undetected, though perhaps major. We cannot say for sure, because of the still primitive state of atmospheric science.

The atmosphere is a totally essential resource of mankind. As I said, it begins at our feet and stretches continuously to the farthest star. We live in it, breathe it, are protected from natural space radiations and meteors by it. It is the only major source for the manufacture of fresh water for the Earth. An average drop of water distills from the ocean and rides aloft in the winds an average of 10 to 15 days before falling to the Earth as lifegiving moisture.

Without the atmosphere our planet would be as barren as the hostile and lifeless surface of the Moon, as improbable abode of intelligent life as the poisonous vapor of Saturn or Jupiter. The problem we face is to conquer the mysteries of our atmosphere, and through knowledge to bring about the mastery of the atmosphere for the benefit of all mankind.

My main purpose in being here today is to urge the development of a comprehensive national program, without which money and energy will not bring results—adequate results. The program should be premised by our realizing several things:

(1) The field experiments and pilot operations required will be large, complex, and will require rigid controls and safeguards of public interest and thus careful planning and management.

(2) A long-term, stably and effectively funded program of fundamental atmospheric research is essential and in large part it will be impossible to distinguish whether this research is more relevant to weather modification or to weather forecasting. These things are closely and essentially intertwined.

(3) We need to bring more of the best young people interested in science into this particular field of science.

Let me turn for a minute to the planning and management questions. We must do a far better job of overall planning and management and of evaluating the logistic requirements of atmospheric modification research and operations.

In its report the National Academy of Sciences Panel states flatly that the present fragmentation of effort in weather modification research and development has led to a situation where many of the fragments are below critical size or quality needed for effective work.

It further states that the present situation doesn't provide proper mechanisms either for setting priorities among large, costly projects, or for planning and managing their scientific and logistic complexities once a project is chosen. We cannot progress adequately until this situation is righted.

The need for more effective management and planning becomes clearer if we discuss some specific cases. There are three kinds of weather modification which, in my opinion, have the brightest prospects for the next few years. In each of these the logistics are difficult and expensive. In each of them, developments in engineering and in scientific research will have to be closely coupled because, as engineering advances are made, the need for specific pieces of basic knowledge will achieve critical significance. And progress in each of them will carry with it a whole series of political, economic, and legal questions.

Take, for example, orographic precipitation. This is the precipitation occurring in regions where a mountain barrier uplifts and thus cools the air that is flowing across it. It now appears certain that in some mountainous regions winter snowpack can be increased by at least a few percent by seeding of all appropriate winter storms with silver iodide. But having said this, we have said a good deal of all we know about it today. We know that it happens, we have some theories to explain why. But there are enormous holes in our knowledge.

Without a doubt we are thus still in the model T era of cloud seeding. We do not yet understand the life cycles of mountain clouds well enough to know the best time or place to insert the silver iodide. We are not yet sure of where to place our generators so that the silver iodide will get to the right part of the cloud, assuming we knew where that was. We do not yet know adequately the abundance of natural seeding nuclei in given cloud systems. The design of seeding generators is still rudimentary and empirical. Engineering and research wisdom must be put to this problem. And so on and so on.

At each step of the way it is important to conduct extensive experiments, studies, and tests to see what results fit our theories about these storms and what show our knowledge inadequate or wrong. This takes planning and coordination.

I would like to talk about hail supression, but time is short, and you will find my remarks in my written testimony. Suffice it to say that NCAR is playing the role cooperatively with the South Dakota School of Mining and Technology in bringing university, governmental, and private cooperation toward management and execution, a first step toward a sound national program of hail suppression.

Air pollution I would likewise like to talk about but I will only mention, although it involves grave national interest and is a mounting concern to our whole economy.

Let me look briefly at what the future may bring in basic research and in related applications and weather modification.

First, we visualize three major steps forward in research capability that come from new technological capabilities that we can foresee. One, the data on world weather; the world is now 90 percent unobserved weatherwise. Achievement of a worldwide capability can come from the balloon, buoy, and satellite program of the World Weather Watch now being effectively pursued by ESSA and many other cooperating groups.

Secondly, we need a computer 100 times, at an estimate, the capabilities of existing computers today. And this seems to be on the horizon of realization.

Thirdly, the ability to program all that we know of data and scientific theory into a computer of this caliber for simulation of weather. This also seems to be on the horizon of capability.

What could be done with this kind of three-fold capability? It is a staggering prospect, even if we look only at weather and climate modification potentials.

The late Harry Wexler of the Weather Bureau, for example, suggested that if lampblack were spread on the polar ice cap, it might change the radiative balance in polar regions and thus warm the surface, increase the melting of ice, and through this influence the climatic patterns of the entire Northern Hemisphere significantly.

Another scheme proposed several years ago by a Soviet scientist was to build a dam across the Bering Strait between Alaska and Siberia in order to regulate the cold Arctic waters, their flow into the warm North Pacific, and ultimately increase wheat producing lands in Kamchatka Peninsula and also in Canada.

A more modest idea, of which I was the author some years ago, speculated about the possibility of creating layers of artificial cirrus clouds, not unlike those that form on jet airplane contrails—and by the way, there hangs another interesting story about these jet airplane contrails which I would like to have time to tell you about.

I speculated that cirrus clouds if they could be produced artificially and spread over the Gulf of Alaska, might act as atmospheric blankets at a critical altitude and thus pump heat into the wind systems and upset their stability. The effect might be to deepen winter storms and divert them farther south. A storm that would otherwise travel eastwardly along the Canadian border might, in my speculative notion, be influenced to dip deeper into the central plains and bring moisture to winter crops.

But there are troubles with all such ideas. First of all, they are highly speculative. Most of them are almost ridiculously costly. A dam across the Bering Strait might cost $50 billion, and we cannot at present foretell whether it will bring any benefits at all.

Perhaps even more important, we cannot at present even determine that such ideas, if tried out in reality, would not backfire, producing harmful effects, perhaps even irreversible harmful effects, not only in their immediate regions but all the way around the globe.

In short, to try such schemes in nature on the basis of the partial knowledge that exists today would entail serious risk that we cannot and must not take.

Given the data, the computer, and the computer science programs that I mentioned above, I believe that we will, within 10 years, be able to test in the computer global-scale weather modification schemes like this cheaply, rapidly, and without danger to life or property. Moreover, the same machine, the same data, and the same programing will provide new dimensions of weather forecasting research and development, perhaps of comparable or even greater practical potential. This is an awesome challenge. The coordination and management involved are correspondingly great.

My written testimony speaks at some length about the necessary role of the universities in this, particularly in respect to their relations to mission-oriented Federal agencies. I point out that a large part of

the country's atmospheric research talent is in NCAR and the universities, and in my view should stay there. But it must not stay there in ivory-tower isolation.

NCAR is and must even more become a key element, I feel, in bridging between the universities and the needs of users, particularly in the domain of public interest.

There are many examples of NCAR's present functions in this regard. NCAR is right now, to be specific, working with a group of university scientists and with NASA and ESSA in planning for the launching of a synchronous satellite for tropical meteorology research. Remember, hurricanes, for example, are tropical storms.

I could give other examples such as NCAR's role with the Bureau of Reclamation or with Colorado State University at NCAR's Climax site, both of these in cloud modification research. Instead I will turn to the closing statement of my written testimony and quote from it on page 20.

In closing, I should like to return once more to discussing where we are today in pursuit of atmospheric modification. Our knowledge is rudimentary. We are far enough along, however, to know how we should behave in order to realize some practical benefits, and we should move as quickly as possible to do so.

The knowledge required for major benefits to mankind, however, is not yet within our grasp. This can be attained only through a national program in the atmospheric sciences that is strong in both basic and applied research, more effectively organized than it is now, and it should be linked more directly to national goals than our atmospheric research effort is today. The ultimate payoff will, I am convinced, be hundreds of times what is now within reach.

At this stage of the game, the line between basic and applied research in atmospheric modification is nearly impossible to draw. Indeed, it will always be difficult to distinguish unambiguously between basic and applied research in the environmental sciences.

It is, in my opinion, logical to assign major responsibility for the Federal Government's program in applied research and development in weather modification to a single agency. And the concept of weather modification encompassed must be as broad as the one I have used throughout my testimony.

But I am not sure that the time will ever come to erect a solid wall of demarcation between the sponsorship of applied research on the one hand and of basic research on the other. Even the scientist himself often doesn't know when he crosses the line. To try to draw it administratively, under the circumstances, will confuse rather than clarify the situation, will hinder rather than promote effective use of new knowledge, and will do nothing to enhance the quality of the basic research carried on at the universities or in NCAR.

Consequently, it is my firm conviction that the Congress should not withdraw the National Science Foundation's authorization to sponsor applied research in atmospheric modification. NSF's role should extend, in this field, to the point of demonstrations of the principles of application, though not to actual operational uses of new techniques or methods.

It would be, in my view, unwise to inhibit scientific groups under NSF sponsorship—and that includes NCAR—from proceeding from

discovery all the way to demonstration of the principles of the discovery's relevance to application. After all, demonstration of relevance in solving practical problems is what the practical world wants and needs from science. It is essential to take all reasonable measures to stimulate just such coupling of research to man's needs.

Thank you.

Senator CANNON. Thank you, Dr. Roberts.

We will next hear from Dr. Kassander.

## STATEMENT OF DR. A. RICHARD KASSANDER, PROFESSOR OF METEOROLOGY, DIRECTOR OF THE INSTITUTE OF ATMOSPHERIC SCIENCES, UNIVERSITY OF ARIZONA; CHAIRMAN OF THE BOARD OF TRUSTEES, UNIVERSITY CORPORATION FOR ATMOSPHERIC RESEARCH

Dr. KASSANDER. Thank you, Mr. Chairman. It is a privilege for me to appear before you as chairman of the board of trustees of the University Corporation for Atmospheric Research. Although it is not possible for anyone to speak for the University community, I welcome the opportunity to speak on its behalf with reference to an enlarged program in atmospheric modification.

Frequent reference has been made to the two recently-released documents relating to climate and weather modification: the National Academy of Sciences—National Research Council two-volume report and that of the National Science Foundation's Special Commission on Weather Modification. In many ways, these are tremendously exciting reports, and are certainly our most definitive and complete documents when considered in the light of a total program in atmospheric modification, as opposed to an important but rather restricted program in cloud seeding.

The commission report discussed the apparent disparity between congressional interest in weather modification and National Science Foundation policy. It has been stated that the academic community has failed to respond to the tremendous challenge of atmospheric modification with its promise of great public benefit. I personally do not subscribe to this reservation and believe there are some measures of activity that support evidence of as healthy a responsiveness as could have been expected in the light of the total obligation of the universities.

In assembling data from various reports, the Academy publication indicates that Federal support of university meteorological research in fiscal year 1965, for example, was about $20 million. In the same year, $4.97 million was in direct support of weather modification, with $1.6 million used in support of academic research. Thus, for reasons of financial pressure alone, only 8 percent of the academic community's resources could have been marshalled in support of weather modification. I believe at least that much was marshalled.

One could then ask what the Government received for this expenditure to the academic community. This is hard to assess, but one measure might be to ask what fraction of the total information cited in the Academy report was generated by academic research. There are 243 literature citations, of which I estimated 96, or approximately

40 percent, are references to work conducted by the academic community. One obviously does not want to push this kind of evaluation too far, but a first impression would be that the academic community has been an active and productive partner in the Nation's search for control of its environment.

The universities have responded to the charge of weather modification research. For example, in 1957 there were only 12 to 15 universities where weather modification research could be carried on under competent scientific direction. Today the number of universities has increased to 40 and 50.

In addition, although it is possible to contribute to scientific and engineering discovery without formal training, significant instances are extremely rare. The academic community has the exclusive responsibility for preparing the minds and imaginations of the people who will bring us the important discoveries to advance the technology.

In view of the above observations, I would like to comment specifically on the relationship of the academic community to the National Science Foundation. The Academy report does offer a hope that, with very carefully devised engineering-oriented tests, more progress could be made in weather modification. The report also points out the very many areas wherein our basic knowledge is deficient on details that are needed for careful planning and analysis for larger programs.

Although the universities can conduct and have conducted modest cloud-seeding programs, larger programs depending on sophisticated and complex logistics, including large amounts of heavy aircraft time, should be able to be more efficiently and effectively conducted by the Federal Government assisted by commercial contractors. However, the parallel study of the "gaps" in our knowledge is a role in which the academic community makes a great contribution; such study is indispensable to good progress of the larger programs.

The enlargement in size of a study does not, by itself, eliminate deficiencies in details of knowledge but more often encompasses more deficiencies to confuse the picture. The partnership between Federal Government and the academic community, as exemplified by the relationship with the National Science Foundation, has been an extremely fruitful and healthy arrangement with even greater potential for the future.

In this latter regard, we should also observe that both reports put heavy emphasis on the alternatives and opportunities of atmospheric modification by, for example, changing the energy transfer processes at the ground or by modification of the agricultural microclimate, and both offer new speculations for ameliorating arid climates. The attainment of a measure of weather control has implicit in it a strong interdependency of food and power production with water production. To consider any of these without due regard for the others is to be delinquent in our concern for the total health and welfare of our society.

There is already some evidence that we can modify or control aspects of our environment that may have much greater impact than will weather control, as we use this term today. Not only must we have the full impact of the physical scientist, but there is clearly an important role for the biological and social scientist. Since it is almost certain that the final realizations of our dream to control our environment can

not even be imagined in our generation, we must maintain the opportunity for one group of scientists to give full rein to the imagination while another group studies and implements ideas that we have today. The National Science Foundation is ideally organized for effective mobilization of the entire scentific community to maintain the flow of new basic information so badly needed for effective applications today and also to nurture the new, but perhaps seemingly impractical, ideas that will form the basis of our technology tomorrow. It is hard to imagine that our country cannot afford both avenues to the great goals set up by the bill under consideration by this committee.

I strongly endorse the principle of the bill to authorize the Secretary of Commerce to carry out a program in weather and climate control research, development, and experimentation. I do not believe it is in the best interest of the public to restrict by law the activities of another agency with the competence to contribute to this enormous task. We cannot know now all the possible areas of science and technology which will contribute to our mastery of our environment, and any limitation of our ability to draw on the total manpower of our Nation can only delay achieving our goals. There are more than enough problems with more than enough work for many decades for the several Government agencies with interest and competence to do this important work. I believe, as resources become available, the contributions of the academic community, which have been great in the past, will be even greater and more significant in the years to come.

Thank you very much.

Senator CANNON. Thank you, Dr. Kassander.

Dr. Haworth, do the other gentlemen intend to testify?

Dr. HAWORTH. No.

Senator CANNON. They will be available in the discussion, as I understand it.

I think it would be well, at this time, for me to note for the record that it is not the intent of the committee, through these hearings, to affect weather modification activities presently underway or the appropriation needed to carry these programs forward. To stop any of these programs would be a great waste in money and effort and it would be a mistake, in my view, for Congress to hold up appropriations for presently authorized programs, because of these hearings. In other words, what we are trying to do is to go into the future picture of what we might do in the way of planning and where we go from here with this legislation if it is approved.

The 1957 report of the Advisory Committee on Weather Control said that seeding of winter-type storm clouds in mountainous areas produced an increase of 10 to 15 percent, and in 1966 the National Academy of Sciences reported precipitation increases of 10 percent.

Does this mean that no further progress can be made with this type of seeding? Would you care to comment on that? In other words, is this about the limit of where we can go with this type of activity?

Dr. HAWORTH. I will answer that in only a very general way and perhaps Dr. Roberts will add some detail.

I don't feel that we have in any sense reached the limit, although there certainly are limits. As was said by Dr. Roberts and as has been said many times, there is still a great deal that we don't know about.

how to do this sort of thing most effectively and under what circumstances, what time, what place, how we can best get seeding into the clouds, etc. We don't even know what is the best particle size or what is the best way to make it.

So there is room for progress.

Senator CANNON. Have we made any progress in this area in the past few years?

Dr. HAWORTH. We certainly have. But it is difficult to determine how much we have made. We certainly are surer of what we are able to do now than we were in 1957. And here I think it might be worth pointing out that one of the very great difficulties—and this is one of the reasons why statistical questions come up so much—is that the effects that people have been able to produce so far are relatively small compared to the naturally occurring differences. Clouds that seem to be just the same will give a lot more rain on one occasion than another, for reasons that we don't thoroughly understand.

It is not as extreme as looking for a needle in a haystack, but it is trying to find a not very large effect under circumstances where natural causes may have brought about changes much bigger than the seeding can now be expected to do.

There are, of course, cases where apparently there have been very large effects, and other occasions where there seems to be very little. Dr. Roberts might want to add to that.

Dr. ROBERTS. I think you have covered the point quite adequately, Dr. Haworth. I think it is going to require somewhat of a new approach, perhaps even a quite different approach to weather modification if we are to visualize very large increases, increases comparable with the naturally occurring increases which are sometimes by factors of two in certain locations.

It may be that if we are ever to achieve results of this sort we will have to go about weather modification by completely different kinds of techniques, such as the effort to modify the general circulation of the atmosphere that brings the moisture and the temperature variations into the region.

Dr. Kassander is quite an expert on these questions. I think perhaps he would want to comment.

Dr. KASSANDER. I don't consider myself sufficiently expert to add very much. I think the most important problem—it appears on the surface that we have not made very much progress. This has been stated by the Australian group, for example, that there is some evidence showing very large increases and there is equal evidence in the same experiment showing decreased precipitation, such that in the average the difference is rather small.

The thing we have to do now is to try to determine the cloud situations where, in advance, we could have predicted which efforts would have made the larger increase and which situations might actually produce a decrease. Under those circumstances we might anticipate that the net result on the days that we attempted to augment precipitation would have been much, much more satisfactory.

Senator CANNON. Of course, the thing that disturbs me, and the point that I am trying to make, is that we were talking in 1957 of a 10- to 15-percent increase. Supposedly we have made or should have

made some progress in this period of time, and yet we are still talking about generally, in terms of a 10-percent increase.

I am curious to know whether you think there is a good chance for progress beyond this point.

Dr. ROBERTS. Certainly there is good prospect for progress beyond that point. I think the real difference that has occurred between 1957 and now is that when the Advisory Committee on Weather Control estimated that a 10-percent increase might be produced, the evidence on which this estimate was made was not universally or even perhaps very widely agreed upon. In the intervening time we have convinced ourselves that there is indeed good scientific evidence that such an increase can be achieved.

Given that, the efforts of a much larger group of people are likely to be involved in developing adequate theories of why precipitation increases can be achieved.

If by trial and error, so to speak, you have discovered the possibility of producing a 10-percent increase, it seems likely, by sophisticated application of scientific and engineering techniques, you will be farther than the first empirical trials. Beyond that, it is difficult to say anything authoritative.

Senator CANNON. In that connection, Dr. Haworth indicated that there would be a corresponding decrease in the downwind areas. And I think Dr. Chamberlain indicated that there was disagreement as to whether there would be less in the downwind areas.

Dr. HAWORTH. I think I said, Mr. Chairman, that this was very uncertain, that in certain circumstances certain observers seemed to have found that effect. But this is considerably less certain than the general positive effect in the target area.

Senator CANNON. Mr. Orville, Chairman of the 1957 Advisory Committee, said there was an extreme shortage of competent scientists and engineers in the field of weather modification, and we have had testimony on that effect today.

Has the situation improved in this area since 1957, or is it still about the same?

Dr. HAWORTH. Yes, it has improved markedly in two respects. One is that there are now many more formal programs of training graduate students in meteorology and atmospheric sciences in general than there were in 1957. For example, in 1956 there were essentially no Ph. D.'s granted in this field. Even in 1959 there were I believe something like 15 or 16 Ph. D.'s that were labelled Ph. D.'s in meteorology. In 1965 there were 50.

So this is growing rapidly.

A second and perhaps equally important factor, is that, especially in understanding the basic phenomena that have been talked about so much here, there is a great deal of room for scientists who had their original training in what I call the fundamental sciences, physics, chemistry, and so forth. Scientists who, as physicists or as chemists, attacked the problems of the atmospheric sciences, and who move on to become atmospheric scientists, if you will. That is increasing very rapidly and is probably equally important in increasing the manpower pool.

Senator CANNON. Are there other stimuli that could be brought into effect that would further improve the situation, or is that going to depend on the level of funding?

Dr. HAWORTH. Of course, it will depend in part on the funding. But in my opinion the most important thing is the psychological effect, that these problems, these areas, are becoming prominent and more youngsters realize that they are interesting and very important in science in general and to society.

In other words, it is going to be easier, if you can use the word, to "recruit", to have people be stimulated to go into these fields. I think that is one of the important things.

This is a much more modest sort of thing at the present, just as you are completely aware, the great interest in space, for example, stimulated many people to go into sciences related to the space effort.

Senator CANNON. The National Academy of Sciences report states "The question of acceptable statistical design and evaluation of atmospheric experiments must be resolved."

What prevents the formulation of adequate statistical designs for experiments and tests now?

Dr. ROBERTS. There have been quite a few questions as to what optimum statistical designs should be, and as you will remember, following the 1957 Orville report, there were considerable criticisms of the statistical methods used there.

Scientists have not been of a single mind as to what the optimum procedures are. I think even today there are doubts in many areas as to the degree of randomization versus the degree of pilot or test operation aimed primarily at increasing water resources.

I think that it will only be through the establishment of a broad national program with adequate management and coordinated guidance on the development of statistical designs that this will come about.

I think the framework to do this is here today. It was not in 1957.

Senator CANNON. Many of the experiments are said to be below a critical size or quality needed for effective work, according to the report. I would like to ask if you agree with that, and if so, why, after 15 or 20 years of experiments, hasn't some action been taken to correct that situation.

Dr. HAWORTH. There is no question but what in the past many experiments have been below critical size. Not only experiments but groups of people have been below critical size. This is one of the problems of organization. It is a field that in many of its aspects is not as susceptible to attack by one scientist and some graduate students and assistants as many other fields.

In the laboratory sense it is but in the field sense it is not. There must be, on the part of both the Federal organizations that support the work and the organizations that carry out the work, greater attention paid to the joining together of forces and of groups and so forth, and of the enlargement of groups, so that there won't be too much fractionated effort in the future.

The situation is certainly much better than it was.

Senator CANNON. The NAS report indicates that the conclusions about silver iodide are still tentative. Why is that after such a long period of testing?

Dr. KASSANDER. I think there is no question but that silver iodide is an effective nucleus in the seeding of freezing clouds. There is ques-

tion—and we still have to do much more work on this—as to the relative role that the freezing process plays in our rainfall process. There is also the question as to how one best releases the silver iodide, whether from the ground or from the air, in order to get into the clouds.

I can only say in this regard, of course, the atmosphere, as those of us who travel in airplanes know, is best described as a miserable boiling place of great turbulence and motion. It is an extremely difficult place to make measurements.

In addition, as is well known, if the rain gage on the ground has moved 10 feet, one is likely to get rather a different answer. And the main problem, which involves statistics, has simply been a matter of trying to get all the little additional pieces of information to try to put a very complex jigsaw puzzle together.

Ten years has been expended on getting these bits and pieces. We have gotton lots of them. There are still some bad holes.

However, the number of people involved, and the number of institutions involved, have increased by approximately a factor of three. The competent scientists have reproduced themselves in more students. The high school programs now include units of meteorological studies so that more students are being attracted to the field.

I think we are now on the threshold where we can hope to muster the kind of manpower needed to thoroughly study these extremely complex and messy situations in the atmosphere. We have the kinds of airplane platforms and other observing tools we need, so that there is great hope that we can make some significant advances even though the last 10 years have essentially been years of equipping our arsenal.

So that perhaps now we feel we can really go to battle.

Senator CANNON. Do you think a high enough priority has been given to the design and execution of effective tests in this particular area?

Dr. KASSANDER. No, sir. I think the crude kind of statistics I offered on university buildup were modest because of the pressure of other needs on the atmospheric sciences and the obligations in other areas. For financial reasons alone, the academic community could marshall only 8 percent. I think for that 8 percent we have made real great progress.

Senator CANNON. The report states, and the hearing here today has brought out, that one question deserving a great deal of attention is the degree to which climate already has been altered or may be altered in the future inadvertently.

What type of funding is NSF doing in this area now for research?

Dr. HAWORTH. There is some general support, but directed more at the total problems of the atmosphere. I think I would be stretching it to say that we have had any concerted program along this line. But we have tried to study, tried to support people who wanted to study, and this is one of the problems. There have not been a great many people who desired to study this sort of thing, the facts of inadvertent changes.

We keep referring to inadvertent changes such as air pollution, and we keep thinking of smoke and such in that connection. There are many other things. We don't know, for example, what effect has there been on the weather and climate by virtue of the fact that the forests

were cut down, and that we have arable land, cultivated land, where there once was prairie grass, and many things of that sort.

Another thing that is in a strict sense a pollutant but not usually thought of as such is the carbon dioxide that comes from all our burning of fossil fuels—coal, oil, gas, and so forth—which is adding to the carbon dioxide content of the air. It is not a pollutant in the sense of doing any harm to us directly, but it could change the temperature balance of the world.

These all need much more attention than they have had, and there needs probably to be more aggressive programs on the part of the Federal Government, NSF, for example, in trying to encourage people to study these problems.

Senator CANNON. Would your answer generally be the same insofar as the economic and social impact of modification is concerned?

Dr. HAWORTH. Yes. There have been some studies, but they have been part of our general programs in the social sciences rather than part of the concerted weather modification program. So the same general answer stands.

Senator CANNON. The NSF report recommends a national laboratory. What do you mean by that recommendation, in view of the fact that the NCAR is in existence?

Dr. HAWORTH. Dr. Chamberlain?

Dr. CHAMBERLAIN. I can speak to this, Mr. Chairman. The Commission document does not actually recommend the creation of a national laboratory. What it does is recommend that the capability of such, what we normally think of as a national laboratory, come into existence.

Specifically the need of logistics capability, of many aircraft for some of these experiments, large computers, and the manpower resources associated with it, need to be made available. But whether it should be made available by the creation of a national laboratory or made available through administrative use of contracts for such service from private industry or otherwise, is a moot question.

Our recommendation ended up suggesting that the President's Science Adviser mount a feasibility study on the best mechanism by which to provide this capability to the scientific community.

Senator CANNON. You don't necessarily recommend then that a separate laboratory be established? Are you recommending a study at the present time?

Dr. CHAMBERLAIN. We are not recommending that a specific laboratory be created. But we are very concerned that the capability that we normally think of a laboratory providing, certainly does need to be made available to the scientific community. And we suggest that a feasibility study not only of the organizational approach to it but also of what its specific capability ought to be, should be undertaken.

Dr. HAWORTH. Mr. Chairman, if I could add one thing to that. You spoke of NCAR. I do not believe that NCAR would be an appropriate laboratory to do the sort of thing—at least in the extreme—that Dr. Chamberlain has talked about.

The purpose of NCAR is to do the underlying research—and I won't use either the words "basic" or "applied"—but the research that

underlies our knowledge of the atmosphere, not only for weather modification but for all aspects, and is very properly a center of activity for the university groups that are interested in studying the atmosphere.

This is done in two ways: One, many university people go and work at NCAR on problems that they could not work on at home, where there is a concentration of effort and so forth that makes their work more effective.

Two, it also provides facilities for university groups working under their normal auspices.

I believe that it would be a mistake to change the emphasis of NCAR and get it into the very large operational types of things that are in the offing with respect to attacking these weather modification problems.

Senator CANNON. The NSF report states the intention of Public Law 85–510 was that the Foundation would carry primary responsibility with the executive branch for weather modification. Subsequently the Federal Council for Weather and Technology took over the coordination role, and the Weather Bureau and the Bureau of Reclamation operate in the research field.

Do you consider that fragmentation of responsibility to be consistent with the intent of Public Law 85–510?

Dr. HAWORTH. I can't speak to precisely what the Congress had in mind in passing Public Law 85–510. But I do feel that what has happened is appropriate and in keeping with the statute.

The responsibility of the Foundation was to do everything it could to see that a program in weather modification moved forward. And I believe in all cases that it is appropriate for an agency that has a sort of a focal point or central role to encourage as much assistance, if you want to call it that, as it can from the other agencies. The other agencies had particular problems that they wanted to attack, and I believe this is entirely appropriate.

The Foundation does have specific responsibility for evaluating, reporting, trying to help coordinate, and some of the things that I mentioned in my testimony, such as the annual symposium, the Foundation's annual report to the Congress and so on, which have been parts of that.

Furthermore, the Foundation felt a responsibility for seeing to it that as much as feasible of the underlying research was done and, of course, it has supported a major fraction of that itself.

Senator CANNON. Would you say that we have a definable national program of weather modification now?

Dr. HAWORTH. It is becoming more and more focused. But, of course, as I have said, and practically everyone here has said, the first job was to learn as much as we could about the natural phenomena that underlie, to try to understand the processes and so forth, after which one could begin to focus down on specifics—focus with greater effort on the more specific things such as the program of the Bureau of Reclamation, and so on.

It is being pretty well coordinated through the efforts of the Interagency Committee on Atmospheric Sciences, which I believe to be a proper mechanism for coordination. I mean this type of committee. And, it is becoming more and more a coordinated program.

Senator CANNON. Do you think we are at a point now where we could actually define a national program of weather modification at this point in time?

Dr. HAWORTH. With pretty fuzzy edges; actually, I think it will inherently be—and as always in cases like this—not a single program, but a combination of programs that one can then perhaps define as a national program.

Senator CANNON. How big an activity do you see weather modification becoming, say, by 1970? We have used the time frame of 1970.

Dr. HAWORTH. I have no reason to disagree with the statements made in the two reports that if funds were available—and one must remember, of course, that there are many other things demanding support—that if funds could become available, then funds at the general levels spoken of by the two reports could be usefully used. It may seem a little strange to say that much when we speak simultaneously of not yet having really adequate supplies of manpower, but one of the important things is that the stage that has now been reached is going to call for much larger experiments, field experiments and things of that sort, that will demand large logistic support, so that the amount of funds expended will be much larger relatively compared to the number of key scientists involved.

As you move from the laboratory and the small field experiment to the very large-scale things, such as the large operations that the Bureau of Reclamation is planning, then the costs go up more than in proportion to the number of scientists.

Senator CANNON. The figure of $40 or $50 million was used here and in testimony earlier. Does that relate to the $20 million that you used in your statement for fiscal year 66, when you said——

Dr. HAWORTH. No. The former was meant to be support for weather modification activities or closely related things for the Federal Government as a whole; whereas my $20 million was the NSF alone, for all the atmospheric sciences.

They are quite different. I believe the Federal support of weather modification as such that has been identified as such, this current year, is a bit more than $7 million. There are some things that are not included in that figure.

For example, nobody knows exactly how much is being spent in logistic support by the military services. This is not always sharply definable. This is one of the reasons that, I believe, the Commission, for example, had to sort of give quite a range to its estimates.

Senator CANNON. That $40- or $50-million figure to be used by 1970, or recommended, say, is that based on a plan or is that based on just a guess-timate?

Dr. HAWORTH. I think I had better let Mr. Chamberlain answer.

Dr. CHAMBERLAIN. It is not worked out to the extent of a very fine building-block approach coming up to that total. However, it is based upon first of all the National Academy's recommendations in regard to the physical sciences, and then has added to it what the Commission discussed in crude terms of the necessary amounts of physical funding for the biological sciences, the law, and the social sciences that the Commission considered to be so important.

The largest blocks of money, however, look like they would go into the field experiments and physical sciences and some of the ecological studies, particularly the field ecological studies.

The simulation work again can be very expensive. But an overriding consideration in the Commission's analysis was that without substantial increases in funding over current levels, the type of field experiments that could be mounted would be inadequate to give us the conclusions which we are seeking; that it is mandatory that there be substantial increases in funds or the logistics necessary for well-designed, meaningful field experiments just plain won't work.

Senator CANNON. In other words, it would be impossible for you to furnish an outline or a plan of action for the amount of funds that you are talking about?

Dr. CHAMBERLAIN. Not down to the last $500,000 in each category. We could not give you that good an estimate. This is one of the basic reasons why the Commission did not attempt to extend its budget projections beyond 1970.

We felt that the progress in the intervening time, would be so substantial and so much better, in that period, would go into careful design of large experiments, that we could beyond 1970 make much better estimates based upon the work in the intervening period.

Senator CANNON. What kind of Federal administrative machinery do you see evolving in this area? You talked about different authority or different placing of responsibility. What do you actually have in mind?

Dr. HAWORTH. As I said in my testimony, I believe that the field has now reached the stage where there needs to be greatly added emphasis to moving on to the more specific applications, that is, with specific objectives in mind, to large-scale field experiments and so on. That the type of central responsibility that NSF has had, which was appropriate during the time when most of the work was of a more basic nature, should now be assigned to another agency—in my recommendation to ESSA. By this, I mean the general central responsibility, as we move on toward development and demonstration and things of that sort.

I believe that NSF should continue very actively and in increasing magnitude to support the underlying research. I don't mean, in any sense, to say that the central agency shouldn't also do underlying research as it finds it appropriate, but I don't believe there should be any change in the point of view that the agencies with specific missions to perform, which also do work in the field——

Senator CANNON. NSF should retain the authority they have now?

Dr. HAWORTH. Yes. And they too should, as their opportunities and needs increase, increase their efforts.

One of the largest-scale examples now is, of course, the Department of the Interior. I believe that they should work intensively in the field. They are responsible for natural resources, and water is a resource. I believe that they should continue to work. And again there should be no bar to their doing research, clear through development and, of course, eventually operations. By operations I mean trying actually to get water for use next year and so on. And the same thing applies to the other agencies.

But I think of being responsible for the general aspects, for the evaluation of the whole field, and so on, should now be assigned to ESSA.

Senator CANNON. Do you think it would be better to administer and regulate weather modification programs through an independent office rather than through an already existing office in the executive department?

Dr. HAWORTH. I believe that—and I will distinguish between the two things—the actual work, the substantive work and so forth, should, I am sure, be in ESSA. It has responsibility of course, general responsibility, for the other aspect, the weather prediction and so forth. These two things have very close relationships, as has been pointed out several times this morning. So I think that belongs there.

I think the regulation should be divorced from any agency, or perhaps I should say subagency, that has any R. & D. or any operational responsibility. But I see no reason why it should not be in the same department—for example, as in the Atomic Energy Commission where that organization is divided into two parts; one is the research and development and promotion of atomic energy, and the other is the regulation. That to my mind is working out very well. It helps. It is, of course, useful for the regulatory agency to have a close enough relationship with the technical agency to be familiar with what is going on.

Senator CANNON. In your statement you referred to the fact that effective January 1, 1966, NSF increased its recordkeeping requirements and imposed on all operators a requirement for advance notice, to it, of any activity. Have you had any filings up to the present time?

Dr. HAWORTH. Dr. Droessler, would you answer that?

Dr. DROESSLER. Yes, we have, and the letters are continuing to come in in a rather steady stream. There are considerable filings already on record.

Senator CANNON. Do you have an estimate as to roughly how many?

Dr. DROESSLER. I would say we have had on the order of 2 dozen or more.

Senator CANNON. Have you found that the information made available to you by the filings is something that is going to be of assistance in the research and development effort?

Dr. DROESSLER. Yes, it undoubtedly will be of assistance because for the first time we will be able to appreciate what plans are being made for new activities in weather modification and also keep abreast of the field activity as it goes forward.

Senator CANNON. How did you keep current with the field activity prior to this requirement? Just by accident?

Dr. DROESSLER. We didn't make an attempt to keep up to date, up to the minute, on the field activities that were ongoing, except those large field activities which were well known to us, because of our general overview.

However, every year we did make an assessment of what had gone on during the past year. In that way we developed a detailed knowledge of the total extent of the activity in the United States.

Senator CANNON. In your statement, Dr. Chamberlain, at page 10, you said, in the second paragraph:

> These figures were derived by estimating the program needs which should be increased in the fiscal year 1966 level of $7.2 million of agency budgets.

That is in relation to your $40 or $50 million a year by 1970. Would that include money for the social and biological studies that were referred to as being necessary in the future?

Dr. CHAMBERLAIN. The $7.2 million does not include any biological and social type of research. However, the $40 to $50 million increase does include such activities because there is no significant activity of that nature currently financed by the Federal Government as we understand it. We do feel that this is one of the basic needs, that is, the support of the social sciences, biology and law. Further, that the NSF should continue to support this research activity, for this is the best mechanism currently within the Federal establishment for communication with individual people throughout the academic world, whether they be social scientists, lawyers, and so on, to initiate individual work that would be of importance to the field.

However, the NSF is not an appropriate mechanism for the mounting of major field experiments which perhaps should be under our other management, that is, that some agency, either existing or new, should be given a major mission of weather modification.

Senator CANNON. Senator Dominick?

Senator DOMINICK. Mr. Chairman, I want to say that I am very sorry, and I apologize to Dr. Chamberlain and Dr. Roberts and the others for not having been here for their full testimony. I look forward to reading it in detail.

I have only one question, which is a pretty fundamental one. Do you feel that knowledge of this phenomenon of weather modification has now gone far enough that applied experiments could be made, for example, in two fields—hail suppression and increased precipitation?

Dr. CHAMBERLAIN. Taking the second part first, the matter of hail suppression, as I understand from our Commission reviews, the matter of hail suppression, there is an unresolved question on the efficacy of cloud seeding for the suppression of hail. Further research would be needed before you could expect this to be really operational. In regard to precipitation augmentation, under some circumstances, the evidence appears to be on the positive side. Increases are of the order of 10 percent for quite a wide distribution of cloud circumstances. But again, further work is necessary before you can consider it operational to the extent that cold fog dispersal can be considered operational. There are still many, many unresolved questions.

Senator DOMINICK. The reason I bring this up, being a practical soul and a nonscientist, as you well know, is that we have continued problems in Congress with the Colorado River Basin as to which State is going to to get what water out of it, and how we are going to get more water into it. One of the major programs that has been suggested from time to time is the importation of water from the other areas.

It occurs to me that, in the process of the weather modification research that is going on, instead of emphasizing the need for canals, dams, and tunnels with the obvious evaporation that you will get, that we might try some applied experiment to try to get more water out of the Colorado River Basin by weather modification, either through additional snow or through additional rain. I would like your estimate of whether it would be feasible to even start a program of this size which would be meaningful.

Dr. CHAMBERLAIN. Carefully designed, adequately instrumented, including the ecological support, such projects could be meaningful and presumably not be detrimental.

Senator DOMINICK. This I presume would have to be pretty carefully coordinated with research on the results and techniques; is that correct?

Dr. CHAMBERLAIN. That is right.

Senator DOMINICK. Would you suggest that there be an overall coordinator of any kind of effort like that. If so, what organization?

Dr. CHAMBERLAIN. The recommendation of the Commission is that the Office of Science and Technology establish a special mechanism for coordination of weather modification activities, including policy as well as allocation of funds among several agencies of the Federal Government.

Senator DOMINICK. One thing that I am concerned about, and I am sure that the chairman in many ways shares the same concern, is an effort not to get into an interdepartmental fight as to who is going to do what to whom. Apparently it is a fundamental psychosis of government that this almost inevitably happens when you are trying something new.

We have an organization now, NCAR, which is coordinating efforts in research in many ways, and Dr. Roberts is here representing NCAR. Some time before we suggested that perhaps NCAR, not being a governmental agency as such, might be in a position to do a lot of the basic ground work on this. Do you have any comment on that?

Dr. CHAMBERLAIN. The Commission did not consider that NCAR had a sufficient authority from which to operate effectively to do this coordination.

Senator DOMINICK. And what commission are you talking about?

Dr. CHAMBERLAIN. This was the NSF special committee on weather modification. However, with the filing of the commission's documents we have been afforded the unusual opportunity as a committee of being allowed to be disbanded.

Senator DOMINICK. As you probably know, the Department of Interior has been moving rather rapidly into a position where they would like to get at least a large portion of control in this field. What is your position on that?

Dr. CHAMBERLAIN. Our position is that any agency of Federal Government, pursuant to the existing executive orders, as well as statutory authority for these agencies, should have the opportunity to pursue such weather and climate modification research as is necessary for the conduct of their particular mission, and that in addition some one Federal agency, either new or already in existence, should be given an overriding specific mission for pursuing technology development of this particular field. The commission did not take a position on which specific agency ought to, if you picked an existing one, have this overriding weather modification mission.

Senator DOMINICK. You mean that is something that we are going to have to wrestle with.

Thank you, Mr. Chairman.

Senator CANNON. The hearings will stand in recess until February 24, at room 1114 of this building. Dr. Haworth, I don't know whether

you have had the opportunity to examine the hearings that were conducted earlier, but we have a very graphic and visual demonstration of effects of cloud seeding under very ideal conditions that Dr. Mordy, who is here from the DRI, presented in connection with his testimony out there. You might want to see some of the photographs and some of that record. I will admit it was under ideal circumstances, but it made a very graphic display of what could be done.

Dr. HAWORTH. Thank you, Mr. Chairman.

Senator CANNON. Thank you very much.

The hearing will stand in recess.

(Whereupon, at 12:30 p.m., the committee was recessed, to reconvene on Thursday, February 24, 1966, in room 1114, New Senate Office Building, Washington, D.C.)

# WEATHER MODIFICATION

THURSDAY, FEBRUARY 24, 1966

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

The committee reconvened at 10:05 a.m., in room 1114, New Senate Office Building, Hon. Peter H. Dominick presiding.

Senator DOMINICK. The committee will come to order.

This is the fourth in the present series of hearings by the Committee on Commerce on weather modification. At the last hearing on Monday, the committee heard testimony from representatives of the National Science Foundation, including the director, Dr. Leland J. Haworth. That testimony was directed, in the main, to the Report of the NSF Special Commission on Weather Modification.

This morning we will hear from representatives of the National Academy of Sciences who will discuss, in part, the final report of the Panel on Weather and Climate Modification. In addition, a representative from the Department of Defense will testify on their extensive weather modification activities.

The Report of the Panel on Weather Modification of the National Academy of Sciences is one of the most significant new publications on the subject. It contains many recommendations. The background information shows the scientific successes and the scientific weaknesses of the present programs.

The successes are not so great that we can ignore the weaknesses. Valuable work is being performed by many groups. There is, however, a real need to bolster what is being done.

The report confirms the 1957 Advisory Committee on Weather Control conclusion "that precipitation increases of the order of 10 percent apparently can result from ground-based silver iodide seeding of winter orographic storms."

In this most publicized area of weather modification, it is a reflection on both the amount of governmental concern and the quality of the work that after the intervening 9 years of effort, one can only say again that increases "apparently" can result.

On Monday the committee heard over and over of the need for research on the biological, social, and economic implications of weather modification. It was with considerable dismay that we learned that next year's budget requests contain no money for this type of research. Weather modification and demodification are important matters. It is not in the national interest that the program should experience this type of neglect, or the haphazard research mentioned in the National Academy report.

Part of the problem, of course, lies in the complexity of the subject. Mark Twain may have been joking, but he made a valid point in his observation about New England weather. He said, "In the spring, I have counted 136 different kinds of weather inside of 24 hours."

The first witness today is Dr. Thomas Malone, chairman of the Committee on Atmospheric Sciences, National Academy of Sciences.

Dr. Malone, it is a pleasure to have you here. You may proceed.

## STATEMENT OF THOMAS F. MALONE, SECOND VICE PRESIDENT AND HEAD OF RESEARCH DEPARTMENT, THE TRAVELERS INSURANCE COS., HARTFORD, CONN.

Dr. MALONE. Thank you, Mr. Chairman. It is a great pleasure to appear before this committee to discuss with you the issues raised by the findings of the panel on weather and climate modification of the National Academy's Committee on Atmospheric Sciences, and to share with you both a vision and a nightmare of the future that, by turn, inspire and trouble the scientific community.

My particular delight in being with you this morning has its roots deep in the hope that the wisdom of Congress will be exercised with the right mixture of prudence and imagination so that our nightmare may be banished forever and the vision remain as a national goal worthy of our mightiest efforts.

The importance of the decisions now before Congress can be summed up succinctly in some thoughtful words set forth a few years ago by the Committee on Science in the promotion of human welfare established by the American Association for the Advancement of Science.

They said:

> For nearly two decades scientists have viewed with growing concern the troublesome events that have been evoked by the interaction between scientific progress and public affairs. With each increment of power, the problem of directing its use toward beneficial ends becomes more complex, the consequences of failure more disastrous and the time for decisions more brief.

They go on to say:

> The problem is not new either in the history of human affairs or of science. What is without past parallel is its urgency.

We in the atmospheric sciences have rather special responsibilities in this regard for three reasons.

Senator DOMINICK. I was interested in your quotation, and I will just break in to ask you a question.

You say:

> With each increment of power, the problem of directing its use toward beneficial ends becomes more complex.

What power are you talking about?

Dr. MALONE. Power over matter, power over energy, the kind of power we are talking about today, potential power over the environment.

Senator DOMINICK. Thank you.

Dr. MALONE. Our concern is for three reasons. The first is the immediate, vital, and profound part played by weather and climate in the lives and affairs of all men.

The second is the special international character of an atmosphere that is constantly in restless motion, crossing and recrossing national boundaries—an international resource, if you will, shared by all men.

The third is the obvious choice that lies before us to use mastery over this international resource to aggravate or to ameliorate conflict among nations.

It seems to me that the particular strength of our position in these early months of 1966—and if I may say so, Mr. Chairman, the challenge and the opportunity before Congress—rests in the fact that there is still time for deliberate thought and decision on the issues raised by the reports of the Academy Panel and the NSF Commission.

The Academy report itself will be summarized by Professor MacDonald, the Chairman of the Panel. I would propose to comment briefly on what I believe to be the principal issues of public policy raised by this report. I don't mean to be presumptious by identifying them, but they seem to me to warrant comment.

They are these:

(1) The need to transform our somewhat fragmented national effort in this field into a coherent national program;

(2) The character of that program;

(3) The size of that program;

(4) The rate of growth at which the national program is developed;

(5) The manner in which it is organized and managed; and

(6) The international implications.

In support of an affirmative conclusion on the first issue are these four points:

First, development of mathematical modeling of physical processes in the atmosphere, the availability of electronic computers, and prospects for more precise measurements—all of which have combined to thrust the problem of conscious and meaningful tinkering with the atmosphere across the threshold that separates speculation from rational and systematic exploration of possibilities and limitations.

Second, demonstration of operational capability in dissipating supercooled fog and the still incomplete, but very persuasive, evidence that rainfall can be influenced by seeding techniques.

Third, the prospects for significant economic benefits in land utilization and water management in a world which is confronted with growing problems of agricultural productivity.

And fourth, the compelling necessity of understanding and being able to anticipate the kinds of inadvertent modification of climate that may be set in motion within the next generation or so as the population expands into an environment with fixed limits.

With respect to the second issue, the character of the national program, quite apart from that portion of the effort which is concerned with national defense, it should possess the attributes of (1) diversity—in that big science should be balanced with little science, research in the physical sciences accompanied by research in engineering and the social and life sciences, and activity in the public sector complemented by activity in the private sector.

Senator DOMINICK. Doctor, I don't pretend to be a scientist, and I am sure you are well aware of that, but what do you mean by big science and little science?

Dr. MALONE. By big science, I mean the kind of expedition into the tropics which requires half a dozen airplanes, large-scale computers, great logistical support, extensive management of many people and large facilities.

By little science I mean the individual investigator carrying out work in his laboratory or at his desk with pencil and paper.

Senator DOMINICK. How big is big?

Dr. MALONE. That is a matter of interpretation. For our purposes, I would say a big project is one which has an annual budget of say a half million dollars or more per year.

A small size is of the order of tens of thousands of dollars a year.

Senator DOMINICK. Thank you.

Dr. MALONE. The second attribute is one of balance. By that I mean a balanced program which addresses itself to the problems of cloud physics, to hurricanes, tropical convection, hail, lightning, water budget, all conscious attempts at intervention, as well as the inadvertent modification caused by an increase of $CO_2$, air pollution, and rocket exhaust at high levels.

The third attribute is integrity, in that the unity of the four principal tasks of the meteorologist be preserved, that is the observation, understanding, prediction, and control of atmospheric phenomena.

Stability, in that budgetary support should be consistent with the long-range nature of the program and should avoid violent fluctuations.

Adequacy, in that the level of the effort should be commensurate with the difficulty and complexity of the problem.

Senator DOMINICK. Doctor, again pardon me for interrupting your direct testimony here. Am I correct in my understanding, that some of the companies that you are affiliated with are engaged in research on forecasting, weather forecasting?

Dr. MALONE. Yes, sir.

Senator DOMINICK. Am I also correct that it is under a grant from FAA or Weather Bureau?

Dr. MALONE. It is the Weather Bureau and the Air Force and other agencies; the Travelers Research Center does contract work for a whole array.

Senator DOMINICK. Is one of these research efforts designed to fulfill a proposed need for accurate 9-hour forecasting?

Dr. MALONE. Yes, sir, several different things, and included is the one of the 9-hour forecast.

Senator DOMINICK. Have reports been issued on the results?

Dr. MALONE. Yes, sir.

Senator DOMINICK. Could you tell me whether or not you feel there has been predictable forward motion in this?

Dr. MALONE. Yes, sir, I believe that progress has been made in prediction and more importantly, in the interpretation of the prediction in terms of the sorts of operational decisions for which the prediction is needed.

By that I mean that there is an uncertainty in any prediction. When you use that prediction in an operational decision, it is helpful to know the degree of uncertainty. This is known as probability forecasting and the value of the forecast is enhanced by incorporating a measure of the uncertainty of the forecast into the forecast itself.

Senator DOMINICK. I don't mean to be blunt, but I am a flier, as you may or may not know. From what you have said we are no further ahead in finding out what is going to happen 9 hours from now than we were before.

Dr. MALONE. Well, I would not be quite that pessimistic, sir.

Senator DOMINICK. Suppose you were a flier, and you receive a weather prediction, and a degree of uncertainty is built into the prediction; how are you supposed to know what you are going to face when you get there?

Dr. MALONE. Well, if I were a flier, and a forecaster gave me a forecast for 9 hours, I would first of all recognize that from previous experience that he is not always going to be right. What I would like very much to know is in this particular instance what kind of confidence he attaches to that prediction. Is he quite sure of it, as he is on some days, or is he relatively unsure of it as he is on other days. This would be useful, I believe.

Senator DOMINICK. As fliers, we have a rule of thumb in our area. If the forecast is for good weather 9 hours from now, we can be relatively assured it will be miserable weather, and vice versa. Have the results of your experimental program been transferred to the Weather Bureau?

Dr. MALONE. Yes, sir, the Weather Bureau has access to all of this. We work quite closely with them.

Senator DOMINICK. Do you know whether the people are being trained in the methods and modes which are advocated in this report, or are there no new methods and modes advocated?

Dr. MALONE. Yes, sir, I think there is continual progress in the application of new techniques and in particular, the use of the computer in analysis of the tremendous amount of data which is available to the airlines forecaster, the airways forecaster, and there is constant updating and incorporation of these newer techniques into operational procedures.

Senator DOMINICK. Is this part of an overall weather modification program then?

Dr. MALONE. No, sir. That is directed at the prediction problem.

Senator DOMINICK. Don't you have to have that in order to be able to determine what you are going to do to modify the weather?

Dr. MALONE. Yes, sir, that was my point here on the unity of the meteorological problem. To the extent that you can't describe something, you can't understand it. So you start with measurement. You can't with any intellectual satisfaction predict something you don't understand, and if you can't predict something, you are limited in the degree to which you can control it, because you don't know whether your intervention produced results or whether those results would have happened by natural processes anyway.

Now it is not quite that rigid, but that is the sequential set of steps which make up the whole problem.

Senator DOMINICK. In the consideration of this 9-hour forecasting proposal, did you go further and try to determine whether it was easier or more difficult to give a 24-hour or 48-hour forecast of general weather conditions? In other words, it might not be accurate within 100 or 200 feet on ceilings or whether the clouds were going to be

scattered or broken, but you could describe the general conditions of the area.

Dr. MALONE. In general, the accuracy deteriorates with increasing time, so that your 24-hour prediction is less precise than your 9-hour prediction, given the same element as the predictant.

Senator DOMINICK. Wouldn't you say that in order to conduct accurate weather modification programs you must be able to determine whether a storm is going to be moving into the area at least 24 or 48 hours ahead of time, so that you can be prepared to start modification programs?

Dr. MALONE. Yes, sir.

Senator DOMINICK. What I am trying to figure out is which comes first. In other words, whether in the effort of trying to modify weather we first need a system of accurate forecasting, or whether we need the science of modification when you already have the weather overhead.

Dr. MALONE. This is a vexing problem, Mr. Chairman.

The evidence indicates that the amount of rainfall can be increased in certain cases by something like 10 percent.

Now it is extremely difficult to predict rainfall within 10 percent of the actual amount that falls. So that we have the anomalous situation in which it seems likely that one can influence the amount of rainfall by a percentage change, which is finer or closer than the limits of satisfactory forecasting.

Senator DOMINICK. Have you any idea how many programs are now in operation on an experimental basis to determine the best methods for weather forecasting?

Dr. MALONE. No, sir, I don't have a ready number to give you. There are programs inside the Government, the Weather Bureau, the Air Force, and the Navy; there are programs at the universities, where forecasting is taught. There are efforts in industrial concerns directed to forecasting, but I don't have a single number that I can give you of which I would be confident.

Senator DOMINICK. How many of these programs is Travelers involved in?

Dr. MALONE. Well, it does work for the Navy, for the Air Force, and for the Weather Bureau.

Senator DOMINICK. These are separate programs?

Dr. MALONE. Yes, sir, they are.

Senator DOMINICK. Separately funded?

Dr. MALONE. Yes, sir.

Senator DOMINICK. Are they operated by the same group of people or different people?

Dr. MALONE. Same group of people; yes, sir, so that the coordination is achieved internally.

Senator DOMINICK. They are all concerned with forecasting?

Dr. MALONE. Not all of the programs that Travelers Research Center is concerned with are forecasting; no, sir. There is an activity within the Center which is addressed specifically to the forecasting problem.

Senator DOMINICK. You said you were doing work for the Navy, Air Force, and for the Weather Bureau; is that correct?

Dr. MALONE. Yes, sir.

Senator DOMINICK. Are you doing anything for FAA?

Dr. MALONE. I don't believe so right now. I can't tell you exactly.

Senator DOMINICK. Do you have more than one program from each of those agencies?

Dr. MALONE. Not in forecasting; no, sir.

Senator DOMINICK. Do you have one forecasting program for each of those agencies, each separately funded?

Dr. MALONE. Yes, sir.

Senator DOMINICK. Is there any interrelation of information between one organization and another?

Dr. MALONE. Oh, yes, sir; the degree of coordination is really very high.

Senator DOMINICK. What is the difference in the three programs?

Dr. MALONE. They are addressed to different kinds of problems. The Navy, for example, is interested in the state of the sea, in the conditions over the marine areas. The Weather Bureau was interested, for example, in the airways forecasting problem. The Air Force is interested in high level problems concerned with the winds, the free air turbulence, the cloud cover at high altitudes for their military missions.

Senator DOMINICK. How long have these programs been going on?

Dr. MALONE. At Travelers or in general?

Senator DOMINICK. At Travelers.

Dr. MALONE. For about 5 years.

Senator DOMINICK. Thank you. Excuse me for interrupting you.

Dr. MALONE. Yes, sir. The character of the program will, to a large extent, be determined by the kinds of things that need doing; that is, the elements of the program. They would appear to be these four:

Basic research directed at a fundamental understanding of the principal aspects of the problem.

Applied research directed at the development of techniques for successfully intervening in normal atmospheric processes as well as for assessing the consequences of inadvertent modification.

Operational application of proven techniques as soon as their efficacy is established.

Regulation as may be needed to protect the interests of the public and to prevent the contamination of field research projects.

It seems clear that the most conspicuous gap in the present national effort is in the applied research activity directed at the development and evaluation of techniques for weather modification.

Important considerations in the third issue, that is, the size of the program, are:

The need to conduct large field studies which require substantial logistical support.

The need to assemble groups that are sufficiently large and diverse in their disciplinary interests to make an impact on a very difficult and complex problem.

The level of $30 million by 1970 is, in my opinion, an austere estimate which takes into account these two factors.

An important consideration in the rate of growth of the program is the availability of competent manpower.

I endorse and call to your attention the comments of the panel that the intrinsic scientific interest and the national importance of this problem are likely to attract to it both the quality and the quantity required to expand the program from a $5 million level in 1965 to the $30 million level of 1970.

Senator DOMINICK. This is very interesting testimony. You say one of the most conspicuous gaps in the present national effort is in applied research activity.

Now what is the effect of the present commercial operators who are working on weather modification in certain areas?

Dr. MALONE. Their effect is to contribute to that gap, or rather to the closing of that gap. The commercial operator has the immediate objective of increasing rainfall. For example, in other words, his objective is a technique which will accomplish the weather modification.

Senator DOMINICK. And some of them are also involved in forecasting, are they not?

Dr. MALONE. Yes, sir.

Senator DOMINICK. Has there been any effort that you know of to try and correlate the results of the commercial operators in the two fields with the gap that you are referring to?

Dr. MALONE. Well, I believe that the studies of the Academy Panel were the first attempt to bring together into a single treatment the results of operational weather modifiers and the various research programs which are conducted around the country.

Senator DOMINICK. You talked about big science a little while ago, in reference to applied research. How big an area are we talking about? Suppose you are going to conduct applied research in a big science category for the production of more precipitation. How big an area are we covering, how extensive is it, and how long would it take to do it accurately?

Dr. MALONE. This depends upon the kind of problem you are attacking. If you are talking about the tropical convection problem, for example, you would be talking about thousands of square miles over the ocean areas. If you are talking about the orographic rain increasing problem, you would be talking about something of the order of 100 square miles. If you are talking about the cumulus problem, you would be talking about an area which would encompass several hundreds of square miles. If you are talking about the——

Senator DOMINICK. Would it be feasible, Doctor, to take the upper reaches of the Colorado River—which I am very familiar with and I am sure you are too—in the high mountainous areas of the Rockies, and conduct applied research activity which would determine more or less scientifically whether or not you could produce more snow or more rainfall in that area?

Dr. MALONE. I am not sure I understand your questions, sir.

Senator DOMINICK. Would it be feasible to prepare a program which would be scientifically accurate in a reasonable sense for the production of more snow or more rain in the upper Colorado River reaches?

Dr. MALONE. Yes, sir.

Senator DOMINICK. And what kind of an expense item are we talking about for a productive program of that kind?

Dr. MALONE. You could put it at various levels, depending upon the amount of basic measurements or basic research or understanding of the process that you wish to build into it.

My estimate here would be that a meaningful program would have a minimum level of several hundreds of thousands of dollars per year. If you instrumented this extensively and included aircraft, radar measurements, the expense could very easily escalate into a million dollars or more per year. This is about the range.

Senator DOMINICK. How long a period would a program of that kind have to be carried on in order to be meaningful?

Dr. MALONE. I would estimate about 3 years, 5 years—I am sure you would get opinions that would require 5 years to get meaningful results. And it would depend upon the kind of design you established as a basis for your experiment.

Senator DOMINICK. Is it correct to say that you must have continuity in these applied research activities on a yearly basis in order to determine whether there is any scientific background for increase in precipitation or snow fall?

Dr. MALONE. In general; yes, sir. I say in general because you can conceive of a design which covers several parts of the country in which you have in effect traded space for time, but you are quite correct, in general you need continuity.

Senator DOMINICK. We had testimony from the National Science Foundation about so-called rain shadow, and whether or not downwind areas get less rain after you have seeded than they would get otherwise.

Have you delved into this problem?

Dr. MALONE. I believe Professor MacDonald is going to delve into this in his testimony. I would be glad to give you my views if you would like them, but this is part of his testimony, and I think you would get a more authoritative response from him than you would from me.

Senator DOMINICK. I just want to say to Senator Hart, who has joined us here, I have been questioning the witness as he is going along in his testimony on matters that concern me and have been bothering me for a number of years. We are now on page 6 of his testimony.

Senator HART. Thank you, Mr. Chairman.

Senator DOMINICK. If you have no questions, we will continue.

Dr. MALONE. Sir, I think we are moving into an issue where you are a master and that has to do with the question of the management of the national program, the reorganization and the administration, agency responsibility of a program with far-ranging socioeconomic, and political consequences.

Do you wish me to resume, Mr. Chairman?

Senator DOMINICK. Please.

Dr. MALONE. Several options would appear to be open. One would be to allocate among existing agencies the four program elements mentioned earlier. Generalized guide lines are provided for this course of action in the report of the NSF Commission. Another, and one that would be quite responsive to the report of the Academy Panel and yet not be inconsistent with the alternatives set forth by the NSF Commission would be to recognize the obsolescence of the administrative division of the environmental sciences in the Government and provide a more appropriate home for weather and climate modification within a new structure that would take proper cog-

nizance of the "increased interdependence among the areas of environmental research and engineering" noted by the Academy Panel. I am sure that it is not necessary to point out the difficulties were this second option to be exercised, but the benefits that might flow from it and the appropriateness of Congress undertaking this task prompt me to suggest it as an opportunity to exercise statesmanship of the highest kind.

The final issue—and one that I would personally rank first in importance—is concerned with the international implications. Neither we in this country nor our counterparts in other countries as yet know how to manipulate large-scale weather processes. A formidable scientific problem must first be solved. But today, it is only a scientific problem. If it is solved, it becomes a political problem incredibly more difficult even than the scientific problem. We see about us the vexations in continuing this kind of problem. The question arises: Would it be possible to ameliorate potential difficulty in things scientific and political by a cooperative effort among nations while problems are only scientific? I think so—for four reasons.

First, as I have already noted, the atmosphere itself is international.

Second, there is a fine tradition of international cooperation in meteorology.

Third, with only 6 percent of the world's population, 20 percent of the world's scientists and 40 percent of the aggregate gross national products, we can multiply our own efforts through cooperation guided by the mind as well as the heart.

Fourth, dedication of this effort to peaceful purposes might in some small way contribute to the unity of a world increasingly troubled and tormented by conflict.

In conclusion, a word about our vision—and our nightmare.

The vision, I believe, is a world in which one finds in place "the suitable new political forms and procedures" that the great mathematician, John von Neuman, pointed out a decade ago will be required after global climate control becomes possible.

A world in which the benefits of weather and climate control are allocated equitably among nations by methods that will have been developed—not by some "novel cure-all" but, as Von Neuman phrased it, by "a long sequence of small, correct decisions"—precisely the kinds of decisions before Congress during this session.

The nightmare is a world in which the conflict—that will probably always, to a greater or lesser degree, be the lot of imperfect man—has been aggravated by dispute over the rights to one of the most international of our natural resources—the atmosphere.

A world in which the "race to the moon" is replaced by a race to extend mastery over the atmosphere; the problem of nuclear proliferation replaced by the proliferation of environmental modification capability.

A world in which scientists meet interminably in Geneva to put the genii back in the bottle.

A world we do not want to see.

A world that need not be.

That is the end of my formal testimony, Mr. Chairman.

Senator DOMINICK. Thank you, Doctor. Senator Hart?

Senator HART. Only to comment on the note you strike in the conclusion here. It is a very succinct expression that should intrigue us and alarm us. You put it well.

Dr. MALONE. Thank you, sir.

Senator DOMINICK. Doctor, the report of the National Academy of Science again refers to the fact that increases of precipitation on the order of 10 percent apparently can result from using ground-based silver iodide.

Why the word "apparently," after 9 years? Haven't we gotten any further than that?

Dr. MALONE. Mr. Chairman, I think that Professor MacDonald is going to address himself to this kind of question in his testimony and again, I don't mean to duck your question, but I know that he is going to include a discussion of this. I don't want to say things he is going to say.

Senator DOMINICK. When you actually have seeding operations going on, do you have any idea of whether the research activities, or applied commercial experiments or efforts are producing the most seeding?

Dr. MALONE. Would you repeat the question, please?

Senator DOMINICK. Yes. I will make it much more simple. Seeding is now going on. Which branch of the present science is doing the most, the commercial firms or the research activities? Can you give us any idea of the scope?

Dr. MALONE. I would guess perhaps commercial. Would you agree with that, Gordon?

Dr. MACDONALD. Yes, sir.

Dr. MALONE. But I can't buttress that with facts.

Senator DOMINICK. Your report also stated that the design development and testing of equipment for field measurement and experimentation have been inadequate.

Now what is the reasoning behind that? Is this lack of basic knowledge or failure to develop the tools or what?

Dr. MALONE. Failure to develop tools; not lack of basic knowledge.

Senator DOMINICK. And in whose area does this responsibility lie?

Dr. MALONE. I think it is a diffused responsibility. It is partly responsibility of the scientific community, partly the responsibility of the Government. It is easy to point the finger at one or the other and say that the Government did not provide enough money or to point the finger at the scientific community and say that they haven't come forward and asked for these things that are possible. I think it is a shared responsibility.

Senator DOMINICK. Could you give the committee any idea of what type of tools you need but don't have and that could be developed?

Dr. MALONE. Specifically the kinds of instrumentation for conducting very comprehensive tracing of the seeding ingredients in large systems, for making measurements of the physical, what we call the physical parameters of the cloud, in other words, the drop size distribution, the number of condensation nuclei in the cloud, these kinds of physical measurements.

Senator DOMINICK. Are we talking about radioactive materials that could be traced by counters, or are we talking about visual type of ingredients?

Dr. MALONE. We are not talking about radioactive materials, specifically. But the point is not addressed to radioactive tracing.

Senator DOMINICK. Are we talking about visual type of ingredients then?

Dr. MALONE. Yes, sir; visual types, and those which are measured by instrumentation, which is an extension of the visual perception, of course. For example, the drop size distribution is something you can't measure with your eye, but you can measure by instrumentation. It is a dimension.

Senator DOMINICK. Do we have anybody working on these problems?

Dr. MALONE. Yes, sir; there are groups working on these. I think the point is that the effort to develop these tools needs strengthening.

Senator DOMINICK. Who is now working on it?

Dr. MALONE. These have been worked on at the University of Arizona, at the University of Chicago, at the National Center of Atmospheric Research, University of Nevada, I believe Colorado State College, at the Pennsylvania State University, at MIT, just to cite a few, and I don't mean to exclude any important work or any important group. There are other groups.

Senator DOMINICK. You arrived at certain conclusions in your report on Project Storm Fury. Could you give us some idea of what these conclusions mean? Was it too small an effort or too large or did it move along the wrong lines?

Dr. MALONE. May I refer that question to Professor MacDonald who is going to address himself to it?

Senator DOMINICK. Perhaps we had better have Professor MacDonald's testimony now. This might clear up some of the questions I have.

Dr. MALONE. I believe it would, sir.

Senator DOMINICK. Thank you.

Professor MacDonald, will you come forward?

## STATEMENT OF DR. GORDON J. F. MacDONALD, CHAIRMAN, PANEL ON WEATHER AND CLIMATE MODIFICATION, NATIONAL ACADEMY OF SCIENCES

Dr. MACDONALD. I am delighted to appear before you and discuss current progress in weather modification. There have been rapid advances in this field in recent years. These advances and their potential benefits to society suggest that this area of science and technology deserves careful and thoughtful consideration by the Government and the Nation.

During the past 2 years, a Panel of the Committee of Atmospheric Sciences of the National Academy of Sciences has carried out a study of weather and climate modification. The purpose of the study was to provide an assessment of the possible modes of the interference with the atmosphere both deliberate and inadvertent and to discuss the principal theoretical and technological problems that are now apparent. In carrying out the study, the Panel took a very broad view of weather modification. Problems in modifying clouds and storm systems were recognized as having an immediacy of interest

not presently shared by other areas. However, the Panel did not restrict its interest to questions of modifying cloud systems, but studied a broad range of scientific and technological problems associated with many aspects of weather and climate modification. In these studies the Panel did not go deeply into the complex legal, sociological, or economic aspects of weather modification, but throughout its work was keenly aware of these nontechnical factors.

Since the completion of the report in November of 1965 a number of new results have been presented in conferences and I will refer to these since they add in a substantial way to certain of the conclusions reached by the Panel. I will first discuss the stimulation and redistribution of precipitation. I will review the fundamental aspects of the precipitation process as a background to the discussion of experiments and operations in increasing rainfall.

It is important in discussing precipitation enhancement to distinguish those projects carried out primarily with the object of increasing our knowledge about rain from those operational projects designed specifically to increase rainfall for commercial profit. The former are guided by objectives and procedures for research and the latter by objectives and procedures of business. The operational experience, however, can be used to provide new knowledge if the limitations of the data are clearly recognized.

The development of rain from water vapor contained within the atmosphere requires a number of physical steps. First, the air must be cooled or water vapor added until the air becomes saturated with water vapor and a cloud forms. The air must contain nuclei which enable the vapor to condense to water or ice. Next, some of the cloud particles, either water or ice, must grow large enough to fall out of the cloud.

The first step, that of cooling the air or increasing the degree of saturation, can be accomplished by the gradual lifting of the air, for example the lifting of air as it flows over a mountain range. The lifting of the air can also result from local heating. For example, cool air from the ocean flowing over a warm beach tends to rise.

There have been proposals to enhance the degree of saturation by changing the thermal properties of the ground, but these projects are still tentative. Most efforts in precipitation enhancement are directed toward increasing the number of condensation nuclei and thus encouraging the transition of water vapor to ice.

Clouds are complex systems and may contain water in a variety of forms. The entire cloud may be warm, above the freezing point, and consist exclusively of liquid droplets. If it is made up of liquid droplets and the temperature is below freezing, it is a supercooled or cold cloud. An ice cloud is one composed entirely of ice crystals. To get precipitation out of any of these clouds, it is necessary to cause some of the minute suspended particles to grow very large, possibly at the expense of other particles.

The particles can grow either by mechanical agglomeration, that is the collision of small droplets or ice crystals to form a large one, or ice crystals can grow at the expense of water droplets. The basis for the growth of ice crystals from water droplets is the difference between the vapor pressure of the water and the ice. In order for the ice crystals

to grow at the expense of water vapor, it is necessary that both ice crystals and water droplets exist. The mixed supercooled water droplet and ice crystal cloud system required by those processes seem to occur frequently in a variety of forms. In all the principal precipitating systems, cyclonic storms, orographic storms, and convective shower clouds, the vertical extent of the cloud mass is usually high enough to reach sufficiently cold temperatures for the two types of particles, water droplets and ice crystals, to coexist.

The basis for increasing precipitation in these mixed cloud systems lies in the introduction of additional nucleating particles. The small particles enable further ice crystals to grow at the expense of the water droplets. A number of substances have been used as nuclei. The most effective appears to be silver iodide, which on burning releases a very large number of extremely small particles, each one capable of initiating an ice crystal provided the temperature is somewhat below freezing.

I now turn to some of the experimental evidence and results from operations. The experimental results can be categorized under the headings of orographic, cumulus, and cyclonic cloud systems.

Orographic cloud systems are those produced primarily by the forced ascent of air passing over mountain barriers. Cyclonic and convective systems are often superimposed. In 1957 the President's Advisory Committee on Weather Control reported that 10 to 15 percent increases of rainfall resulted from the introduction of silver iodide nuclei into orographic wintertime storm systems in the western coastal regions of the United States. This early result was challenged by statisticians who complained of the methods of analyzing the data. The statisticians suggested a properly randomized experiment and this was begun near Santa Barbara, Calif. Unfortunately, the results of this experiment were indecisive, since it was believed contamination of certain of the control areas resulted from commercial efforts at rainmaking. This early difficulty illustrates the kinds of problems that are raised in attempts to obtain definitive information on the effectiveness of cloud seeding.

Perhaps the most complete study of seeding of orographic storm systems is now underway in California under the sponsorship of the Pacific Gas & Electric Co. This program is not discussed in the Panel report but preliminary results were presented at the Weather Modification Section of the Fifth Berkeley Symposium on Mathematical Statistics and Probability held in December of 1965. This experiment is company planned and company executed in the Lake Almanor region, 200 miles northeast of San Francisco. It is scheduled for 5 years; this is the fourth year and 2 years of data have been analyzed. The target area in which the seeding is supposed to increase the precipitation is 500 square miles and is in the lee of the Sierras. For southerly flows the air is still rising over the target area. The Pacific Gas & Electric workers have stratified the data in four ways: with respect to the wind, which is either southerly or westerly and with respect to the temperature at the 7,500-foot level. The clouds are termed warm if the temperature is greater than 23° F. at 7,500 feet and are called cold if the temperature is less than 23° F. at 7,500 feet.

With southerly flow, no additional precipitation was detected when the seeded target areas were compared with the control areas. With westerly flow, the cold clouds, that is, those clouds with a temperature less than 23° F., gave 32 percent more precipitation, and the chance of obtaining such an increase purely as a result of statistical fluctuations is about one in a hundred. On the other hand, the westerly warm clouds, when they were seeded, gave 23 percent less precipitation.

I next turn to the seeding of cumulus clouds. The University of Chicago Whitetop project has studied the precipitation from shower-producing summertime cumulus in southeast Missouri over a period of 5 years. Preliminary analysis of the experiments which were properly randomized in the statistical sense showed an increase of 5 to 10 percent of the precipitation in the seeded clouds.

At the Berkeley conference a new and important study from Australia was reported. In this study, individual cumulus clouds have been seeded. The results are striking. Sixty clouds in all have been investigated. Of these, 23 involved clouds with temperatures less than 14° F at the cloud tops. In these, the precipitation was seven times greater in the seeded cases than in the unseeded. The warm clouds with a temperature greater than 14° F showed less precipitation in the seeded cases. These results have led the Australian workers to reinvestigate earlier long-term projects for which cloud-top temperatures were available.

Cold clouds show positive anomalies ranging from 10 to 40 percent as a result of seeding while warm clouds show decreases in precipitation ranging from 4 to 25 percent. These last results illustrate the complexity of the physical processes within a cloud. Furthermore, at the present time there is no known physical reason which would explain why seeding is more effective in cold clouds.

There have been fewer experiments on extratropical cyclonic storm systems. The most complete study has been carried out in Israel, where randomized silver iodide seeding of winter cloud systems conducted over 4½ years shows 15 percent more rain on seeded days than might have been expected.

During the course of its investigation, the National Academy of Sciences Panel obtained over a hundred reports of commercial rainmaking operations. The Panel then selected certain of these reports for an independent evaluation. Fourteen of the selected reports were concerned with projects in the Eastern and Middle Atlantic States and covered a wide range of meteorological conditions. The projects ran from 19 days to 5 months and in all but one of the 14 cases there was an increase in precipitation, with an average increase of about 15 to 20 percent. This result was so striking that the Panel asked for and obtained additional studies by the Rand Corp. and the U.S. Weather Bureau. These independent groups substantiated the Panel's results.

The Panel also studied four long-term projects in the westerly United States. Here increases averaged about 10 percent in the seeded areas as compared with the control regions.

The analysis of these operational results combined with a close study of the experiments led the Panel to conclude that there is increasing

but still somewhat ambiguous statistical evidence that precipitation from some types of cloud systems can be increased or redistributed by seeding techniques. The evidence is complex and in part contradictory. The Panel thus concludes that the enhancement of precipitation is in the research and development stage and that one should approach large-scale operation with caution, since there are conditions where seeding may lead to a decrease rather than an increase of precipitation.

The Panel also investigated the question as to whether or not the local increase of precipitation would result in a decrease in precipitation downwind of the area of increase. The data are insufficient for any firm conclusion, but what data are available show no rain shadow effect.

I will now turn from the questions of precipitation enhancement and redistribution to other aspects of weather modification. It has been postulated that hail can be suppressed by the introduction of nuclei such as silver iodide. The physical basis for this suggestion is that the formation of many ice crystals will prevent the growth of any one ice particle to a very large dimension as is required for the formation of hail.

Extensive efforts aimed at reducing hail have been carried out in Argentina, Switzerland, and the Soviet Union.

In Switzerland the preliminary analysis of the data suggests that seeding increases the frequency of hail rather than decreases it, while in Argentina it appears that a small reduction in the frequency of hail follows from seeding. The workers in the Soviet Union are most enthusiastic about hail reduction and have mounted sophisticated operational programs, but hard data on the results of their projects are not available.

The introduction of many ice crystals or of chaff into lightning-producing clouds may reduce the frequency of fire-producing ground strokes. Preliminary experiments carried out in the Western United States indicate that, indeed, substantial reduction in lightning strokes can be produced in this way.

In certain regions of the world fogs at temperatures below freezing present a hazard for aircraft operations. The seeding of these fogs has been shown to be effective in cutting lanes for landing and takeoff. On the other hand, there is no known way of dispersing warm fogs, that is fogs whose temperature lie above 32° F.

Preliminary experiments have been carried out by a team of U.S. Weather Bureau and U.S. Navy scientists in attempting to modify hurricanes. The variability of hurricanes is so great and their dynamics and energetics so little understood that the Panel concludes that it is impossible to determine whether or not changes were brought about in the hurricanes.

In the above discussion I have emphasized the deliberate change of our atmospheric environment. As civilization grows more complex, society places greater burdens on the atmosphere. We are just beginning to appreciate that the atmosphere is not a dump of unlimited capacity, but we do not yet know what the critical capacity of the atmosphere is or by what effects it should be measured. For example, we can consider carbon dioxide introduced into the atmosphere as a result of the Industrial Revolution.

It is generally agreed that the amount of carbon dioxide has increased by 10 to 15 percent in this century and that this increase is due to the burning of fossil fuels. Calculation of the effects of this increased carbon dioxide are still tentative and crude, but they indicate that the temperature averaged over the surface of the earth has increased by two- or three-tenths of 1° Fahrenheit, and that this increase will continue as a result of further introduction of carbon dioxide into the atmosphere. An increase of temperature of similar magnitude might also result from the water vapor introduced into the high atmosphere by the planned supersonic transports. However, the Panel has not come to any firm estimate because the residence time of the water vapor in this part of the atmosphere is still unknown.

In a sense each city is an experiment in weather modification. It is known that urban regions have climates that differ significantly from the surrounding rural regions. We know very little of the causes of these differences. For example, there are data that suggest that in cities the temperature and rainfall are greater than in the surrounding areas. What is not known is whether these differences are due to the artificial energy sources within the city, to the changing of the heat absorption characteristics by construction or to changing the roughness of the ground.

In summary, I believe that it is now time for an increased effort on a national scale in the fields of weather and climate modification. The emphasis in these efforts should be on research and development. In the precipitation enhancement there are a multitude of unanswered questions. For example, why should the seeding of cold clouds be more effective than the seeding of warm clouds?

Why is there an apparent decrease in the effectiveness of seeding with the passage of time in a given locality?

Is this due to a carryover of the nuclei or is it due to a feedback effect resulting from changing the thermal characteristics of the ground by increased moisture?

Too many questions remain unanswered for the Nation to embark on very large operation projects in rainmaking without the most careful planning based on experimentation. However, it is important that the advances in research and development go forward with operational efforts and that new understanding of the atmosphere be quickly translated into operational methods which may benefit the whole of society.

That is my statement, Mr. Chairman.

Senator DOMINICK. Thank you, Doctor.

I think this has been very helpful to our understanding of some of the problems that we are faced with.

Senator Hart?

Senator HART. The chairman by his questions has indicated a much greater understanding of some of these problems than the other member of the committee that is here this morning.

How many students are in the planetary and space science department at UCLA?

Dr. MACDONALD. It is a graduate department. About 50 students working toward a doctorate degree in the general field of planetary sciences.

Senator HART. What will the majority of them do upon graduation?

Dr. MacDonald. Some will work in atmospheric sciences, some will work on problems dealing with the earth's interior, some will work in space-related areas.

Senator Hart. There is a broad employment opportunity available?

Dr. MacDonald. Yes, indeed. There is an area for which the demand far outstrips the supply.

Senator Dominick. Doctor, I have a few questions. You referred to hail problems in Switzerland, the Soviet Union, and Argentina, where experiments have been going on. Did you do any investigation of commercial operations in Canada?

Dr. MacDonald. Yes; we have looked at commercial operations in Canada, some in this country. None of them have been as extensive programs as the ones that I mentioned, and, again, we find complexity in the results. There are individual cases where the data apparently indicate a reduction in hail. There are other cases where again the data indicate an increase in frequency in hail.

Senator Dominick. Did these situations vary according to geographic location where the applications were going on?

Dr. MacDonald. We have attempted to make a crude stratification of the data on the basis of geographic locality, and on general meteorological conditions, and have not been able to get a clear separation between when seeding would be effective and when it would not be.

Senator Dominick. I was interested in your statement regarding hail because earlier you had said that cold clouds, if we may call them that in nonscientific terms, produced more precipitation.

For example, Switzerland, which is undoubtedly colder than the Argentine except in the Andes area, is producing more hail, than the Argentine, which would seem, offhand, to comply with this cold-warm theory.

Dr. MacDonald. Indeed, in Switberland there was an increase in frequency of hail and also an increase in total amount of precipitation associated with the seeding operations, so this kind of correlation apparently holds up. Unfortunately, we do not have good data on the cloud top temperatures either in Switzerland or in Argentina to make clear comparison.

Senator Dominick. You also refer to the introduction of additional amounts of carbon dioxide over the last 60 years.

Dr. MacDonald. Since 1900 we would estimate the 10- to 15-percent increase.

Senator Dominick. In previous conversations with Dr. Roberts, he has referred from time to time to ozone. What is ozone?

Dr. MacDonald. Ozone is a form of oxygen. It plays an important role in our atmosphere in that it is formed as a result of ultraviolet radiation striking the atmosphere at high levels and it plays an important role in controlling the thermal balance within the atmosphere—that is, where the atmosphere is warm and where it is cold. And there have been suggestions in the past of changing the amounts of ozone.

We did not look specifically at this problem. The industrial contamination, the introduction of ozone by industrialization is completely negligible, but the big production is just due to the ultraviolet coming in from the sun and striking the atmosphere.

Senator DOMINICK. And contamination in the air, as a result of industrialization, does not increase the degree of saturation of ozone?

Dr. MACDONALD. Not at these high levels. Locally, of course, it is very much a problem, and I am quite aware of it, living in Los Angeles. Whether or not it has an influence on the climate, the long-term climatic situation in a local area, based on the situation as in Los Angeles, is not certain. This is one of the problems that we point to. We do not know the extent to which the climate—the long-term weather conditions within a limited area—is influenced by the pollutants, by the local energy sources, by the construction, and so forth.

Senator DOMINICK. Am I correct in understanding that ozone is poisonous?

Dr. MACDONALD. I am certain if you were breathing nothing but pure ozone you would not survive. I don't know how one would define it in a medical terminology. In low concentration it is just a high irritant.

Senator DOMINICK. Have you heard of any reports that the so-called ozone layer is coming down in terms of height?

Dr. MACDONALD. No. Observations and fairly careful monitoring of the ozone layer have been underway for the last 15 years. It fluctuates in its intensity and somewhat in its position with the solar cycle. That is, there is long-term variability, but it is small and there is no noticeable long-term change of the total character of the ozone layer.

Senator DOMINICK. You would be surprised, then, if another scientist should dispute this?

Dr. MACDONALD. Yes, and we would have an interesting argument.

Senator DOMINICK. We deferred before on my questions to Dr. Malone on the need for additional tools. Do you have any comment on that?

Dr. MACDONALD. Yes. In order to carry out the kind of studies that are needed to determine whether or not seeding actually is increasing precipitation, and identifying the mechanism by which this is happening, we have to improve our ability to describe the cloud.

Now, this improvement can come about in many ways. Dr. Malone referred, let's say, to the kind of instrumentation that you carry aboard airplanes and fly through a cloud and determine essential instantaneous distribution of cloud droplet size. This is an important factor because it determines how the cloud droplets themselves grow and reach a critical size.

Another kind of instrument that one would wish to carry aboard an airplane and needs very marked improvement are instruments designed to count the number of nuclei. Dr. Malone referred to the question of following the path of the nuclei. A problem that we have is that there is an apparent difference in the effectiveness of seeding, depending on whether the silver iodide is introduced at ground level or in airplanes, and is a major question that still remains unanswered. What is the path that the nuclei follow as they enter into the cloud? Are they indeed carried up by the internal drafts, the upgoing drafts within the center of the cloud, or do they follow on a much more complex pattern? Is it better to seed at ground level than to seed within the cloud itself? These are the kind of questions that would be an-

swered by detectors that permit you to count the nuclei and count them in essentially in real time.

Senator DOMINICK. In these experiments that you referred to on precipitation, were the nuclei introduced by ground-burning generators or airborne?

Dr. MACDONALD. Generally the operations that are carried out for commercial reasons introduced the silver iodide by ground-burning generators. The white top experiments, some of the Australian experiments, and some of the others I referred to, introduced the silver iodide from airplanes.

Senator DOMINICK. On page 6 of your statement you referred to a properly randomized experiment begun at Santa Barbara and you said that results were indecisive since it was believed contamination of certain control areas resulted from commercial efforts of rainmaking.

Dr. MACDONALD. Yes, sir.

Senator DOMINICK. I presume you felt these control areas should be free from seeding activities?

Dr. MACDONALD. That is correct.

Senator DOMINICK. You were concerned that commercial activities had carried over into these areas?

Dr. MACDONALD. That is right.

Senator DOMINICK. Were these control areas actually target areas of commercial operators?

Dr. MACDONALD. They were in the vicinity of target areas of commercial operations.

Senator DOMINICK. I see. How much of a shortage is there of qualified manpower in the research that is now going on? Is it serious, progressive, or decreasing?

Dr. MACDONALD. I don't believe that there is a serious manpower problem in the field of weather modification at present. It is a field that is rapidly developing. From the scientific community it is growing, and I would suspect that many people who are perhaps working on other aspects of atmospheric sciences may devote a greater portion of their efforts to weather modification. I think that the problems have an excitement, an intellectual quality to them, that will draw scientists from other fields. I think that the problems of what goes on in a cloud are of interest to chemists in his studies of nucleation, of colloidities, to the physicists in the studies of hydrodynamics. One says this interest already is developing. And in the long term, I think that the field will carry itself, that the intellectual excitement and the long-term possible benefits to society will encourage a lot of people to go into this field. I feel very optimistic about the manpower situation.

Senator DOMINICK. That is encouraging, Doctor.

On page 6 you refer to the fact that the experiment at Pacific Gas & Electric is scheduled for 5 years, that this is the fourth year and 2 years of data have been analyzed.

Do you have any idea why only 2 years have been analyzed?

Dr. MACDONALD. This is a company-sponsored and company-implemented project. They have limited manpower, and it is a small project within the company, and——

Senator DOMINICK. This is being coordinated with UCLA?

Dr. MACDONALD. No. We are aware of their work, and follow their presentations at meetings with great interest.

Senator DOMINICK. Is this under contract or are they doing it themselves?

Dr. MACDONALD. They are doing it themselves.

Senator DOMINICK. Neither you nor Dr. Malone, as far as I can see, has indicated the direction that the Federal Government might go in this program as to whether or not we should keep the programs of research and applied research separated among the various agencies or whether we ought to try and put them together in one agency or a new agency.

Do you have any thoughts on that?

Dr. MACDONALD. I do, but I would be speaking now more as an individual rather than as representing the panel. The panel's view was that weather modification is in itself a small part of atmospheric science. Atmospheric science is, again, a small part of the environmental sciences. One cannot usefully consider this small part without looking at the others, and that the problems are common in many aspects. The subjects are interdisciplinary in the sense that they involve physics, chemistry, and engineering, and that the environmental sciences at present are diffused through many agencies. The big science part of the environmental science is the field project, going out and mounting a big program. It is unlike the big science in physics, which is a big accelerator. It requires logistic support, whereby ability to go into some part of the environment, the ocean, the atmosphere, and even the solid earth, and operate within that environment, requires platforms to carry out measurements.

We feel that the present situation in which responsibility is diffused through these many agencies has not led to an optimum use of the Nation's resources, but we do not go on within the panel to make any firm recommendations. We feel this is a problem that we should bring to your attention.

Senator DOMINICK. In other words, you are going to let government fight government instead of getting involved in the middle?

Dr. MACDONALD. Yes, sir. I think in the present instance, this may be the wisest course. [Laughter.]

Senator DOMINICK. Well, under no stretch of the imagination could we say we now have a national weather modification program?

Dr. MACDONALD. I believe this is a correct statement. The National Science Foundation during the past 8 years has played a very important role in supporting weather modification research. Other agencies have their programs designed to fulfill the agencies' mission. But I do not believe that under any stretch of the imagination, as you put it, we have a national program, and I think we need one.

Senator DOMINICK. Let me get your viewpoint on one more thing. Do you see any problems in permitting commercial applications of weather modification programs to continue?

Dr. MACDONALD. First, with respect to the scientific aspects, I think that there is every reason to believe that we can learn a great deal about the atmosphere by studying the reports of commercial operations, that new standards should be set for the level of reporting and this is one of our recommendations, that in the past, reports where available, were not always in the best shape, and a great deal could be learned from these operations.

Secondly, however, one has to be careful that the kind of experience of the Santa Barbara experiment is not repeated, that, if a scientific experiment or research and development kind of experiment designed to determine whether or not one can bring about increase in precipitation, let's say, in a certain region, there is very little chance of contamination from commercial sources. This will continue to be a problem.

I think, of course, that these scientific considerations are almost secondary to the economic, legal, and sociological questions that a very much increased level of commercial seeding will bring about. These, I am certain, would present very serious problems. But they are outside our area of competency.

Senator DOMINICK. I can see lots of difficulties in trying to tell commercial operators that they have no right to contract with a landowner for producing more precipitation in a certain area, simply because a university or someone else wants to conduct an experiment. It has to be done on a cooperative basis more or less.

Dr. MACDONALD. It certainly does, and I think the procedure one would follow in this would be that these long-term research and development-oriented projects would be announced, attempts would be made to plan these in areas that would be unlikely that there would be commercial operations in the succeeding 3 to 5 years, the time scale that I think most people would agree is required in order to get good statistics.

It is only in working together and determining where it is likely that there will be commercial operations that one could do this. One is obviously not going to carry out a scientific experiment in, let's say, a ski resort region, where there is going to be over the years a good deal of commercial operations.

Senator DOMINICK. There have been reports that high-altitude nuclear explosions have created a change in the upper air pressures which, in turn, have increased the degree of the bends in the jetstream.

This has had the effect of increasing the intensity of weather in various sections of the country. It either gets colder, or cold air from the north goes deeper into the south.

Dr. MACDONALD. We looked very carefully at a number of these suggestions and I think we can state categorically that there is no evidence whatsoever that the nuclear explosions brought about any measurable change in the lower part of the atmosphere. There is one change that is measurable that has been brought about, and that is the abundance of lithium in the upper atmosphere has changed. One can see this by very sophisticated observations of the airglow, nighttime airglow, that there is now a higher abundance of lithium, at 75 miles up in the atmosphere than there was before the test. But that, I think, is the sole change that one has been able to detect.

Senator DOMINICK. Has anybody made any effort in the process of this weather analysis to determine the course of the so-called jetstream over a period of time?

Dr. MACDONALD. Yes, sir, there have been climatological studies of this.

Senator DOMINICK. In other words, to chart them on a map and see where they go?

Dr. MacDonald. Yes, sir, and follow them in detail over the years.

Senator Dominick. Have there been any changes?

Dr. MacDonald. There are always changes but there is certainly no sudden change or marked change that one can identify with a particular event. The way to say it is, referring to your very apt quotation from Mark Twain, on a longer time scale, there are many more than 136 different kinds of weather. There is a very great spectrum of possible conditions and if we look at the configurations of a jetstream at any one time, it will differ from the configuration at a later time. But there is no overall change or sharp change that we can identify for the particular event.

Senator Dominick. Has there been a change recently in the bends in the jetstream, so that these bends are much deeper than they were before?

Dr. MacDonald. Tom, do you know?

Dr. Malone. Yes, there are changes. We have been particularly conscious of this in the Northeast where we have a severe drought, and the change has been of a prevailing northwesterly flow at these high levels, which carry the storms off the coast. More recently, a greater preponderance of the southwestern flow which has given us some badly needed rainfall. Our problem is that we don't understand what causes these changes as yet.

Senator Dominick. Senator Hart?

Senator Hart. You heard Dr. Malone, who preceded you, make the comment and conclusion about desirability of international cooperation and he noted that there is a fine tradition of international cooperation in meteorology.

Is there free exchange of information of that sort? If, for example, if country A had made at least some tentative finding that would indicate why the jetstream bent the other way, is that made immediately available to us or to you?

Dr. MacDonald. There is very fine interchange of information in the atmospheric sciences. For instance, the kind of day-to-day observations that are required for predictions are made available on an international basis almost immediately. The International Weather Service obtains the data even from Communist China, essentially in real time. As far as the scientific advances have been concerned, there has been a very free interchange.

The point that Dr. Malone was making was that there is a danger that geophysical warfare might become important and we would wish to do everything that we can in these early preliminary stages to attempt to prevent any move in that direction.

Senator Hart. What specific action should the Federal Government take to move in the direction you suggest?

Dr. Malone. I would endorse the recommendation of the NSF Commission, that a statement of policy be issued by a responsible officer of the Government; I believe the President was mentioned, setting forth our intent to use any capability that was developed in this program in a, well, a humanitarian sense within the limits of normal prudence in maintaining national security. I would strongly endorse the recommendation, and I believe that is the important action.

Senator Dominick. Thank you both very much.

59-528—66—pt. 1——11

The next witness is Dr. Chalmers W. Sherwin, Deputy Director of Defense Research and Engineering for Defense Research and Technology, Department of Defense.

Dr. Sherwin.

## STATEMENT OF DR. CHALMERS W. SHERWIN, DEPUTY DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING FOR DEFENSE RESEARCH AND TECHNOLOGY, DEPARTMENT OF DEFENSE; ACCOMPANIED BY COMDR. WILLARD HOUSTON, CHIEF OF THE ENVIRONMENTAL SCIENCES PROGRAM, DEPARTMENT OF DEFENSE

Dr. SHERWIN. Senator Dominick. My name is Chalmers W. Sherwin, and I am Deputy Director of Defense Research and Engineering for Research and Technology, which area includes the atmospheric sciences portions of the Defense Department program.

Senator DOMINICK. Can you speak up or pull the microphone closer so the people in the back can hear you?

Dr. SHERWIN. The Department of Defense interest in weather modification is focused on the desire to influence natural weather phenomena that have an adverse effect on military operations. Included are such phenomena as fog, clouds, thunderstorms, and other severe storms such as typhoons and hurricanes. The presence or absence of these forms of weather influences nearly every conceivable form of military operation whether it be subsurface, land or sea surface or air operations. Air operations of all kinds are particularly sensitive to weather.

The DOD recognizes that there are many other major objectives for weather modification; for example, to fill reservoirs, provide water for agriculture and hydroelectric power, to suppress hail, et cetera. While these problems are of interest to the DOD, their solution is regarded as the business of the civilian agencies.

Although the problems of immediate concern to the DOD would possibly be solved eventually by other agencies or private endeavors, military operations are hampered by these problems now.

For example, during the Korean conflict, weather modification was used to dissipate cold fogs from some military airfields. Having this capability, we have turned our attention to contract and in-house research programs on warm fog, marine fog and stratus, trade wind cumulus convection, hurricane modification, formation and dissipation of clouds, reduction of the severity of thunderstorms, dissipation of lightning and the dissipation of whiteout. Theoretical studies, field measurements and experiments, and development of specialized instrumentation are all involved in this effort. The following table (see p. 165) summarizes the present Department of Defense effort in weather modification.

I have here two or three pages which gives a chart of our program which I will not read unless you wish me to do so. It is just a tabulation.

It adds up this year, this fiscal 1966 to $1.12 million, approximately. Fiscal 1967, it is scheduled to be slightly higher, $1.21 million.

So we are carrying on a level of effort of about a million dollars.

As can be seen from the table, the DOD effort is mainly in the area of research and experimentation. However, the DOD does have a capability for using some weather modification techniques operationally when needed, such as mentioned above for the dissipation of cold fogs or additionally for the suppression of condensation trails from aircraft.

With regard to the S. 2916, 89th Congress, the proposed Weather Modification Act of 1966, I believe that the chairman has already received the comments of the Department of Defense from the Secretary of the Air Force. Two points were stressed in those comments.

First is the need for the Department of Defense to be free to pursue those activities in the area of weather modification that are needed to enhance the accomplishment of its mission. This same statement applies to other Federal agencies in addition to the Department of Defense and is in keeping with the position of the National Science Foundation's Special Commission on Weather Modification in NSF Report 66–3.

The position, as stated by the Special Commission, was:

> Federal agencies should undertake such operational activities as may be required for the effective discharge of their missions; e.g., suppression of lightning by the Forest Service, fog dispersion by the Federal Aviation Agency and rainfall augmentation for the reservoir system of the Department of Interior. Also, pursuant to Executive Order 10521, Federal agencies should be free to conduct and support such research and development as may be required in the discharge of their mission.

The above wording was also adopted as the position of the Interdepartmental Committee for Atmospheric Sciences. Inclusion of such a statement in the proposed legislation would not only clearly allow the Department of Defense to pursue the work necessary to its mission, but would also encourage the broad scale approach that is needed by the Federal Government to realize the full potential of weather modification and climate control at the earliest possible date.

The second point is that the DOD recommends the separation of the regulatory function from the operational research and development function within the Department of Commerce. This position also is essentially an endorsement of the position taken by the Special Commission and which has been adopted by the Interagency Committee of Atmospheric Sciences.

Other than the above suggestions, the Department of Defense interposes no objections to S. 2916.

Senator DOMINICK. Mr. Sherwin, I thank you for your statement and for the details which you included within it. I think they are very helpful to the committee.

On your second point, you recommend the separation of the regulatory function from the operational research and development function within the Department of Commerce. How would you separate the regulatory function?

Dr. SHERWIN. Presumably the research and development function in operational function would be in that part of Commerce associated with weather control. I assume it would be ESSA.

We would suggest that an independent part of the Department of Commerce be responsible for regulation, which would have also to

regulate the Department of Commerce programs as well as those from Defense and other places.

In other words, we have no strong recommendation except to be separated organizationally in the Department of Commerce.

Senator DOMINICK. In other words you don't want a star chamber trial and I would completely agree with that.

Dr. SHERWIN. You see Commerce is one of the active organizations in this field and therefore the judge must not be too closely associated with the performer in this case.

Senator DOMINICK. Dr. Sherwin, are the results of the research done for DOD classified?

Dr. SHERWIN. Most of them are not.

Senator DOMINICK. And to what agencies or to what other groups are these experiments revealed?

Dr. SHERWIN. Most of them are distributed, without classification, to the whole meteorological community and to all other agencies involved. We have given details of this program here, I believe, completely to the ICAS coordinating program, so we have nothing in our current program that I know about which has any special classification.

Senator DOMINICK. Is there any one place that you know of where a person can go to see what research has been done and what is presently being conducted?

Dr. SHERWIN. Yes; I believe that the spot is the Interagency Committee for Atmospheric Sciences. I happen to be the Defense Department member. This Committee has set up groups which study and coordinate the program in many different aspects of atmospheric sciences of which the activities and weather control are a part. The report of this Committee and the reports given to the Committee by us and by other agencies provide, as far as I understand, a very complete description of the entire program in the United States supported by the Government.

Senator DOMINICK. Who are the members of the Interagency Committee for Atmospheric Sciences?

Dr. SHERWIN. The Chairman is Dr. Hollomon, the Assistant Secretary of Commerce for Science and Technology. I am the member from the DOD. Dr. Hayworth, the Chairman of NSF, is the member from NSF, and other agencies have people on this Committee.

Senator DOMINICK. How big a group is it?

Dr. SHERWIN. There actually are about 15.

Senator DOMINICK. How often do they meet?

Dr. SHERWIN. They meet about once a month and in addition they have working panels which go into detail on the coordination of specific parts of the program, such as, for example, weather modification and other categories, too.

Senator DOMINICK. Are their reports made public?

Dr. SHERWIN. Yes, they are.

Senator DOMINICK. Are they printed reports?

Dr. SHERWIN. Yes. They can be obtained from the Chairman, Dr. Hollomon. I might add that I feel—excuse me.

Senator DOMINICK. Do you have anything to do with the National Center for Atmospheric Research in Boulder?

Dr. SHERWIN. We have a great deal of technical communication with them. I believe, however, that the Defense Department does not provide direct research support to the organization. We do not support it financially.

Senator DOMINICK. Does the ICAS receive reports from private industrial research in this field or from commercial operators, or is it just from Government-sponsored research?

Dr. SHERWIN. Its job is with Government-sponsored research and I believe its reports focus on Government activity. I am not aware of an organized effort to bring in the entire research program in atmospheric sciences not funded by the Federal Government. Individual members know about it, but I think it is not part of the main report or analysis of the program.

Senator DOMINICK. I am asking these questions because the Government seems to be getting more and more into the research end. Sometimes I wonder if we are not conducting research for the sake of research. One of the things that has always bothered me, in the Department of Defense as well as other governmental agencies, is the question of whether a new person coming into the field can get the benefit of what has gone on in the past, or whether he has to duplicate a good deal of the work that has already been done.

It would strike me that ICAS, if it is all encompassing, would be a very fruitful area for any researcher to delve into before he even starts a new experiment.

Dr. SHERWIN. Yes, it is, and the reports from ICAS provide a complete description of all of the programs in atmospheric sciences supported by the Government.

Senator DOMINICK. But they do not take in anything that the universities are doing unless they are Government funded?

Dr. SHERWIN. Well it just happens that in the atmospheric sciences area, there is very little funding outside of the Federal Government. I am not sure what fraction it is, but only a few percent is commercially funded, real research work. There is some seeding and other operational work, but very little research is supported elsewhere, so we cover automatically most of the program, over 90 percent.

Senator DOMINICK. Have you done anything—and I frankly have not had a chance to review these tables—about evolving new tools for research measurement that were referred to by Dr. Malone and Dr. MacDonald?

Dr. SHERWIN. Yes, indeed we have. We have developed, for example, instruments for one of our main interests, warm fog. Now warm fog is an extremely serious military problem because it prevents the use of airfields and also prevents ground visibility in military operations. It is a very difficult field and if you look at our program you will see a very large fraction is focused upon the warm fog problem.

One of the instruments developed, for example, by the Air Force is a special laser instrument designed to measure the properties of warm fogs. And we have developed other instruments that have to do with determining the properties of nuclei over oceans that get coated by organic material, which appears to be evaporated from the ocean.

Senator DOMINICK. Do you feel that you have made significant progress in the development of the proper tools for this type of research?

Dr. SHERWIN. As far as I know the tools are not the limitation. The problem is the understanding of the phenomena once we observe it, so I believe that we have adequate support in the tools in the areas we are concerned with.

Senator DOMINICK. Then, you don't think that the National Academy of Sciences is necessarily correct in stating that there is need for additional tools and additional means of measurement and things of this type?

Dr. SHERWIN. For the Defense Department type of programs, perhaps we are more specialized—I think that we are in a fairly good state with respect to measurements. It may not be true of the other areas.

Senator DOMINICK. In the NAS report, it states "that atmospheric circulation cannot be considered independently of the oceans." It goes on to say that systematic operational observational surveillance of the oceans is virtually nonexistent.

What are we doing through the DOD, if anything, to help overcome this or would you disagree with the premise?

Dr. SHERWIN. The observation over the oceans is very important and it is very deficient.

Senator DOMINICK. It is very what?

Dr. SHERWIN. Very deficient. We are deficient in information over the oceans. The DOD is doing several activities in this area.

One, we are developing automated buoys which can be moored anywhere in most parts of the ocean and to sit there and report water temperature and wind and precipitation information by high frequency radio back to land. These can be operated for months at a time without attention.

We have a very extensive flight patrol operation which the Navy operates out of Guam and out of Jacksonville and Norfolk, to collect oversea information in areas where the shipping lanes do not provide it.

We feel that there could be a substantial increase in instrumentation on merchant ships which could collect better meteorological data with a relatively small cost.

And finally, we are very interested in exploiting the development of satellites for observing the weather throughout the whole earth as well as particularly over the oceans, which are of particular importance of course to military operations.

Senator DOMINICK. The National Science Foundation report stated that the FAA and the Air Force regulations on the use of small seeding rockets or tethered seeding balloons or free seeding balloons near any airport are prohibitory.

Would you comment on that?

Dr. SHERWIN. I am not familiar with that comment. I wonder if I could call on Commander Houston, my technical assistant in this program, to answer your question?

Senator DOMINICK. For the record would you give us your name and position?

Dr. SHERWIN. Commander Willard Houston, Chief of the Environmental Sciences Division in my office.

Commander HOUSTON. At present there is no Air Force regulation issued concerning the matters you discussed. There is one in preparation, however, that has not been issued.

The only regulation concerning this activity is a Federal Aviation Agency regulation which has been with us for many years. Essentially it is one designed to protect the safety of commercial aircraft. In all the upper air observations that have been conducted in this country and to a large extent in foreign countries also, you are restricted at present from flying any object weighing more than 6 pounds from a balloon unless you separate it by 50 feet from another object of similar weight, two objects of 6 pounds each separated by 50 feet from a single balloon without special permission. Any other time you wish to fly an object to gather information from the outer atmosphere you must obtain special permission from the Federal Aviation Agency in order that you do not interfere with aviation. So that pilots will not, of course, run into large unknown objects.

Senator DOMINICK. There are proposed experiments which would put balloons at different levels of the atmosphere to float around the world, presumably reporting back on the weather. It is my understanding that these are made out of plastic and they follow the wind currents since they are not very heavy.

Do you have a feeling that this is going to interfere in any way with the mission of the DOD or the Air Force or create any kind of a hazard?

Commander HOUSTON. No, sir, I do not.

Senator DOMINICK. How significant do you feel the concept is that weather modification is a weapon or a weapon system?

Dr. SHERWIN. I believe that I can state with assurance that at the present state of confidence and knowledge, it has no direct military weapon-type of activity value. The ability to control warm fog for landing is very important.

I must correct myself at one point. It is possible that if over land and over the ocean in particular, one could with confidence generate clouds, cumulus clouds, one could produce concealment in favor of one's own operations from flight observation or satellites, so in that the ability to produce clouds could have direct military utility and in that sense would be a component of a weapons system.

Do you want to add anything to that, Commander?

Commander HOUSTON. No, sir.

Senator DOMINICK. To what extent is DOD interested in the forecasting problems?

Dr. SHERWIN. We are very interested in the forecasting problem. It is of vital interest and we have put a very large effort on it for many years, large scale mathematical modeling of the atmosphere has been supported by DOD since the early 1950's and we have large operational and practical experiments in precision forecasting and a great interest and plans for expanding our effort in the use of synchronous meteorological satellites for improving precision weather forecasting.

Senator DOMINICK. Those are not included then in the charts that you have here, because you don't consider this as part of a weather modification program?

Dr. SHERWIN. They are an essential basis upon which a good program can be built, particularly if you are going to modify the weather in a large scale. We do not count them as weather modification per se.

The weather modification in DOD is about $1 million per year. Our program in atmospheric sciences is something like 30 or 40 times as large, and is focused upon many other related problems, but not specifically weather modification.

Senator DOMINICK. Being a pilot I am a little more concerned with this than most people, but it strikes me that by this time we should have been able to have some reasonable idea of what the weather is going to be, at least 24 hours ahead of time. There are certain areas in our country, including my own, where this seems to be beyond the capability of those people who are now doing it. I just wonder whether we are making any improvement on it. We can't even get within 20 degrees of temperature, much less cloud cover.

Commander HOUSTON. We, of course, face the very same problem in the Department of Defense, and in most instances we do not have the benefit of the extensive observing network that is present in your part of the country or anywhere in the United States. The forecasting problem has been with us a long time. We have made considerable improvements. The work in the DOD is primarily aimed at improving your forecasting capability where you have a rather insignificant amount of information.

The area you wish to forecast is often not very cooperative in providing you with the detailed information needed to generate an accurate forecast. We have made considerable progress and in certain areas, such as satellites, we look forward to tremendous strides in the future.

As a meteorologist for the last 24 years, I feel that science has progressed but there is a long way to go, sir.

Senator DOMINICK. How are you getting along on your Stormfury research?

Commander HOUSTON. Stormfury is a combined research program with the U.S. Weather Bureau. The Navy's principal contribution to this is to provide certain aircraft and certain dispensing tools whereby the operation is carried out. It also participates in the scientific design of the program and in the evaluation of the data. The project ran for 2 years. We laid off for 1 year and again this past season it was operated again. However, in the past season no hurricanes moved into the area that is allowed for seeding.

As you must realize, very careful control is maintained in order that no hurricane is seeded in such position that it could affect a land mass within a 48-hour period after the seeding. This makes it difficult to find hurricanes in the proper juxtaposition to our aircraft bases where we can get out to the storm, monitor it, seed it, and get back home within the range of the aircraft and still have it far enough away not to affect land masses.

The results of the 2 previous years' work are still under analysis. They were inconclusive. A corollary effort made in conjunction with Stormfury was to look at very large trade wind cumulus clouds and do some seeding of them to see if the principles that were being investigated could not be tested on a less violent form of nature.

This work has continued all 3 years and results there are very encouraging. In a number of instances clouds have been seeded, these are the large cumulus clouds that extend up to above 20,000 feet, and have caused the clouds apparently to change rather dramatically.

It is inconclusive, however, because it did not happen in all cases.

Senator DOMINICK. I want to come back to that, but I want to ask you this question first.

The National Academy of Science report states and I quote:

> Many of the components of the synchronous satellite airplane submarine system needed to determine the hurricanes energy budget are already being implemented in various Government agencies. But so far there is no program organized to make use of the opportunity that these new tools present.

Now, would you comment on that or give me some clear idea of what they are talking about? I should have asked this of Dr. Malone, I guess, earlier.

Commander HOUSTON. My understanding of Project Stormfury, sir, is that it is just designed to do what you are referring to, make use of all of the available tools of the trade to understand better the hurricane energetics and the possibilities of doing something about them.

Senator DOMINICK. I wonder if I could interrupt you here and ask Dr. Malone if he would like to comment on that.

Exactly what are you referring to there?

Dr. MALONE. This conclusion was arrived at after several lengthy sessions with Dr. Joanne Simpson, who is project director. She had done some extraordinarily fine work bearing on this problem. It is quite clear that the problems of coordination among agencies are well handled, but they are extremely difficult problems. It takes a lot of negotiation.

I think the whole thing was summed up when she said that her greatest problem was box lunches. What she really meant was that the administrative task of bringing to bear all of these things in the kind of mode of operation, that she had diluted the scientific thrust of her work. There are tremendous logistical problems in getting out into a hurricane, or a tropical convection area, a half dozen airplanes, equipped with radar, computers, this is what the Academy had in mind, sir.

Senator DOMINICK. You say there is no program organized to make use of the opportunity that these new tools present.

What type of program is she talking about or is NAS talking about?

Dr. MALONE. It is a program which would be a substantial extension of the Stormfury project now, which would make more extensive use of satellites, the kind of synchronous satellite, as a matter of fact, that Mr. Sherwin was talking about, which is a very promising new tool.

The use of automated ocean buoys for measuring surface temperature, the kind of concept which involves the use of the submarine to get underneath the hurricane and measure the conditions near the surface of the water. These are the kinds of ambitious large-scale undertakings that have been proposed.

Senator DOMINICK. But they are not being carried out in any program now?

Dr. MALONE. Not of this dimension; no, sir.

Senator DOMINICK. What you are saying then is that we have a program which needs to be enlarged if we are going to get any real benefits of the means of determining a hurricane's energy?

Dr. MALONE. It is not a criticism and should not be so construed.

Dr. SHERWIN. May I make a comment on that issue?

The Stormfury support aircraft included a fairly large contingent of Navy specially equipped airplanes and some from the Weather Bureau, and represent an incremental effort on a very large existing base. What I am trying to say is—if you can afford the Stormfury experiment, you can only afford it if you use the incremental effort of people that have large facilities already. You cannot afford to generate facilities only for this purpose.

For example, to run a submarine in the middle of a hurricane and to make certain measurements, you could not afford a submarine for that. You have to use a submarine that the Navy is operating or perhaps some other research-type machine which probably couldn't handle this type of navigation.

In other words, the big expense of experiments in weather modification, or even observation, require literally the coordinated effort to be efficiently operated by a large number of agencies, sometimes a large number, certainly several.

Senator DOMINICK. At the present time in Project Stormfury, are you using submarines as well as aircraft?

Dr. SHERWIN. This has not been done yet. It was suggested by the National Academy of Science that this be done this summer.

Has that been done? Have we received a formal request yet?

Commander HOUSTON. Not to my knowledge.

Dr. SHERWIN. We understand that the Defense Department has not received a formal request to use submarines for this purpose.

Senator DOMINICK. Who is the chief operator of this Stormfury? Is it the Navy Department, Defense, or Weather Bureau?

Commander HOUSTON. The Director is Dr. Simpson, as Dr. Malone said. However, there is a joint responsibility with the Navy. There is a Navy project director also, and the two work very closely together. The primary problem of the Navy director is to control the aircraft. The Navy provides one large aircraft with airborne control facilities whereby it can monitor the position of all of the other aircraft involved to make sure that no two aircraft get too close to each other and no aircraft gets lost in the storm.

In addition, the Navy provides the very high altitude jet aircraft needed to get over the storm to drop the seeding agent into the storm.

The Weather Bureau provides certain instrumented aircraft to make measurements in the storm.

The coordination of all of this flight activity is done by the Navy project officer from the command aircraft.

Senator DOMINICK. What I am trying to find out—I guess it is pretty obvious by now—is whether we have a clash between various agencies here, because if Dr. Simpson has asked that something be done about getting a submarine for what reason wasn't it done?

Commander HOUSTON. I don't think the request was made in sufficient time to have done anything for the last year, and it has not been acted on for the next hurricane season. Of course right now all resources of the Department of Defense are somewhat strained.

Dr. SHERWIN. I might add, incidentally, that Commander Houston is one of the few people here who has been in and out of many hurricanes in naval aircraft and he has seen these up close.

Senator DOMINICK. All I can say is I sympathize with him.

Thank you very much. I think that is all we have for this morning.

(DOD table follows.)

*Summary of Department of Defense weather modification activities*

| Area of investigation | Objective | Type of investigation | Investigator | DOD funding fiscal year 1966 | Cognizant DOD component |
|---|---|---|---|---|---|
| Cold fog, whiteout | To develop techniques to dissipate fog and whiteout in cold regions. | Field observations laboratory experiments. | U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, N.H. | $30,000 | Army CRREL. |
| Warm fog, thunderstorms, lightning, aerosols. | To develop techniques usable by a tactical Army to effect the reduction in intensity of thunderstorms, dissipation of lightning, and dissipation of warm fog and clouds. | Field experiments, laboratory experiments, field observations, instrument development, mathematical analysis. | Atmospheric Sciences Laboratory, Ft. Monmouth, N.J. | 190,000 | Army ASL. |
| Warm fog | To study growth rate of fog and relate to electrical variations that accompany formation and dispersal. | Observation and analysis | E. Bollay Associates, Boulder, Colo. | 20,000 | Navy ONR/BuWEPS. |
| Warm fog | To test a theoretically derived relationship between the optical properties of fog and the small ion density. | Observation and analysis | Litton systems | 25,559 | Navy ONR. |
| Trade wind cumulus convection. | To grow a trade wind cumulus cloud from clear air under appropriate conditions of humidity and temperature. | Field experiments and observations. | University of Hawaii | 60,000 | Navy ONR/BuWEPS. |
| Aerosols warm fog | To determine how the coating of fog droplets in some west coast fogs inhibits normal evaporation and dissipation. | Field sampling and chemical laboratory analysis. | Atmospheric Research Group, Altadena, Calif. | 25,000 | Navy, Bureau of Naval Weapons. |
| Convective clouds | To mathematically model the dynamics of a convective cloud and compare with natural cloud measurements. | Mathematical modeling and field observations. | Douglas Aircraft Co., Inc., Santa Monica, Calif. | 29,500 | Navy, Naval Research Laboratory. |
| Condensation, nuclei convective clouds, warm fog instrumentation. | 1. Achieve an understanding of natural cloud and atmospheric processes; search out processes which may be artificially modified. 2. Develop instruments and techniques needed to understand natural processes and to evaluate modification efforts. | Mathematical modeling, field sampling and observation laboratory experiments instrument development. | Naval Research Laboratory | 375,000 | Navy, Naval Research Laboratory. |
| Hurricane modification (Stormfury), trade wind cumulus convection. | To determine if the force of hurricane winds can be reduced. | Field experiments, field observations, instrument development, theoretical analysis. | Bureau of Naval Weapons, Naval Ordnance Test Station, China Lake, Calif. | 200,000 | Navy (joint U.S. Navy-U.S. Weather Bureau project). |
| Statistical analysis | To determine if a 7-year experiment in hail suppression affected rain fall. | Mathematical analysis | University of California, Berkeley, Calif. | 20,000 | Navy ONR/BuWEPS. |
| Cloud nucleation | To study the mechanism of freezing water droplets as a process of cloud nucleation. | Laboratory experiments | University of Nevada | 22,000 | Navy ONR/BuWEPS. |
| Warm fog | To develop instruments to measure drop size distributions and optical properties of fog. | Instrument development, field observations. | Technical Operations, Inc., Burlington, Mass. | 70,000 | Air Force AFCRL. |
| Warm fog | To determine the life cycle of warm fogs in terms of physical parameters. | Field samplings and observations analysis. | Singco Inc., Burlington, Mass | 70,000 | Air Force AFCRL. |
| Warm fog | To perform data reduction services for processing field observations. | Mathematical analysis | University of Dayton, Dayton, Ohio. | 10,000 | Air Force AFCRL. |
| Warm fog | To determine the life cycle of warm fogs in order to develop feasible dissipation techniques. | Mathematical analysis | Air Force Cambridge Research Laboratories. | 30,000 | Air Force AFCRL. |

Senator DOMINICK. The committee will meet tomorrow at 10 a.m. for further hearings in room 5110 of the New Senate Office Building.

The committee is adjourned.

(Whereupon, at 12:05 a.m., the committee was adjourned, to reconvene at 10 a.m., on Friday, February 25, 1966.)

# WEATHER MODIFICATION

FRIDAY, FEBRUARY 25, 1966

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

The committee reconvened at 10 a.m., in room 5110, New Senate Office Building, Hon. Howard W. Cannon presiding.

Senator CANNON. The committee will come to order.

This morning's hearing on the weather modification is the fifth of the current series. At yesterday's hearing, the committee heard testimony from representatives of the National Academy of Sciences and the Department of Defense. Part of the discussion was about the correlation between weather prediction and weather modification, and about the role of the commercial operators.

It is significant that these points were raised and today's witnesses will be able to elaborate on these and other topics. Today, we will hear testimony from representatives from the Department of Commerce and the Department of the Interior.

The first witness today is Dr. J. Herbert Hollomon, Assistant Secretary for Science and Technology, Department of Commerce.

## STATEMENT OF DR. J. HERBERT HOLLOMON, ASSISTANT SECRETARY OF COMMERCE FOR SCIENCE AND TECHNOLOGY; ACCOMPANIED BY DR. ROBERT WHITE, ADMINISTRATOR, ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION, AND GORDON CHRISTENSON, ASSISTANT GENERAL COUNSEL, DEPARTMENT OF COMMERCE

Dr. HOLLOMON. Senator Cannon, I have with me this morning Dr. Robert M. White, who is the Administrator of the Environmental Science Services Administration, and Mr. Gordon Christenson, who is Assistant General Counsel for the Department of Commerce.

I have a statement, sir, which I would like to submit for the record, if I may, and then try to make its key points more briefly in the presentation.

Senator CANNON. Very well. You may proceed as you so desire.

Dr. HOLLOMON. I am pleased to be here today to have the opportunity to present the views of the Department of Commerce on weather modification, S. 23 and S. 2916, bills on this subject.

The question these hearings can illuminate and help answer is how we shall achieve a coherent national policy for weather modification. The Department of Commerce strongly supports sound steps toward such a policy, including needed legislation and favors the purposes of S. 2916.

The President said last week in his transmittal message to Congress on the annual weather modification report:

> Two sets of problems face us, and both are difficult. One consists of finding out how to modify the weather and climate, and the second consists of determining how best to utilize this knowledge for the benefit of mankind once it is achieved.

The first of these requires an expanded and redirected effort in the science and technology of weather modification itself. This should proceed without delay, with major reliance upon the resources of the Environmental Science Services Administration in the Department of Commerce.

Senator CANNON. Do you mind if I interrupt as you go along?

Dr. HOLLOMON. No.

Senator CANNON. What do you mean by a redirected effort, and why do you say there should be a redirected effort?

Dr. HOLLOMON. We believe there needs to be very much more concentration on broad field experiments, which I will try to make clear later, and there should be a more intense evaluation of both the benefits and the possible harmful consequences of weather modification efforts. We should examine in a broader way how to modify severe storms, for example, so that there is some redirection toward what I consider more developmental kinds of application rather than as it has been largely in the past, toward basic sciences. This is what I mean by redirected.

Senator CANNON. In other words, more in the operational area?

Dr. HOLLOMON. More applied research and development directed toward operational applications than in the basic sciences.

The second problem the President presented requires thorough considerations of public policy of economic, legal, and social consequences, when the scientific results are put to use privately or by the Government. It means thoughtful study, dialog, and debate on questions of public law and organization.

These considerations should begin at once, though there are immediate steps which can be taken in support of the expanded Federal research program. Before long, however, we must decide what kinds of future policies and regulatory controls are desirable for public and private activities seeking to modify the weather or climate.

In my statement I give a brief review of the bills before you, which I don't think is necessary verbally. Thereafter I would like to describe the need for redirection of the national effort in weather modification and try to outline what we believe are the elements and scope of this redirection. Then I shall discuss the capabilities of the Department of Commerce and other agencies.

Finally I think it is appropriate to spell out our recommendations for needed legislation to support the immediate research effort and suggest some legislative questions for the consideration of the Congress.

S. 23 directs the Secretary of the Interior to conduct a program in five geographic areas of the United States to increase usable precipitation. The Department of the Interior already has underway a program similar to that proposed in the bill.

It has certain mission responsibilities concerning the Nation's water resources, and we support its efforts in using weather modification to

assist in carrying out its mission. But we do not believe that legislation is necessary for this purpose. For this reason, we do not recommend enactment of S. 23.

S. 2916 would transfer to the Secretary of Commerce the authority now in the National Science Foundation to carry out a weather modification program, including applied research, development, and experimentation.

It would restate such authority, but in greater detail than the Foundation's existing statutory authority. It also would limit the research authorized to that for applied research, development, and experimentation.

It would provide authority for the transfer of personnel, property, and appropriations and would repeal existing statutes authorizing the Director of the National Science Foundation to conduct a weather modification program.

It would make clear that the National Science Foundation would continue to have authority for scientific studies in weather modification as part of the atmospheric sciences.

Further, S. 2916 would authorize the Secretary of Commerce to issue regulations affecting any operation of commercial enterprises engaged in weather modification which conflict with or impede any authorized activities. It would require a report to Congress, within a year after enactment, or recommendations for additional legislation concerning the enforcement of such regulations.

The authority now in the National Science Foundation to hold hearings and obtain information also would be placed in the Secretary of Commerce.

The bill specifically would authorize international cooperation under the policy guidance of the Secretary of State and would require the Secretary of Commerce or his designee to be a member of the U.S. delegation at intergovernmental meetings and conferences relating to weather modification and climate control.

We fully support the purposes of S. 2916, although we believe that it is premature and that the aspects of this bill which relate to reorganization in the executive branch can be accomplished best through an executive reorganization. A Presidential reorganization plan along these lines is now under active consideration.

We do not agree, however, that the authority in the Secretary of Commerce should be limited to applied research since there are many scientific investigations of a fundamental nature which would be carried out in any large scale weather modification research or experimentation program.

Also, if legislation on this subject is enacted, it should contain effective authority to limit private weather modification activities providing they are in direct conflict with the research or experiments carried out by the Department of Commerce.

Authority to issue regulations governing these conflicts would be of little significance to any large-scale research effort if there is no enforcement mechanism.

Senator CANNON. What do you have in mind there, the types of things that would be in direct conflict?

Dr. HOLLOMON. Let me give you an example. Suppose you have laid out in a certain area of the country a very major program of cloud

seeding or other kind of modification activity, which required large amounts of field equipment and in which there had been planning of a very substantial kind, and then inadvertently, due to a private activity, this whole area was contaminated by seeding by private parties. This would be a conflict between the research and development effort of the Federal Government, it would obviously waste the taxpayer's money and might make the results of these experiments completely invalid.

Senator CANNON. Has there been any evidence of conflicts up to the present time in the limited areas that we have been going ahead in, that is, between the commercial operators and the funded Government research programs?

Dr. HOLLOMON. I personally do not know of any. One of the difficulties, of course, is that we have not had adequate reports of what actual activities were taking place in the private sector of the economy, and therefore it has been somewhat difficult to know when this kind of contamination is possible.

There is another technical problem which I think is interesting and that is that we have not been adequately monitoring condensation nuclei throughout the country, to see what the persistence is, how long it persists after someone has put them in the atmosphere, and over what regions. And it has therefore been difficult to tell exactly what the possible contamination might be.

I can't explicitly answer the question. Dr. White may be able to.

Dr. WHITE. Yes. During the Santa Barbara project in 1957–59, there was some doubt cast upon the results of this project because of possible contamination by other seeding activities.

Senator CANNON. Now you say there has been no cataloging up to the present time? Would the NSF requirement now in effect, giving them notice, would that help bring this into proper perspective?

Dr. HOLLOMON. It certainly would. We have been discussing it at some length. As you know, the recent regulations the National Science Foundation has issued under their authority do require notification of experiments. We think this is essential, if we are going to take advantage of the work of other people. We can learn from them. On the other hand, we can assure that there won't be contamination either by Federal experiments affecting theirs or conversely.

I think this notification is an essential element of any national program.

While it is too early at this time to write comprehensive legislation on weather modification, in our view such legislation may be necessary and certainly deserves thoughtful study.

Sound legislation can strengthen any Presidential action and may well be necessary for an orderly achievement of national objectives in weather modification and climate control.

I have three general comments to make before discussing the scope of the new national effort. The substance of these comments may already be familiar to you—thanks to the studies and reports issued over the past year by the Weather Bureau, by the Panel on Weather Modification of the National Academy of Sciences, by the Special Commission on Weather Modification of the National Science Foundation—established after recommendation by the Interdepartmental

Committee on Atmospheric Sciences, of which I am chairman—and by the statements which this committee has heard in the course of these hearings.

My first comment concerns the importance of weather modification. We must keep in mind at all times the vast potential benefit of weather modification to the people of the United States—in fact, to all mankind.

If we can develop the capability to blunt and weaken the thrust of hurricanes, tornadoes, and other severe storms, to increase, lessen, or redistribute precipitation, to suppress hail in crop areas, to cope with lightning discharges in forest areas, and to dissipate all types of fog, we would have a notable scientific and technological achievement which would provide enormous economic benefit.

If we can ever develop the ability to modify weather and climate on a large scale—to effect slight increases or decreases in the average annual rainfall or temperature over a particular locality—we would have a truly staggering achievement. I need only cite here the implications of such an achievement for world food production.

My second comment is that modern science and technology have now brought us to the stage at which it is possible to carry out a broad program of scientific research to determine what types of weather modification are feasible and under what conditions. In this respect, the National Science Foundation, in supporting research, has laid a scientific foundation, and we are now ready for more extensive field tests and experiments.

Our understanding of the physical and chemical processes of the atmosphere and our theories of atmospheric phenomena, while still deficient in many respects, provide a strong base from which to pursue new knowledge about weather modification.

Using the high-speed electronic computer, we have been creating mathematical models for the simulation of atmospheric phenomena. Soon we will be able to experiment with the atmosphere under "controlled" conditions in a computer and seek a deeper scientific understanding of the greater forces affecting weather and climate. And we will be able, we hope, to predict what it means to interfere with these dynamic forces.

We now have a new capacity for observing the atmosphere and gathering the raw data that the research scientist must have. For example, we now are considering an international effort to bring the total global atmosphere under proper observation using satellites and other new technological developments which will be vital to any exploration of large-scale weather modification.

Also, we now have systems to place manmade materials into the atmosphere more effectively, that were unavailable to us a few years ago. These developments—if taken all together—have brought weather modification out of the realm of speculation and have made it possible for the scientists for the first time to determine what types of weather may be modified and controlled. It will take many years of hard work—decades of work in the case of the larger forces of weather. But the point is that we can now develop the scientific and technological capacity to explore how to affect many different kinds of weather conditions.

59-528—66—pt. 1——12

My third comment is that there is now evidence that we may already be able to increase or redistribute precipitation from some types of cloud and storm systems by seeding techniques. In some rainfall, increases have averaged between 10 and 20 percent.

Although the President's Advisory Committee on Weather Control in 1957 reached similar conclusions, I could not have said this with as great confidence 6 months ago. Verifying this evidence was one of the important results of the recent report of the NAS Panel, composed of some of the Nation's leading scientists, which undertook a very thorough scientific review of the evidence.

The Soviets indicate that hail storms possibly can be affected.

The foregoing comments demonstrate that scientifically we are on the threshold of achieving real progress in weather modification research. Conversely, the NAS Panel and the NSF Commission point out that at present the United States lacks a broad, systematic, and comprehensive program to extend and exploit available scientific knowledge.

For example, during fiscal year 1965 the Government spent only about $5 million for direct weather modification studies. During the current fiscal year it will spend approximately $7 million.

Both the NAS Panel and the NSF Commission have called this level of expenditure inadequate and feel it should be increased to $20 to $30 million by 1970.

The NSF Commission also feels that an additional equivalent amount should be available for the conduct of related basic research and the acquisition of facilities.

Further the NAS Panel believes our efforts have been fragmentary and subcritical, far below the size and quality for effective work.

Both the NAS Panel and the NSF Commission urge an immediate and thorough study of ways and means of improving the U.S. efforts in weather modification.

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

What should be the scope of this new national program? The report of the NAS Panel suggests four broad areas of study.

The first is the modification of clouds and storm systems. This would embrace the augmentation and redistribution of precipitation, hail mitigation, lightning suppression, the dissipation of both supercooled and warm fog, and the modification of hurricanes and tornadoes.

The second is the modification of weather and climate over large areas. Here we would be concerned with the science which relates to the altering of the general circulation of the atmosphere. We have no known way of doing so at the present time.

The third area is the modification of local and regional climates. This would involve such things as altering the agricultural microclimate to reduce plant damage due to frost, excessive heat and wind, and ameliorating desert conditions over limited areas.

The fourth activity is the inadvertent modification of the atmosphere by man's activities. Here we would be concerned with the rising level of carbon dioxide in the atmosphere due to the burning of fossil fuels,

with the effects of air pollution and smog on weather and climate, with the effects of alterations in the rural landscape such as forestation, deforestation, and irrigation, with the effects of the injection of additional water vapor into the stratosphere by the supersonic transport, with the contamination of the very high atmosphere by rocket exhausts, and with the meteorological side effects of weather modification experiments.

I should like to emphasize that the question of the inadvertent modification of the weather needs to be as carefully examined as the advertent steps we take. One of the most serious possible problems we have in the future in air pollution is the rising level of the $CO_2$ content of the atmosphere which, if some of the scientists are correct, would indicate it may change the general temperature of the earth and have very serious effects with respect to the melting of the ice cap.

This is not something we can say with any definiteness at the moment, but it is certainly a concern that all of us should have, and we should be monitoring and studying these inadvertent things we are doing to the atmosphere.

At this point I would like to emphasize again that we need to expand our general understanding of the science and technology of weather modification and climate control and to assess the economic, technical, political, social, and legal consequences of the results.

Some of the general functions which would be part of this major responsibility should also include such activities as information gathering, preventing interference with Federal research, considering public safety, possibly paying meritorious claims, and indemnifying Federal contractors and grantees, and cooperating internationally.

I think these issues having to do with the less technical aspects of weather modification, from a scientific point of view, are important, and I think your committee should consider them most seriously.

In a field as new as weather modification, and in which activities are so widespread, information gathering is important. We can find out what each of the Federal departments and agencies is doing through an interagency coordinating mechanism. But what of the activities of State, local, and private groups?

Under its statutory authority, the National Science Foundation is expressly empowered to obtain information by regulation, subpena, or otherwise, to the extent necessary to carry out the purposes of the act.

For many years the National Science Foundation relied upon voluntary after-the-fact reports from State, local, and private cloud seeders. Recently, however, it has issued regulations compelling them to furnish information on their weather modification activities, both advance notices of an intention to seed clouds, and after-the-fact reports.

This authority is vital and should be continued in any expanded program. It is the only way we have of obtaining a total view of what is being done in the United States in the field of weather modification, and the information we gather will also help in the study of particular problems. The agency with the major responsibility must have this information-gathering authority, which needs, in our opinion, to be clarified and strengthened.

Another important problem is how to prevent interference with Federal weather modification projects. As weather modification ac-

tivities increase in number throughout the Nation and extend over more and more territory, there is a growing risk that weather modification research projects conducted by the Federal Government or by groups operating under Federal contract or grant may be severely handicapped by the cloud-seeding activities of State, local, and private weather modifiers.

If the problem is neglected, every weather modification research project conducted by or for the Federal Government and covering a substantial geographical area could be vitiated. The best way to deal with this problem is to authorize the Federal Government to limit any State, local, or private weather modification activity when there are reasonable grounds for belief that it would interfere with another Federal project.

Another potential problem of interference with Federal projects carried out by contractors or grantees might arise under State laws.

About half the States have now enacted laws dealing with weather modification. They are not uniform. Some are concerned with the rights and powers of the State in weather modification. Others regulate private weather modifiers in one way or another. And one State, Maryland, has prohibited all cloud seeding for a period of 2 years.

These State laws do not bind the Federal Government and cannot legally limit or affect the authorized weather modification activities that the Federal Government conducts through its own officers and employees.

However, a broad, systematic national program on weather modification cannot be carried out by the Federal Government solely through its own officers and employees. The Federal Government will have to seek the assistance, through contract or grant of both industry and the scientific community in our universities and research institutions, and these contractors and grantees, even though they would be operating with Federal funds, would, in all likelihood, be subject to the laws of the various States on weather modification.

Accordingly, we should seriously consider Federal legislation which would exempt such contractors and grantees from compliance with State laws on weather modification to the extent that their activities are being conducted at the direction of or with the approval of the Federal Government and are supported by Federal funds. This exemption might also be extended to include injunctions by State courts.

In any event, the Federal Government should see to it that the spirit and policy of the various State laws on weather modification are respected to the fullest extent possible.

There is another broad question in weather modification that has to do with public safety.

Because we lack comprehensive knowledge about weather modification, there may be some danger that large-scale Federal weather research experiments may endanger public safety. We must consider whether this potential danger will require a single agency to have authority to modify or limit Federal experiments where there is unreasonable risk of endangering life or threatening damage to property.

Still another serious problem is the question of liability for harm caused by the Federal Government. The present scientific view is that the risk that a weather modification activity will cause catastrophic harm is minimal. Nonetheless, we must face the possibility that a broad and vigorous program might inflict some damages on innocent

third parties in particular cases. If a claimant can satisfactorily establish a causal relationship between the damage he has suffered and a weather modification activity conducted by the Federal Government, we should consider whether he should be compensated even though there is no fault.

At present, there is no Federal statute which clearly authorizes the payment of a weather modification claim of this type. We believe it is desirable for the agencies of the Federal Government to have authority of this kind. It should be considered within the traditional limits for similar activities.

A significant portion of a national weather modification program will be conducted by Federal contractors and grantees. What is their liability? They do not share in the sovereign immunity of the Federal Government and will be subject to suits for damages. In many instances of liability, they will be fully protected by insurance. In other instances, however, they may have been unable to obtain insurance, or they may sustain liability in excess of the available limits of insurance.

Fairness demands that the Federal Government carefully consider whether it should have authority to indemnify its contractors and grantees who suffer liability in the performance of governmental weather modification research—where the contractor or grantee cannot obtain adequate insurance and is not himself at fault. The Federal departments and agencies cannot do so, however, without express statutory authorization. The question of indemnification must be settled before large-scale research is undertaken for the Government by private contractors or grantees.

Large-scale weather modification activities raise a particularly serious problem about international cooperation. The movement of the atmosphere knows no national boundaries, and a weather modification activity within one nation, if sufficiently large, can affect the weather of other nations. The nations of the world will ultimately have to develop a mechanism to control weather modification activities that can have effects beyond the borders of any one nation.

At the present time the international forum in which the governments of the world meet to exchange views and/or coordinate the problems of weather modification is the World Meteorological Organization, which is a specialized agency of the United Nations. The United States is a member, and the Administrator of the Environmental Science Services Administration is the permanent U.S. representative to the Organization. In time the United States will, however, undoubtedly wish to enter into new international arrangements—both for international cooperation in weather modification research and for the international control of weather modification activities. The international activity alone will require the most careful planning and coordination.

Senator CANNON. What is being done by the World Meteorological Organization now?

Dr. WHITE. It has been conducting reviews of what is going on in the various countries. It has issued reports summarizing this work, and has taken the general stand that in the case of large-scale weather modification, one should know what the consequences will be before one attempts to accomplish it in the field.

Senator CANNON. In other words, it has just been a matter of drawing together information so far? They have had no direct participation in the field of research, either in basic or applied?

Dr. WHITE. That is correct, Mr. Chairman. It is principally a coordinating body. It is not an operating body and does not conduct research by itself.

Senator CANNON. What about the World Weather Watch? Is that part of the same organization?

Dr. WHITE. The World Weather Watch, Mr. Chairman, is being planned by the World Meteorological Organization, with the participation of the various nations. They would not operate the World Weather Watch. The various aspects of the World Weather Watch would be operated by the various member countries in accordance with the plans agreed upon.

Senator CANNON. Would that information be channeled through some other source?

Dr. WHITE. It would be channeled through the World Meteorological Organization, sir.

Senator CANNON. Doctor, getting back to this previous statement relating to indemnification of Federal contractors and grantees, you indicated that the question must be settled before large-scale research is undertaken through private contractors or grantees. I was wondering, has there been any reluctance on the part of private contractors or grantees, insofar as the Government programs up to this time are concerned?

Dr. HOLLOMON. It is my understanding that in some cases at the moment some of the private contractors are having some difficulty obtaining adequate insurance. I know of no specific reluctance, but I do understand that the difficulty of getting insurance is increasing. As you may know, there has been a case in Texas in which, as a result of an injunction, experiments were prohibited on the part of private parties.

Senator CANNON. And, of course, there have been some damage suits filed, too. But I don't know whether that involves any of the direct Government grantees or not.

Dr. HOLLOMON. I do not believe there has been such a case where it involved the direct Government grantees.

The launching of an expanded weather modification program on a national scale will undoubtedly create future problems which we can't anticipate. Uutimately, a regulatory body may be required which would function separately from the research and operational programs of the Federal agencies. That body at some time in the future even may be called upon to prescribe regulations for private operations and, possibly, the technical and financial qualifications of those who may engage in weather modification activities or to license these operations. One major responsibility will be to study and assess the national program and periodically report the results of this study to the President and the Congress with emphasis on the need for future regulatory controls. This duty might well be spelled out in any legislation enacted.

We do not believe it is wise at this time to consider the nature of such controls.

I should like to describe briefly the activities of the Environmental Science Services Administration. This Administration was created

by Reorganization Plan No. 2 of 1965, which consolidated the Weather Bureau, the Coast and Geodetic Survey and the Central Radio Propagation Laboratory of the National Bureau of Standards.

In his transmittal message to the Congress, the President stated this "new Administration will then provide a single national focus for our efforts to describe, understand, and predict the state of the oceans, the state of the lower and upper atmosphere, and the size and shape of the earth."

ESSA's Weather Bureau has been heavily involved in weather prediction and weather modification research.

In its role of weather prediction, the Weather Bureau observes, measures, records, reports, and forecasts the weather for the public benefit. It also provides special forecasting services which are of immense benefit to aviation, agriculture, shipping, and other commercial, as well as Government interests. It maintains about 300 principal stations throughout the United States. In addition, there are about 12,000 part-time observation facilities. As weather is international, the Weather Bureau receives observations from all over the world. Data are evaluated by high-speed electronic computers and transmitted to users by teletypewriter and facsimile.

I would like to make the point that the weather modification role of ESSA is bound to its weather-prediction role much like siamese twins with a common heart. Weather modification research cannot be viewed as something apart from weather prediction, since they both use similar data and equipment. Both require sophisticated observational equipment, such as satellites, radar, ocean and land observations, and balloon soundings. If we fail to recognize this fact, we run the risk of inefficiency in the use of facilities and in scientific research. There are other reasons why weather prediction and modification are bound together. If we ultimately attempt to modify the weather on a large scale, we shall have to be able to predict beforehand what would have happened had we not made the attempt.

In addition, many field experiments will require particular atmospheric conditions, and we must be able to predict when these conditions will exist. And when any particular type of weather modification becomes fully operational, the decision as to whether to modify the weather in a given instance will depend in large measure on our prediction of what the weather will be if we don't modify it.

Finally, weather modification research requires considerable background information that only the atmospheric sciences can provide, such as the movement of water through the atmosphere.

In its weather modification and associated activities, ESSA has a large corps of scientists and engineers—numbering approximately 200—with special capabilities in the field of weather modification and related areas. About 25 percent of these have doctorates. It also has research facilities throughout the United States for weather modification.

I would like to comment to you on several of these. The largest single project has been Project Stormfury, in cooperation with the Navy, to seek to determine the structure of hurricanes and how they may be modified. At its National Severe Storms Laboratory in Norman, Okla., it is conducting extensive research on tornadoes. The Norman Laboratory is also studying the origin and structure of hail. And ESSA is now designing a project for the Great Lakes area, which

is a vast natural laboratory for the study of atmospheric processes and the structure of storms. These projects require extensive facilities—a network of observing stations, radar, and most costly, specially instrumented aircraft.

In precipitation augmentation, ESSA has carried out scientific evaluation studies of various cloud-seeding activities to assist the NAS Panel. To follow up the work of the Panel, ESSA is now designing a project in the Northeast to determine under what conditions precipitation augmentation and redistribution is possible in the eastern portion of the United States.

I have already commented on the large computer facilities now in existence studying the simulation of the atmosphere and one of the largest and most sophisticated of these is Geophysical Fluid Dynamics Laboratory of ESSA.

We have also begun in ESSA to study the interactions and the exchanges of energy between the atmosphere and the underlying earth and oceans. As the NAS panel pointed out, an understanding of these exchanges is fundamental to the development of a capability in large-scale weather and climate modification and in the modification of local and regional climates. Investigations are also underway on the physics and chemistry of the atmosphere.

Finally, I must not fail to point out the problem of the inadvertent modification of weather and climate by man himself—by the burning of fossil fuels, by the expansion of cities, by the flight of aircraft, and by the launching of space vehicles. ESSA is very much concerned with the meteorology of inadvertent modification. It is continually monitoring the levels of carbon dioxide in the atmosphere and analyzing the effects of man's activities on weather and climate. This activity will support the missions of agencies and others trying to do something about pollution of the atmosphere or city smog.

I should emphasize that, in addition to the scientific facilities and skills of the Department of Commerce and other agencies, the private resources of industry, universities, and the scientific community have proved essential in past weather modification research. The continued use of these resources through contracts and grants must be accelerated and amplified in carrying out a strengthened national weather modification program.

Senator CANNON. What will be the effect of transferring NSF authority to ESSA on the existing programs in the universities and private organizations?

Dr. HOLLOMON. I think the existing programs should be continued and expanded, Mr. Chairman.

Senator CANNON. In other words, there would be no contemplated change in the conduct of these programs, going ahead with these programs.

Dr. HOLLOMON. Only insofar as we learn something new, which obviously means we ought to modify them. But the general thrust of those programs in my opinion should continue, Mr. Chairman.

Senator CANNON. Is ESSA now supporting university research in weather modification?

Dr. WHITE. We support extensive university research in the atmospheric sciences. We have not had a large amount of resources in the particular field of weather modification in past years, and our support for particular items labeled weather modification in the universities

has been small. But our general contract program in support of atmospheric research in the universities has been quite substantial.

Senator CANNON. Where have you been conducting that? In many or just a few universities?

Dr. WHITE. All over the country. Many universities indeed have contractual support from the ESSA organization.

Senator CANNON. For example, my own State University of Nevada, is their program supported by ESSA?

Dr. WHITE. That is not supported by ESSA, Mr. Chairman. I don't have a list of the contracts available. But we support projects at MIT, University of Wisconsin, Florida State University, and a large number of others. I have provided a list.

Senator CANNON. The list will be included in the record at this point. You may proceed.

U.S. DEPARTMENT OF COMMERCE

ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

*University research contracts and grants in the atmospheric sciences*

[In thousands of dollars]

| | Fiscal year 1965 | Fiscal year 1966 (as of February 1966) |
|---|---|---|
| Institute for Atmospheric Sciences: | | |
| University of Chicago: | | |
| Studies of hurricanes and other tropical phenomena | 60.0 | |
| Severe storm morphology | | 60.0 |
| Dynamics of low-latitude circulation (joint with NESC) | | 22.5 |
| University of Colorado: Studies of Kraichnan's theory of turbulence | | 19.4 |
| Colorado State University: | | |
| Studies of circulation and weather patterns in the tropics | 35.0 | 35.0 |
| Atmospheric conditions associated with hurricane formation | | 23.8 |
| Florida State University: | | |
| Hurricane and other tropical meteorological studies | 19.8 | |
| Fluctuations of planetary atmospheric circulation (joint with NESC) | | 10.0 |
| Johns Hopkins University: Theoretical and experimental studies in geophysical hydrodynamics | 18.9 | 15.4 |
| University of Maryland: Observational studies of the atmospheric and oceanic planetary boundary layers | 19.8 | |
| Massachusetts Institute of Technology: | | |
| Extended forecast studies | 40.0 | |
| Research on air-sea interactions | | 15.0 |
| Prediction of tropical cyclone tracks | | 17.2 |
| University of Miami: | | |
| History of climatology of tropical cyclones in the Caribbean area | 5.4 | |
| Investigations of hurricanes by radar | 28.9 | 21.0 |
| Undergraduate research participation in atmospheric sciences | 7.5 | 17.7 |
| Hurricane tritium project | | 42.9 |
| Investigation of techniques for high altitude ozone measurements | | 39.5 |
| Use of synoptic and numerical models for forecasting hurricane motions | | 9.4 |
| Extent and periodicity of hurricane season in the North Atlantic | | 5.5 |
| Hurricane and tropical storm research | | 13.1 |
| University of Michigan: | | |
| Investigation of atmospheric turbulence transfer processes over Lake Michigan | 64.8 | 62.1 |
| Mean meridional circulation in the atmosphere | 33.7 | |
| Investigations of air-sea interaction processes in Great Lakes region | | [1] 14.5 |
| New York University: | | |
| Numerical models of synoptic-scale ocean circulation systems | | 23.2 |
| Severe storms research | | 5.0 |
| University of Oklahoma: | | |
| Severe storm radar investigations | 4.2 | 12.4 |
| Supporting work for severe storms research | 2.5 | 4.2 |
| Statistical and dynamical analysis of severe storms | | 10.5 |
| Oklahoma State University: Use of balloons for atmospheric turbulence measurements | | 6.0 |
| University of Oslo (Norway): Atmospheric motions research | 13.0 | |
| Woods Hole Oceanographic Institute: | | |
| Clouds physics in trade winds and hurricanes | | 3.4 |
| Physics and dynamics of "Stormfury" cumulus experimental data | | 15.0 |
| University of Wisconsin: Empirical and theoretical studies of atmospheric energetics (joint with NESC) | 20.4 | |

See footnote at end of table.

*University research contracts and grants in the atmospheric sciences*—Continued

[In thousands of dollars]

| | Fiscal year 1965 | Fiscal year 1966 (as of February 1966) |
|---|---|---|
| Institute for Oceanography: Woods Hole Oceanographic Institute: Investigation of land-sea interaction in littoral zones during large storms | | 18.5 |
| National Environmental Satellite Center: | | |
| University of California (Los Angeles): Studies of cloud bands, using satellite data | | 15.7 |
| University of Chicago: | | |
| Interpretation of meteorological satellite data | 90.0 | |
| Dynamics of low-latitude circulation (joint with IAS) | | 26.5 |
| Colorado State University: Investigation of effects of Large Mountain ranges on atmospheric flow, using satellite data | 140.0 | 48.2 |
| Florida State University: | | |
| Fluctuations of planetary atmospheric circulation (joint with IAS) | 19.9 | 20.6 |
| Tropical storm investigations in the Atlantic, Caribbean, and Gulf | 80.4 | 45.0 |
| University of Hawaii: Hurricane circulation | | 14.1 |
| Johns Hopkins University: Study of 6.3 micron water vapor absorption band | 10.0 | 20.0 |
| University of London: Dynamics of mesoscale features | | 11.0 |
| University of Maryland: Ozone radiance and satellite instrumentation | | [1] 60.0 |
| University of Miami: Satellite data applications in hurricane research | 9.0 | 18.6 |
| University of Michigan: | | |
| Incorporation of satellite data in numerical weather analysis | 32.1 | [1] 30.0 |
| Support for balloon-borne instrument tests | 42.2 | |
| Study of radiance spectrum of 15 micron $CO_2$ band | 31.9 | |
| University of Oklahoma: Investigations of convective and orographic cloud systems using satellite data | 69.4 | |
| Pennsylvania State University: Studies of relation between infrared radiation and meteorological variables | 21.8 | 4.2 |
| St. Louis University: "Temporal" tropical storm investigation | | 50.0 |
| Texas A. & M. University: Moisture analysis from satellite data | | 19.0 |
| Tohoku University (Japan): Atmospheric radiance of $CO_2$ | | 10.0 |
| University of Utah: Mesoscale dynamics | | 20.0 |
| Virginia Military Institute: | | |
| Engineering analysis of satellite spectrometer | 3.1 | |
| Optimum design of satellite instrumentation | 12.4 | 1.3 |
| University of Wisconsin: | | |
| Empirical and theoretical studies of atmospheric energetics (joint with IAS) | 103.5 | [1] 55.0 |
| Studies in atmospheric energetics based on aerospace probing | 334.0 | |
| Atmospheric radiance and satellite instrumentation | | [1] 337.0 |
| Weather Bureau: | | |
| University of California: Evapotranspiration studies | 19.0 | |
| Drexel Institute of Technology: Measurement and analysis of meteorological data from an instrumented tower | 115.8 | |
| University of Michigan: Evaluation of meteorological probability prediction system | | 9.8 |
| Memphis State University: Humidity sensor elements research | 4.6 | 3.0 |
| Montana State University: Forecasting cold waves near Helena, Mont | | 20.0 |
| University of Oklahoma: Mesoscale analysis and forecasting | | [1] 20.0 |
| Pennsylvania State University: | | |
| Clear air turbulence studies | 6.4 | 8.8 |
| Analysis of meteorological data from an instrumented tower | 7.4 | |
| Study of physical processes important in fog formation | 13.4 | |
| Environmental Data Service: | | |
| University of Akron: Statistical studies of wind gusts | 3.0 | 5.0 |
| University of Arizona: | | |
| Dendroclimatic studies | 6.0 | 6.0 |
| Relation of circulation patterns to drought | | [1] 10.0 |
| University of Florida: Investigation of evapotranspiration from orange groves | | 4.7 |
| Iowa State University: Effects of weather on crops | 9.0 | |
| Kansas State University: | | |
| Agricultural uses of climatic data | 4.0 | |
| Effects of drought on Great Plains economy | | 10.9 |
| University of Miami: Study of recent climatic changes in selected areas | | 9.4 |
| Massachusetts Institute of Technology: Long-range prediction methodology | | 10.0 |
| University of Nebraska: Wind-barrier-induced variations in plant response | 5.0 | |
| Pennsylvania State University: Plastics as ultraviolet radiation sensors | 4.9 | |
| Rutgers University: Relation of drought to quality and quantity of surface water | | 29.5 |
| Texas A. & M. University: Study of weather and its effect on nitrate poisoning in livestock | 2.8 | |
| University of Texas: Preliminary study of large-scale meteorological factors producing drought | | 3.0 |
| University of Wisconsin: Development of net radiometer integrator | 4.8 | |

[1] Proposed.

Dr. HOLLOMON. I will now speak of weather modification activities of other Federal agencies.

To be successful, an expanded national weather modification program will require weather modification to be specially applied to the missions of other Federal agencies. The Department of Commerce, of course, we believe should be concerned with advancing the science and technology of weather modification generally. The Department of the Interior, however, must assess the Nation's water resources and investigate weather modification techniques to carry out this specific mission. The Federal Aviation Agency must conduct research into safe and efficient methods for the dissipation of airport fog. Similarly, the Department of Defense is concerned with research into the military applications of weather modification, and the National Science Foundation must continue to support basic scientific studies that relate to weather modification.

### REGARDING COORDINATION OF THE FEDERAL PROGRAM

The Interdepartmental Committee for Atmospheric Sciences (ICAS), which was established by and reports to the Federal Council for Science and Technology, has in the past coordinated matters of basic policy in weather modification as part of atmospheric science. It will continue to do so and can easily be strengthened in this role, if necessary.

While ICAS provides a competent body for the coordination of questions of basic policy, there is a definite need for the coordination of weather modification operations and supporting research. Recent experience suggests that this need for coordination of operational aspects should follow the successful pattern for coordinating meteorology, as set forth in Bureau of the Budget Circular A-62. Under this circular, the Department of Commerce coordinates the meteorological activities of the Federal departments and agencies and to do this has established, in ESSA, an Office of Federal Coordinator for Meteorological Services and Supporting Research.

It has a competent staff in that direction and provides a report every year to the Congress on the total program in meteorology. It has not so far included weather modification. It would be our recommendation to do so. It has also been possible, as a result of this coordinating mechanism, to save money on the part of various agencies, to provide a common program and common directions for the program.

Having examined the scope of a redirected national weather modification program and discussed the activities of ESSA and other agencies, I return to the legislation now being considered.

As I said earlier, there are two sets of problems now facing us. The first is acquiring the knowledge to change the weather and control climate. The second is deciding how best to use this knowledge. To carry out an expanded Federal research program, legislation is desirable now (1) to authorize appropriate limitations on State and private weather modification activities which would interfere with Federal research, and (2) to clarify existing authority to permit regulations to be issued requiring full reporting of private activities before they occur.

It is reasonably clear, however, that comprehensive legislation may be necessary for a coherent national policy covering both sets of problems with emphasis on the regulatory aspects. If legislation is enacted now, it would be desirable in such legislation to call for studies and reports on the regulatory controls that will be necessary in the future. These studies could form the basis for comprehensive legislation dealing with the following problems, as well as others.

We would like to raise for the committee some questions which we think need to be carefully considered:

(1) Whether expanded authority is necessary to clarify the scope of research and experimentation necessary to carry out the major responsibilities for advancing the science and technology of weather modification and climate control, after any executive reorganization.

(2) Whether the broad national objectives should be established by legislation.

(3) Whether the Secretary of Commerce should have appropriate authority to assess all private and State research and operational programs to preclude endangering the public safety.

(4) Whether the Secretary of Commerce and heads of other agencies should have appropriate authority to pay claims resulting from their research and to indemnify Government contractors and grantees, within traditional limits.

(5) Whether there should be clear authority that Federal contractors and grantees are exempt from State laws and regulations on weather modification.

(6) Whether it is desirable for the Secretary of Commerce to have appropriate authority to facilitate international cooperation in weather modification activities, including the authority to enter into international arrangements on behalf of the United States, subject to the foreign policy guidance of the Secretary of State.

(7) Whether the Secretary of Commerce should have regulatory responsibilities which would be a function separate from the conduct of research and development.

Mr. Chairman, the problems we have in achieving a coherent national policy in weather modification are extraordinarily complex. If we cope with them boldly and with imagination, the opportunities we have can be extended to benefit all mankind. And we in the Department of Commerce stand ready to help this committee in its deliberations in any way possible.

(Full text of statement follows:)

STATEMENT OF J. HERBERT HOLLOMON, ASSISTANT SECRETARY OF COMMERCE FOR SCIENCE AND TECHNOLOGY

Mr. Chairman and members of the committee, I am pleased to be here today and to have the opportunity to present the views of the Department of Commerce on weather modification and on S. 23 and S. 2916, bills on this subject.

The question these hearings can illuminate and help answer is how we shall achieve a coherent national policy for weather modification. The Department of Commerce strongly supports sound steps toward such a policy, including needed legislation, and favors the purposes of S. 2916.

The President said last week in his transmittal message to Congress on the annual weather modification report:

"Two sets of problems face us and both are difficult. One consists of finding out how to modify the weather and climate. The second consists of determining how best to utilize this knowledge for the benefit of mankind once it is achieved."

The first of these requires an expanded and redirected effort in the science and technology of weather modification itself. This should proceed without delay, with major reliance upon the resources of the Environmental Science Services Administration in the Department of Commerce. The second requires thorough considerations of public policy—of economic, legal, and social consequences, when the scientific results are put to use privately or by the Government. It means thoughtful study, dialog and debate on questions of public law and organization. These considerations should begin at once, though there are immediate steps which can be taken in support of the expanded Federal research program. Before long, however, we must decide what kinds of future policies and regulatory controls are desirable for public and private activities seeking to modify the weather or climate.

After a brief review of the bills now before you, I shall describe the need for a redirection of national effort in weather modification and outline the elements and scope of this redirection. Then I shall discuss the capabilities of the Department of Commerce and other agencies. Finally, I think it appropriate to spell out our recommendations for needed legislation to support the immediate research effort and suggest some legislative questions for consideration.

### S. 23 TO AUTHORIZE THE SECRETARY OF INTERIOR TO CONDUCT PROGRAMS FOR INCREASING PRECIPITATION

S. 23 directs the Secretary of the Interior to conduct a program in five areas of the United States to increase usable precipitation. The Department of the Interior already has underway a program similar to that proposed in the bill. It has certain mission responsibilities concerning the Nation's water resources, and we support its efforts in using weather modification to assist in carrying out its mission. But we do not believe that legislation is necessary for this purpose. For this reason, we do not recommend enactment of S. 23.

### S. 2916 TO AUTHORIZE THE SECRETARY OF COMMERCE TO CONDUCT A WEATHER MODIFICATION PROGRAM

S. 2916 in effect would transfer to the Secretary of Commerce the authority now in the National Science Foundation to carry out a weather modification program, including applied research, development, and experimentation. It would restate such authority, but in greater detail than the Foundation's existing statutory authority. It also would limit the research authorized to that for applied research, development, and experimentation. It would provide authority for the transfer of personnel, property, and appropriations and would repeal existing statutes authorizing the Director of the National Science Foundation to conduct a weather modification program. It would make clear that the National Science Foundation would continue to have authority for scientific studies in weather modification as part of the atmospheric sciences.

Further, S. 2916 would authorize the Secretary of Commerce to issue regulations affecting any operation of commercial enterprises engaged in weather modification which conflict with or impede any authorized activities. It would require a report to Congress, within a year after enactment, on recommendations for additional legislation concerning the enforcement of such regulations. The authority now in the National Science Foundation to hold hearings and obtain information also would be placed in the Secretary of Commerce.

The bill specifically would authorize international cooperation under the policy guidance of the Secretary of State and would require the Secretary of Commerce or his designee to be a member of any U.S. delegation at intergovernmental meetings and conferences relating to weather modification and climate control.

We fully support the purposes of S. 2916, although we believe that it is premature and that the aspects of this bill which relate to reorganization in the executive branch can be accomplished best through an executive reorganization. A Presidential reorganization plan along these lines is now under active consideration. We do not agree, however, that the authority in the Secretary of Commerce should be limited to applied research since there are many scientific

investigations of a fundamental nature which would be carried out in any large scale weather modification research or experimentation program. Also, if legislation on this subject is enacted, it should contain effective authority to limit private weather modification activities in direct conflict with the research or experiments carried out by the Department of Commerce. Authority to issue regulations governing these conflicts would be of little significance to any large-scale research effort if there is no enforcement mechanism.

While it is too early at this time to write comprehensive legislation on weather modification, in our view such legislation may be necessary and certainly deserves thoughtful study. Sound legislation can strengthen any Presidential action and may well be necessary for an orderly achievement of national objectives in weather modification and climate control.

### GENERAL COMMENTS ON WEATHER MODIFICATION

I have three general comments to make before discussing the scope of the new national effort. The substance of these comments may already be familiar to you—thanks to the studies and reports issued over the past year by the Weather Bureau, by the Panel on Weather Modification of the National Academy of Sciences, by the Special Commission on Weather Modification of the National Science Foundation (established after recommendation by the Interdepartmental Committee on Atmospheric Sciences of which I am chairman), and by the statements which this committee has heard in the course of these hearings.

My first comment concerns the importance of weather modification. We must keep in mind at all times the vast potential benefit of weather modification to the people of the United States—in fact, to all mankind. If we can develop the capability to blunt and weaken the thrust of hurricanes, tornadoes, and other severe storms, to increase, lessen, or redistribute precipitation, to suppress hail in crop areas, to cope with lightning discharges in forest areas, and to dissipate all types of fog, we would have a notable scientific and technological achievement. And if we can ever develop the ability to modify weather and climate on a large scale—to effect slight increases or decreases in the average annual rainfall or temperature over a particular locality—we would have a truly staggering achievement. I need only cite here the implications of such an achievement for world food production.

My second comment is that modern science and technology have now brought us to the stage at which it is possible to carry out a broad program of scientific research to determine what types of weather modification are feasible and under what conditions. In this respect, the National Science Foundation has laid a scientific foundation and we are now ready for more extensive field tests and experiments. Our understanding of the physical and chemical processes of the atmosphere and our theories of atmospheric phenomena, while still deficient in many respects, provides a strong base from which to pursue new knowledge about weather modification. Using the high-speed electronic computer, we have been creating mathematical models for the simulation of atmospheric phenomena. Soon, we will be able to experiment with the atmosphere under "controlled" conditions and seek a deeper scientific understanding of the greater forces affecting weather and climate. And we will be able to predict what it means to interfere with these dynamic forces.

We now have a new capacity for observing the atmosphere and gathering the raw data that the research scientist must have. For example, we now are considering an international effort to bring the total global atmosphere under proper observation using satellites and other new developments in technology which will be vital to any exploration of large-scale weather modification. Also, we now have systems to place manmade materials into the atmosphere (to make changes in it) that were unavailable to us a few years ago. These developments—if taken all together—have brought weather modification out of the realm of speculation and have made it possible for the scientist for the first time to determine what types of weather may be modified and controlled. It will take many years of hard work—decades of work in the case of the larger forces of weather. But the point is that we can now develop the scientific and technological capability to explore how to affect many different kinds of weather conditions.

My third comment is that there is now evidence that we may already be able to increase or redistribute precipitation from some types of cloud and storm systems by seeding techniques. In some rainfall, increases have averaged between 10 and 20 percent. Although the President's Advisory Committee on

Weather Control in 1957 reached similar conclusions, I could not have said this with great confidence 6 months ago. Verifying this evidence was one of the important results of the recent report of the NAS Panel, composed of some of the Nation's leading scientists, which undertook a very thorough scientific review of the existing evidence. The Soviets indicate that hailstorms possibly can be affected.

As the President emphasized in his recent message, the key question today is not "whether" and "when" to modify the weather and climate, but "what" to modify, "how" to modify it, and "who" should carry it out. The immediate technical problem is a general one which must be approached as a whole, for the technical questions are largely the same for hurricane control as for other specific applications. The task we must begin is to organize the necessary scientific and technical resources to learn what can be done and how best to do it and to assess the consequences, considering all parts as a whole.

### NEED FOR REDIRECTION OF NATIONAL WEATHER MODIFICATION EFFORTS

The foregoing comments demonstrate that scientifically we are on the threshold of achieving real progress in weather modification research. Conversely, the NAS Panel and the NSF Commission point out that at present the United States lacks a broad, systematic, and comprehensive program to extend and exploit available scientific knowledge.

For example, during fiscal year 1965 the Government spent only about $5 million for direct weather modification studies concerned with introducing foreign materials in the atmosphere. During the current fiscal year, it will spend approximately $7 million. Both the NAS Panel and the NSF Commission have called this level of expenditure inadequate and feel it should be increased to $20 to $30 million by 1970. The NSF Commission also feels that an additional equivalent amount should be available for the conduct of related basic research and the acquisition of facilities.

Further, the NAS Panel points out that in the past our efforts have been fragmentary and subcritical—far below the size and quality for effective work.

Both the NAS Panel and the NSF Commission urge an immediate and thorough study of ways and means of improving the U.S. efforts in weather modification.

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

### SCOPE OF NEW NATIONAL PROGRAM

What should be the scope of this new national program? The report of the NAS Panel suggests four broad areas of study. The first is the modification of clouds and storm systems. This would embrace the augmentation and redistribution of precipitation, hail mitigation, lightning suppression, the dissipation of both supercooled and warm fog, and the modification of hurricanes and tornadoes. The second is the modification of weather and climate over large areas. Here we would be concerned with altering the general circulation of the atmosphere. We have no known way of doing so at the present time. The third area is the modification of local and regional climates. This would involve such things as altering the agricultural microclimate to reduce plant damage due to frost, excessive heat and wind, and ameliorating desert conditions over limited areas. The fourth activity is the inadvertent modification of the atmosphere by man's activities. Here we would be concerned with the rising level of carbon dioxide in the atmosphere due to the burning of fossil fuels, with the effects of air pollution and smog on weather and climate, with the effects of alterations in the rural landscape such as forestation, deforestation and irrigation, with the effects of the injection of additional water vapor into the stratosphere by the supersonic transport, with the contamination of the very high atmosphere by rocket exhausts, and with the meteorological side effects of weather modification experiments. These four areas for study deal, of course, only with atmospheric research. Beyond them, a broad, systematic national program must bring under study many other effects of the various types of weather modification, their value and their implications, both in this country and internationally.

At this point I must emphasize again that we need to expand our general understanding of the science and technology of weather modification and climate con-

trol and to assess the economic, technical, political, social, and legal consequences of the results. As both the NAS Panel and the NSF Commission suggest, a single agency should have major responsibilities for advancing the general technology of weather modification, subject, of course, to the mission responsibilities of other agencies. Some of the general functions which would be part of this major responsibility should also include such activities as information gathering, preventing interference with Federal research, considering public safety, possibly paying meritorious claims and indemnifying Federal contractors and grantees, and cooperating internationally. Let me explore these in greater detail, since they are of immediate concern.

### INFORMATION GATHERING

In a field as new as weather modification and in which activities are so widespread, information gathering is important. We can find out what each of the Federal departments and agencies is doing through an interagency coordinating mechanism. But what of the activities of State, local, and private groups? Under its statutory authority, the National Science Foundation is expressly empowered to obtain information by regulation, subpena, or otherwise to the extent necessary to carry out the purposes of the act. For many years the National Science Foundation relied upon voluntary after-the-fact reports from State, local, and private cloud seeders. Recently, however, it has issued regulations compelling them to furnish information on their weather-modification activities, both advance notices of an intention to seed clouds and after-the-fact reports. This authority is vital and should be continued in any expanded program. It is the only way we have of obtaining a total view of what is being done in the United States in the field of weather modification, and the information we gather will also help in the study of particular problems. The agency with the major responsibilities must have this information-gathering authority, which needs to be clarified and strengthened.

### PREVENTION OF INTERFERENCE WITH FEDERAL PROJECTS

Another important problem is how to prevent interference with Federal weather modification projects. As weather modification activities increase in number throughout the Nation and extend over more and more territory, there is a growing risk that weather-modification research projects conducted by the Federal Government or by groups operating under Federal contract or grant may be severely handicapped by the cloud-seeding activities of State, local, and private weather modifiers. If the problem is neglected, every weather modification research project conducted by or for the Federal Government and covering a substantial geographical area could be vitiated. The best way to deal with this problem is to authorize the Federal Government to limit any State, local, or private weather modification activity when there are reasonable grounds for belief that it would interfere with another Federal project.

Another potential problem of interference with Federal projects carried out by contractors or grantees might arise under State laws.

About half the States have now enacted laws dealing with weather modification. They are not uniform. Some are concerned with the rights and powers of the State in weather modification. Others regulate private weather modifiers in one way or another. And one State—Maryland—has prohibited all cloud seeding for a period of 2 years. These State laws do not bind the Federal Government and cannot legally limit or affect the authorized weather modification activities that the Federal Government conducts through its own officers and employees. However, a broad, systematic national program of weather modification research cannot be carried out by the Federal Government solely through its own officers and employees. The Federal Government will have to seek the assistance, through contract or grant, of both industry and the scientific community in our universities and research institutions. And these contractors and grantees, even though they would be operating with Federal funds, would, in all likelihood, be subject to the laws of the various States on weather modification. Accordingly, we should seriously consider Federal legislation which would exempt such contractors and grantees from compliance with State laws on weather modification to the extent that their activities are being conducted at the direction of or with the approval of the Federal Government and are supported by Federal funds. This exemption might also be extended to include injunctions

by State courts. In any event, the Federal Government should see to it that the spirit and policy of the various State laws on weather modification are respected to the fullest extent possible.

### RELATIONSHIP TO THE PUBLIC SAFETY

Because we lack comprehensive knowledge about weather modification, there may be some danger that large-scale Federal weather research experiments may endanger public safety. We must consider whether this potential danger will require a single agency to have authority to modify or limit Federal experiments where there is unreasonable risk of endangering life or threatening damage to property.

Still another serious problem is the question of liability for harm caused by the Federal Government. The present scientific view is that the risk that a weather modification activity will cause catastrophic harm is minimal. Nonetheless, we must face the possibility that a broad and vigorous program might inflict some damages on innocent third parties in particular cases. If a claimant can satisfactorily establish a causal relationship between the damage he has suffered and a weather modification activity conducted by the Federal Government, we should consider whether he should be compensated even though there is no fault.

At present, there is no Federal statute which clearly authorizes the payment of a weather modification claim of this type. We believe it is desirable for the agencies of the Federal Government to have authority of this kind. It should be considered within the traditional limits for similar activities.

### INDEMNIFICATION OF FEDERAL CONTRACTORS AND GRANTEES

A significant portion of a national weather modification program will be conducted by Federal contractors and grantees. What is their liability? They do not share in the sovereign immunity of the Federal Government and will be subject to suits for damages. In many instances of liability, they will be fully protected by insurance. In others, however, they may have been unable to obtain insurance, or they may sustain liability in excess of the available limits of insurance.

Fairness demands that the Federal Government carefully consider whether it should have authority to indemnify its contractors and grantees who suffer liability in the performance of governmental weather modification research—where the contractor or grantee cannot obtain adequate insurance and is not himself at fault. The Federal departments and agencies cannot do so, however, without express statutory authorization. The question of indemnification must be settled before large-scale research is undertaken for the Government by private contractors or grantees.

### INTERNATIONAL COOPERATION

Large-scale weather modification activities raise a particularly serious problem. The movement of the atmosphere knows no national boundaries, and a weather modification activity within one nation, if sufficiently large, can affect the weather of other nations. The nations of the world will ultimately have to develop a mechanism to control weather modification activities that can have effects beyond the borders of any one nation.

At the present time the international forum in which the governments of the world meet to exchange views and/or coordinate the problems of weather modification is the World Meteorological Organization, which is a specialized agency of the United Nations. The United States is a member, and the Administrator of the Environmental Science Services Administration is the permanent U.S. representative to the Organization. In time the United States will, however, undoubtedly wish to enter into new international arrangements—both for international cooperation in weather modification research and for the international control of weather modification activities. The international activity alone will require the most careful planning and coordination.

### STUDIES AND RECOMMENDATIONS

The launching of an expanded weather modification program on a national scale will undoubtedly create future problems of a novel nature beyond just those mentioned above. Ultimately, a regulatory body may be required which would

function separately from the research and operational programs of the Federal agencies. That body at some time in the future even may be called upon to prescribe regulations for private operations and, possibly, the technical and financial qualifications of those who may engage in weather modification activities or to license these operations. One major responsibility will be to study and assess the national program and periodically report the results of this study to the President and the Congress with emphasis on the need for future regulatory controls. This duty might well be spelled out in any legislation enacted.

### WEATHER MODIFICATION ACTIVITIES OF ESSA

In turning next to the capabilities of the Department of Commerce for undertaking major responsibilities in weather modification activities, we should review what has been done and what is planned by the Department's Environmental Science Services Administration. As you know, ESSA was created by Reorganization Plan No. 2 of 1965 which consolidated the Weather Bureau and the Coast and Geodetic Survey. In his transmittal message to the Congress, the President stated this "new Administration will then provide a single national focus for our efforts to describe, understand and predict the state of the oceans, the state of the lower and upper atmosphere, and the size and shape of the earth."

ESSA's Weather Bureau has been heavily involved in weather prediction and weather modification research.

In its role of weather prediction, the Weather Bureau observes, measures, records, reports, and forecasts the weather for the public benefit. It also provides special forecasting services which are of immense benefit to aviation, agriculture, shipping, and other commercial, as well as Government interests. It maintains about 300 principal stations throughout the United States. In addition, there are about 12,000 part-time observation facilities. As weather is international, the Weather Bureau receives observations from all over the world. Data are evaluated by high-speed electronic computers and transmitted to users by teletypewriter and facsimile.

I must here make the explicit point that the weather modification role of ESSA is bound to its weather prediction role much like siamese twins with a common heart. Weather modification research cannot be viewed as something apart from weather prediction, since they both use similar data and equipment. Both require sophisticated observational equipment, such as satellites, radar, ocean and land observations, and balloon soundings. If we fail to recognize this fact, we run the risk of inefficiency in the use of facilities and in scientific research. There are other reasons why weather prediction and modification are bound together. If we ultimately attempt to modify the weather on a large scale, we shall have to be able to predict beforehand what would have happened had we not made the attempt. In addition, many field experiments will require particular atmospheric conditions, and we must be able to predict when these conditions will exist. And when any particular type of weather modification becomes fully operational, the decision as to whether to modify the weather in a given instance will depend in large measure on our prediction of what the weather will be. Finally, weather modification research requires considerable background information that only the atmospheric sciences can provide, such as the movement of water through the atmosphere.

In its weather modification activities, ESSA has a large corps of scientists and engineers—numbering approximately 200 with special capabilities in the field of weather modification and related areas. About 25 percent have doctorates. It also has research facilities throughout the United States for weather modification. Let me describe some of its projects.

In conjunction with the Navy, ESSA has been conducting Project Stormfury, which is seeking to determine the structure of hurricanes and how they may be modified. At its National Severe Storms Laboratory in Norman, Okla., it is conducting extensive research on tornadoes. The Norman Laboratory is also studying the origin and structure of hail. And ESSA is now designing a project for the Great Lakes area, which is a vast natural laboratory for the study of atmospheric processes and the structure of storms. These projects require extensive facilities—a network of observing stations, radar, and specially instrumented aircraft.

In precipitation augmentation, ESSA has carried out scientific evaluation studies of various cloud-seeding activities to assist the NAS Panel. To follow

up the work of the Panel, ESSA is now designing a project in the Northeast to determine under what conditions precipitation augmentation and redistribution is possible in the eastern portion of the United States.

Through its Geophysical Fluid Dynamics Laboratory, ESSA has created mathematical models of the atmospheric processes on high-speed electronic computers so that we may experiment with the atmosphere. The Laboratory now utilizes one of the largest computers in the United States. The work of this Laboratory has already generated much new scientific information of great value to our efforts to understand and control the weather and climate.

We have also begun in ESSA to study the interactions and the exchanges of energy between the atmosphere and the underlying earth and oceans. As the NAS Panel pointed out, an understanding of these exchanges is fundamental to the development of a capability in large-scale weather and climate modification and in the modification of local and regional climates. Investigations are also underway on the physics and chemistry of the atmosphere.

Finally, I must not fail to point out the problem of the inadvertent modification of weather and climate by man himself—by the burning of fossil fuels, by the expansion of cities, by the flight of aircraft, and by the launching of space vehicles. ESSA is very much concerned with the meteorology of inadvertent modification. It is continually monitoring the levels of carbon dioxide in the atmosphere and analyzing the effects of man's activities on weather and climate. This activity will support the missions of agencies and others trying to do something about pollution of the atmosphere or city smog.

I should emphasize, that in addition to the scientific facilities and skills of the Department of Commerce and other agencies, the private resources of industry, universities, and the scientific community have proved essential in past weather modification research. The continued use of these resources through contracts and grants must be accelerated and amplified in carrying out a strengthened national weather modification program.

### WEATHER MODIFICATION ACTIVITIES OF OTHER FEDERAL AGENCIES

To be successful, an expanded national weather modification program will require weather modification to be specially applied to the missions of other Federal agencies. The Department of Commerce, of course, will be concerned with advancing the science and technology of weather modification generally. The Department of the Interior, however, must assess the Nation's water resources and investigate weather modification techniques to carry out this specific mission. The Federal Aviation Agency must conduct research into safe and efficient methods for the dissipation of airport fog. Similarily, the Department of Defense is concerned with research into the military applications of weather modification and the National Science Foundation must continue to support scientific studies in weather modification.

### COORDINATING THE FEDERAL PROGRAM

The Interdepartmental Committee for Atmospheric Sciences (ICAS), which was established by and reports to the Federal Council for Science and Technology, has in the past more than adequately coordinated matters of basic policy in weather modification as part of atmospheric science. It will continue to do so and can easily be strengthened in this role, if necessary.

While ICAS provides a competent body for the coordination of questions of basic policy, there is a definite need for the coordination of weather modification operations and supporting research. Recent experience suggests that this need for coordination of operational aspects should follow the successful pattern for coordinating meteorology, as set forth in Bureau of the Budget Circular A–62. Under this circular, the Department of Commerce coordinates the meteorological activities of the Federal departments and agencies and to do this has established, in ESSA, an Office of Federal Coordinator for Meteorological Services and Supporting Research.

### LEGISLATIVE RECOMMENDATIONS AND PROBLEMS

Having examined the scope of a redirected national weather modification program and discussed the activities of ESSA and other agencies, I return to the legislation now being considered.

As I said earlier, there are two sets of problems now facing us. The first is acquiring the knowledge to change the weather and control climate. The second is deciding how best to use this knowledge. To carry out an expanded Federal research program, legislation is desirable now (1) to authorize appropriate limitations on State and private weather modification activities which would interfere with Federal research, and (2) to clarify existing authority to permit regulations to be issued requiring full reporting of private activities before they occur.

It is reasonably clear, however, that comprehensive legislation may be necessary for a coherent national policy covering both sets of problems with emphasis on the regulatory aspects. If legislation is enacted now, it would be desirable in such legislation to call for studies and reports on the regulatory controls necessary in the future. These studies could form the basis for comprehensive legislation dealing with the following problems, as well as others:

(1) Whether expanded authority is necessary to clarify the scope of research and experimentation necessary to carry out the major responsibilities for advancing the science and technology of weather modification and climate control, after any executive reorganization.

(2) Whether the broad national objectives should be established by legislation.

(3) Whether the Secretary of Commerce should have appropriate authority to assess all private and State research and operational programs to preclude endangering the public safety.

(4) Whether the Secretary of Commerce and heads of other agencies should have appropriate authority to pay claims resulting from their research and to indemnify Government contractors and grantees, within traditional limits.

(5) Whether there should be clear authority that Federal contractors and grantees are exempt from State laws and regulations on weather modification.

(6) Whether it is desirable for the Secretary of Commerce to have appropriate authority to facilitate international cooperation in weather modification activities, including the authority to enter into international arrangements on behalf of the United States, subject to the foreign policy guidance of the Secretary of State.

(7) Whether the Secretary of Commerce should have regulatory responsibilities which would be a function separate from the conduct of research and development.

Mr. Chairman, the problems we have in achieving a coherent national policy in weather modification are extraordinarily complex. If we cope with them boldly and with imagination, the opportunities we have can be extended to benefit all mankind. And we in the Department of Commerce stand ready to help this committee in its deliberations in any way possible.

Senator CANNON. Thank you very much, Dr. Hollomon, for a very fine statement.

In connection with your point No. 7 there, of course, you pose this as a question to us, but I would like to ask you whether you believe that ESSA is the right agency to regulate activities in weather modication, and if so, why?

Dr. HOLLOMON. I do not believe at this time there should be regulation. My personnal view is that we are not ready for the regulation of private activities, except insofar as they affect the Federal programs. I do not believe that we now have enough knowledge, and we don't have enough experience. I am sure that I would not be ready to recommend to you the character of that Federal regulation, as to whether, for example, the Federal law should preempt the laws of the States in this regard.

I think that is a very serious question. So therefore I don't think we are concerned at the moment with the problem of regulation of private activities except insofar as they affect the Federal program.

Senator CANNON. In other words, your answer is that you don't think there is any need for the regulation except in these limited areas at the present time, either by ESSA or anyone else?

Dr. HOLLOMON. Except for the regulation that would affect Federal programs.

Senator CANNON. Where it might interfere with the Federal programs?

Dr. HOLLOMON. Right. In that case it is our view that the ESSA organization should arrange for a group separately to make these decisions, that is, separately from the people who are actually carrying out any research and development in that field. And they should do it because they have a widespread reporting capability through the various weather offices, and they have, also, or should have, available to them the technical expertise of their own people and of the other Government agencies.

That kind of regulation I think one can vest in ESSA. But I do not believe we are ready to vest in anybody the regulation of private activities generally.

Senator CANNON. Does the Weather Bureau or ESSA have a plan or program for sizable activity in weather modification at this time?

Dr. WHITE. Mr. Chairman, we are working on such a program and generally the nature of our program would be to follow up on the recommendations of the National Academy Panel and to develop a broad program to meet these recommendations.

Dr. HOLLOMON. We have an outline of a plan, Mr. Chairman. We have not yet put dollar figures to it. We would be prepared to supply to the committee the details of what we think ought to be done. But in general, as Bob White said, what it goes to is to implementing the technical recommendations of the NSF Committee, NAS Committee, and the earlier study of the Weather Bureau.

Senator CANNON. You say it is in the process of being put together? You don't really have a complete plan worked out?

Dr. HOLLOMON. I have not a complete plan we are ready to submit for the record this morning. On the other hand, we are prepared to provide that to you if you would like us to do so.

Senator CANNON. Well, you are talking about while we are considering this matter; is that it?

Dr. HOLLOMON. Oh, yes; right.

Senator CANNON. Who participated in the development of this program you are putting in, what agency?

Dr. WHITE. This program or this plan we are now working on is being worked on by the scientists within our own organization.

Dr. HOLLOMON. This is one of the reasons why, Mr. Chairman, I don't want to submit it for the record this morning, because I want to insure that discussion is carried out among all of the agencies. The plan we have this morning is in response to a request of mine to the Weather Bureau to draft what they believe ESSA needs to carry out a major program within their own organization, and it has not yet been discussed in detail with the other affected agencies.

This is one of the things I think is essential.

Senator DOMINICK. Mr. Chairman, unfortunately, I have to go to an executive committee meeting of another committee at this point.

I have a number of questions that I would certainly like to ask Dr. Hollomon and Dr. White. As soon as this other meeting is over, I shall come back.

Senator CANNON. Now, Doctor, you have indicated that there should be some regulation, and in view of the fact that ESSA is apparently going to get into the operational field, too, do you think there is any conflict of interest here in having ESSA as a regulatory agency and also the operational agency?

Dr. HOLLOMON. Of course, any authority which is given by a reorganization plan runs to the Secretary of Commerce and does not run to ESSA. I would recommend any legislation in this regard running to the Secretary of Commerce under the general authority of the Reorganization Act of, I believe, 1952.

My own view at this moment is that it is perfectly satisfactory the way ESSA is organized at the moment, for the regulatory aspects having to do with the prevention of interference to be vested in ESSA, but in a completely separate group from that which is responsible for the research and development. I believe that would be satisfactory.

If it turns out to have any conflict of interest, which I can't imagine at the moment, I would then suggest to the Secretary that this be vested in the Secretary's Office, rather than in ESSA. But as long as it is a major technical question on regulation—that is, does a particular technical operation conflict with another technical operation? I really think such a technical judgment is best vested in an organization that can bring the technical forces throughout the Government to bear on it.

When we get to the other question, however, to where one is regulating essentially commercial activities, I think this poses an entirely different kind of problem.

The AEC has a similar kind of problem, of course; the problem of supporting research and development in atomic energy on one hand and being responsible for insuring that the regulations with respect to safety of atomic nuclear plants on the other hand are properly maintained. What they have done is completely separated those two operations, but still keeping them within AEC.

I think from what knowledge I have of it, it has worked reasonably satisfactorily. But I assure you I think they should be clearly separate, and the President and the Congress should be able to get reports on each issue and not from the same people.

Senator CANNON. The Weather Bureau has not been an exponent of weather modification historically. How do you account for their move now to be the dominant agency in this field?

Dr. HOLLOMON. Mr. Chairman, there are three comments I would like to make on that subject. One is that the reorganization with respect to providing the ESSA organization, which was recommended by the President last year, has done a tremendous amount to change the responsibilities and attitudes of both the ESSA organization and others in the Government.

The second comment I would make, which I tried to say indirectly in my statement, is that the old order does have the same motivation to change. Dr. White and I and the technical people in the Weather Bureau believe that there are serious questions and possibilities about

weather modification that this country cannot refuse to evaluate and seek the possible benefits of.

I think another fact of the matter is that there were true questions in the scientific community in the 1950's that made the people feel that broad studies were premature. The statistical evidence was not clear.

I think the evidence is becoming clearer; people are becoming more convinced. Personally, I find myself in a strange position in this business. I was one of the close associates with Langmuir and Schaefer. I personally wrote one of the early scientific papers on the subject of weather modification. Perhaps my own bias has something to do with the change in the feeling of our own organization and the possibilities.

Senator CANNON. Isn't it a fact that there is a great deal of competence in the weather modification field outside of the Weather Bureau and ESSA today?

Dr. HOLLOMON. Of that there is no question.

Senator CANNON. In private life, universities and foundations. As a matter of fact, I think there is probably more competence outside of the Weather Bureau and ESSA in this field than inside; wouldn't you say that is true? Or is that sort of putting you on the spot?

Dr. HOLLOMON. I think if you add up the total technical effort in the country, without doubt the total number in the technical field, in all of the private and public organizations, probably exceeds that in ESSA.

On the other hand, I think with the basic work that goes on in the general dynamics of the atmosphere, cloud physics, Project Stormfury, and on tornadoes, ESSA has competence and it is a growing competence in this area. I simply think that there have been substantial changes in this organization, and that they will continue.

Dr. WHITE. Mr. Chairman, with your permission, I would like to respond to that question, because it has been raised by a number of people.

I think it is important that the record reflect that the Weather Bureau has always taken a realistic attitude toward weather modification. Now it has been very active in weather modification in the past. It was heavily involved in a large-scale rain project in the West many years ago.

Senator CANNON. When was that and where?

Dr. WHITE. That was called the ACN project. I don't have the exact date. It was in 1953–54. We must recognize that many of the weather modification experiments that were conducted during that period produced inconclusive results. And the indications on the basis of these inconclusive results was what was required was more fundamental research in the atmospheric sciences and all of the problems of the weather modification.

The program of the National Science Foundation was for the purpose of acquiring this additional basic knowledge.

The Weather Bureau some 4 or 5 years ago decided to initiate a program on hurricane modification. This was and still may be the single largest effort in weather modification in this country, requiring the deployment of many, many aircraft, I believe about 17 of them. It is one of the most difficult projects in weather modification that one could conceive of carrying on. It is viewed as a research activity.

There have been questions in the scientific community, for example, as to whether we should go ahead with a project such as this. But it certainly is not an evidence of conservatism. I would also like to respond to your question about the competence in weather modification in ESSA.

We have many scientists who have been involved in various aspects of the atmospheric science research and all atmospheric science research in one way or another is related to weather modification. There is also no question that in the university community, private industry, and all of the other groups in the country, there is a much larger competence in the field of weather modification than we have in our organization. The competence must be used wherever it is.

Senator CANNON. I know, Doctor, you referred to some of the interest of other agencies. I wonder if you could perhaps spell that out a little better for the record? If you are not prepared to do so right now—but I would be interested in having it spelled out in more detail, the interest of, for example, Department of Defense, Agriculture, Interior, AEC, NASA, other agencies that may be directly involved.

If you wish, you can supply that for the record.

Dr. HOLLOMON. Let me supply it for the record, Mr. Chairman.

Senator CANNON. All right.

(The information referred to follows:)

*Estimated Federal weather modification program, fiscal year 1966*

[Thousands of dollars]

| Department or agency | Fog and cloud dissipation | Precipitation modification | Hail suppression | Lightning modification | Severe storm modification | Other | Total |
|---|---|---|---|---|---|---|---|
| National Science Foundation | 30 | 1,220 | 350 | 100 | 100 | 600 | 2,400 |
| Commerce | | 35 | 35 | 130 | 320 | 130 | 650 |
| Army | 160 | | | 90 | | | 250 |
| Navy | 550 | | | | 200 | | 750 |
| Air Force | 260 | | | | | | 260 |
| Interior | | 2,980 | | | | | 2,980 |
| Agriculture | | | | 120 | | | 120 |
| Totals | 1,000 | 4,235 | 385 | 440 | 620 | 730 | 7,410 |

Source: Based primarily on data collected by Interagency Committee on Atmospheric Sciences.

Senator CANNON. Now do you see this action before us now as a means of moving the weather modification program ahead faster or do you think this is going to be another just sort of coasting along type of thing?

Dr. HOLLOMON. I hope it would be a matter of moving. I don't know what it will be. But I would express my hopes in this field:

First, I think the combination of the President's proposed reorganization plan and legislation which I hope can be worked out in the near immediate future will substantially strengthen the weather modification activities in this country.

Second, I think the same combination will lay the groundwork for future questions of public policy, regulation, economics, that will be necessary when we become successful or more successful in any of

these fields. I sincerely hope that the result of the legislation in S. 2916, as it develops, will be to thoroughly and appropriately stimulate substantial increases in the weather modification activity in this country, both in ESSA and in other agencies.

Senator CANNON. Senator Pearson?

Senator PEARSON. Dr. Hollomon, in line with what you just said, and with reference to your comment that the first problem is acquiring knowledge, is the thrust of this legislation to increase our activity in weather modification, or is it to decide who is going to do the job?

Dr. HOLLOMON. The purposes of the legislation, as it now lays on the table, seem to me to be twofold: One is to help decide who is going to do the job, and the second is to provide for the basis of certain kind of regulation and policy questions that are immediately raised by this field.

Senator PEARSON. Excuse me, Doctor, would you please start over again?

Dr. HOLLOMON. I think the present thrust of the legislation as now drafted does two things. One, it assigns certain responsibilities with respect to weather modification and secondly, provides certain indications of regulations that may be needed immediately in this field.

It does not provide for the major expansion of the program, as now drafted.

Senator PEARSON. Is there a great deal of uncoordinated effort, private and governmental research today?

Dr. HOLLOMON. Right now?

Senator PEARSON. Yes.

Dr. HOLLOMON. Yes, sir.

Senator PEARSON. You said you would submit for the record the degree of participation of the various Federal agencies.

Dr. HOLLOMON. We will be glad to do that.

Senator PEARSON. I am sure that will be very helpful to us. But where is the activity outside of the Government taking place? Is it primarily in the private weather modification——

Dr. HOLLOMON. There is a large number— 25, 50, or something like that—of private parties who engage in private weather modification activities. This is primarily in New England, the West, the Middle West.

Senator PEARSON. Any State agencies?

Dr. HOLLOMON. State agencies? As such, I do not believe there are any State agencies, subject to correction. I don't remember them offhand.

But there are a very large number of private experimenters, and I hope they will continue to go forward. One of the major findings of the National Academy of Sciences' Panels on this subject was that the data of the weather modification activities of private parties were very useful in determining what the consequences were, and these data had not been available to the Federal Government heretofore.

Senator PEARSON. You mentioned that, in regulating private and State activity, you would do it only so far as it would affect Federal participation?

Dr. HOLLOMON. At this time.

Senator PEARSON. Are you anticipating a problem or do you think there are existing problems?

Dr. HOLLOMON. Dr. White commented on an experiment in Santa Barbara, where it is believed that there was possible contamination of an experiment, in this case by private parties. As this program expands, I think it is perfectly clear that the possibility of contamination of one or the other sets of operations will be a serious question.

Senator PEARSON. Thank you.

Senator Dominick is back, so why don't you go ahead, Senator Dominick?

Dr. HOLLOMON. May I interpose one comment?

There is a possible way to deal with this problem of regulation, interference with Federal parties, which we are considering, and that is to lay out a zone in which certain Federal experiments are going to be performed for a time and suggest during that period there be no contamination.

Senator PEARSON. Of course, all of this is regional. Weather modification is not going to be subjected to State lines or areas.

Dr. HOLLOMON. That's right.

Senator PEARSON. It is very close to the problem of air and water pollution, as a matter of fact, or water pollution.

Dr. HOLLOMON. I quite agree with you, Senator.

Senator DOMINICK. Doctor, do I gather from your statement that the Weather Bureau feels that it is possible at this point to increase precipitation from weather modification programs?

Dr. HOLLOMON. We think that the evidence is clear that this possibility is very strong; yes, sir.

Senator DOMINICK. This is the same conclusion that was reached in 1957, isn't it?

Dr. HOLLOMON. Yes. Well, I think the conclusion as stated in the bare statement is essentially the same; yes, Senator. But I think the evidence is substantially greater today than it was in 1957.

Senator DOMINICK. The evidence is substantially greater?

Dr. HOLLOMON. Yes, sir.

Senator DOMINICK. Evidence from what?

Dr. HOLLOMON. From experiments which have been carried out by private seeding operations, by Government operations, and by the large Australian experiments, the evidence I think is substantially greater.

Senator DOMINICK. You feel then that although it would have been possible to go ahead in 1957, that it now looks like it has even a better probability of success?

Dr. HOLLOMON. "Go ahead" is a difficult question. I believe that the program was justified in 1957; I certainly wouldn't want to try to look back and say whether the right things were done in 1957 or 1964 or 1965, but I do believe it is now necessary to substantially increase the activities leading to enhanced precipitation, to determine the conditions under which that can be done.

Senator DOMINICK. Is it your feeling that Commerce is the agency which should have overall authority in this field?

Dr. HOLLOMON. That is a very difficult question. I don't know what you mean by "authority." Certainly I don't believe that all the weather modification and activities of the Federal Government should be carried out by a single agency; no, sir, I don't believe that.

Senator DOMINICK. In your statement you recommended that the Commerce Department at least be given a much larger share in the activities. Is that correct?

Dr. HOLLOMON. I believe Commerce should be given a major responsibility with respect to weather modification broadly, yes, sir. This we believe is consistent with the recommendation of the NSF Commission, and consistent with the recommendation of the National Academy of Sciences Panel.

Senator DOMINICK. I am trying to be clear in my own mind as to really what you are recommending, because in your statement you recommended that existing activities continue through the agencies that are now dealing with them.

Dr. HOLLOMON. I did; yes, sir.

Senator DOMINICK. Then you said you wanted some kind of change where the control was in the Weather Bureaus, as I understand it.

Dr. HOLLOMON. No, sir; I did not say "control." I tried to imply three things, there are three or four major kinds of weather modification activities that affect almost any kind of program, almost any kind of program you would carry out.

First off, what you are really trying to do is to modify in some substantial way the characteristics of the atmosphere. In some cases this will produce enhanced precipitation. In some cases it will produce diminution of precipitation, presumably. In some cases it will affect hail production, in some cases it may, in the future, affect hurricanes. But in every case what you are doing is trying to modify the basic characteristics of the atmosphere.

Now this basic problem, the technology of it, how to simulate it on computers, how to provide the right kind of statistical analysis, there are common problems. No matter what you do in weather modification, there is a certain common aspect of weather science and technology. I believe we should have some common agency that assures that we are advancing that common technology, without restricting the ability of the FAA, as an example, to be able to do technical work with relation to fog dispersal at airports.

But that technical work should be brought together and evaluated to see how it relates to the overall problem and how that same technical information can be used by other people.

Senator DOMINICK. Am I correct in understanding from your comments that ICAS is not able to coordinate and correlate these programs?

Dr. HOLLOMON. The Interagency Committee for Atmospheric Sciences has been primarily concerned with the problem of coordinating the more basic research activities and has been concerned with general policies with respect to weather modification. I think it should continue to have that responsibility.

Secondly, however, we are now proceeding to much larger experiments, hopefully of many more diverse kinds. They will be more connected with possible operations, where one changes the weather in a certain area. We need to predict that change, and correlate it with other activities. That kind of coordination, I think, should follow the general coordination mechanism which is specified in Bureau of the Budget Circular A-62, which assigns to the Department of Com-

merce the responsibility of carrying out the coordination of meteorological activities. The problem is becoming one of coordinating major field programs, hopefully, in the future, and their relationship to weather prediction and the relationship of semi-operational programs.

Senator DOMINICK. Now, in general you have advocated as a part of your recommendations that the Commerce Department be given authority to prohibit either State or private weather modification programs where they might interfere with any Federal activity.

Dr. HOLLOMON. I do.

Senator DOMINICK. What is the position that the Government has with regard to the citizen on this, who wants to go forward with getting increased precipitation on his land in order to prevent disaster and he is told by the Federal Government he can't do it?

Dr. HOLLOMON. We haven't worked out the procedures in any detail certainly, but my view of the procedure that should be adopted is that the scope of the Federal programs and the geographic areas in which they are going to be operated should be made public. Then, by the same token, the scope of the private parties' activities, what they intend to do in a given area, should also be made available to the Government and the public.

The determination then has to be made on a reasonable basis by due process as to whether or not there would be interference with some major Federal program by a private party. And we should be able to cause the private party to delay or to change his program during that period or otherwise the major Federal program will simply not be able to be carried out or evaluated.

Senator DOMINICK. For example, suppose the Federal Government decided it was going to go into a hail suppression program in one of the hail areas of the country. It has a target area for doing this and it issues an order saying that no other hail suppression programs or cloud modifications can be carried on which might interfere with this.

Dr. HOLLOMON. In a certain area, for a certain period of time.

Senator DOMINICK. Suppose a State program or a private operator has a different theory on how hail suppression should be carried out. You prohibit him from doing it, and they cannot carry on because the Federal law presumably preempts the field.

Dr. HOLLOMON. Only for Federal programs now.

Senator DOMINICK. Yes, I understand that. Then let's take the possibility that the Federal Government is wrong. What happens to the landowner who is wiped out?

Dr. HOLLOMON. Well, in my view, in any such process, the private party should be able to have a hearing, and a determination made under these conditions as to where the public interest lies. This is not any unusual activity. But I see no alternative, to be able to provide a secure area for appropriate experiments, if we are to progress in this field. Because otherwise the experiments cannot be evaluated.

Senator DOMINICK. Let me ask you this question and perhaps this will bring it out more clearly.

Dr. HOLLOMON. I will also say the following: It is certainly possible that a recommendation would be made that the experiment might

be delayed on the part of the Federal Government for a certain period. In other words, I think——

Senator DOMINICK. You could only do this during the hail season, so that is pretty hard.

Dr. HOLLOMON. Another area could be chosen, for example, if it has equal technical characteristics.

Senator DOMINICK. What degree of disagreement is there between the Weather Bureau or the other agencies, and the State modification and private modification programs as to how best to go about a given problem?

Dr. HOLLOMON. Could you repeat that? I don't quite understand it.

Senator DOMINICK. What degree of difference is there in the operational techniques between the Federal research programs and the State and local programs? Do they use different techniques? Do they have different theories? Do they have different principles as to how to attain a set result?

Dr. HOLLOMON. Certainly there is a variety of ideas about when is the best time to carry on seeding. These are some of the things that are not definite. There are certainly notions as to the—there are things we don't understand about the amount of concentration that is required. There are certainly differences in view, I would suspect, technically, in a field such as this, which is still in the experimental stage. If that was an answer to your question.

Senator DOMINICK. That helps, because this leads to my next question and that is, what therefore gives the Government a superior expertise over the State or local programs?

Dr. HOLLOMON. I did not intend to imply that. I simply said if we were going to have a very substantial program in the Federal Government; and if we are going to lay out experiments which, let's say, depends upon a certain concentration of seeding element; and if then in an uncontrolled fashion, the conditions are modified, inadvertently or advertently, by someone else, that chain of events vitiates the results of the experiments. That is all I am saying. I didn't say our knowledge is greater than anyone else's.

Senator DOMINICK. But the difficulty is if the Federal Government starts a research program and prohibits anybody else from operating, this is exactly what you are saying.

Dr. HOLLOMON. I beg your pardon.

Senator DOMINICK. The difficulty with trying to resolve this problem is that if you give any Federal agency the right to prohibit any other activities in the area, the research program conducted by the Federal Government is of sufficient national interest that no one else can do anything in the area, even if it means the destruction of somebody's property.

Dr. HOLLOMON. Even if what means the destruction of somebody's—you mean the natural phenomena?

Senator DOMINICK. The failure to go ahead with the other system.

Dr. HOLLOMON. On the other hand, Senator, it seems to me that the Federal Government should give due notice as to what the experiment is going to be in the area. This does not indicate that all areas of the country, by any manner of means, would be preempted by the Federal Government, but only those areas where the Government has specific

experiments to undertake. I simply don't know how one would proceed without this kind of authority.

Senator DOMINICK. How good is the reporting system from State and local operations to ICAS?

Dr. HOLLOMON. At this time?

Senator DOMINICK. Yes.

Dr. HOLLOMON. We have not undertaken to obtain these reports. This was a responsibility, up until now, of the National Science Foundation. Until recently they had not obtained these reports. They only carried this, their responsibility forward, on a voluntary basis. It was as a result of discussions among ICAS, and the National Science Foundation, myself, and others that the current regulations by the National Science Foundation were published. This is only, as I think you know, a recent act on the part of the NSF.

Senator DOMINICK. In Colorado, for example, we have a State scientific advisory board, advising the Governor what weather modification programs to go into, and we also have some private operations in our area, because of the dryness on the eastern slope and the need for getting more snow in the mountains.

Now if we are going to conduct a Federal program, I would presume therefore all of these activities would be stopped.

Dr. HOLLOMON. I wouldn't think so, Senator. I would think you would have a program in which you would notify the appropriate people as to the limited area in which the program is going to be carried forward and the purposes. Then a fair determination would be made as to the balance of the interests in the matter.

I think that this is certainly an appropriate process which would have to be established. And I hope I am not stating or implying that all programs in any State would be stopped. I don't think that is the appropriate thing to do. And I feel very strongly that this is not now the time to determine that the Federal Government should issue regulations affecting private parties, except in this narrow area.

Senator DOMINICK. Yesterday we heard a statement describing big science and little science, in terms of experimentation or applied research. How big an area is covered by the type of program geographically?

Dr. WHITE. Hundred miles on a side.

Dr. HOLLOMON. This is the kind of area one is talking about. Of course in hurricanes one is talking about larger areas.

Senator DOMINICK. Yesterday they were talking about a hundred square miles being a big science area. This is 10 miles by 10 miles, not a 100 by a 100.

Dr. HOLLOMON. The experiments have been planned and carried out, in the West for example, on the order of 10,000 square miles, and the experiments in Stormfury, seeding with respect to hurricanes, are very large areas.

Senator DOMINICK. The seeding with regard to hurricanes, however, is mostly done over the ocean, as I understand it, where there can be no impact on land masses for 48 hours?

Dr. HOLLOMON. That is what we try to do, that is correct.

Senator DOMINICK. How big are the operations now being conducted by State or private programs in terms of geography?

Dr. WHITE. We do not have at the present time extensive private weather modification programs being supported out of ESSA——

Dr. HOLLOMON. No, he didn't ask that question.

Senator DOMINICK. I am talking about private operators.

Dr. HOLLOMON. The scale of private programs. Pacific Gas & Electric is over a large area. There are other programs that cover small areas. There are a wide variety.

Senator DOMINICK. Do they have them as big as 100 miles by 100 miles?

Dr. WHITE. I wouldn't be able to answer that question. The sizes vary, Mr. Chairman.

Senator DOMINICK. In your statement, Dr. Hollomon, you refer to one of my pet peeves with the Weather Bureau and that is forecasting. Throughout you imply that weather prediction carried on by the Weather Bureau is of enormous value to the country. I am sure I could find 9 out of 10 citizens that disagree with you on that, but the major point I would like to stress is your view of the relationship between forecasting and weather modification.

Dr. HOLLOMON. I tried to make this clear in the statement. I hate to let your comment about the value of weather prediction go without making some response.

Senator DOMINICK. Go ahead. I expected you to defend it.

Dr. HOLLOMON. Perhaps I will surprise you. It is perfectly true that there are still large inaccuracies from time to time in weather prediction, the ability to predict in exactitude the character of the atmosphere, is not yet complete. In my view, it will always be a difficult subject. I do not, however, feel there is any question on two points, first, that the prediction of the weather on a quantitative basis has substantially improved in this country over the last 10 to 15 years, and, second, that it is still improving.

Senator DOMINICK. By "quantitative," you mean, the amount of it?

Dr. HOLLOMON. I am talking about the degree of accuracy with respect to quantitative objective measures of such things as wind velocities, temperature, that sort of thing, made for a given region. There has been substantial improvement and that has come about largely, but not entirely, due to two factors:

One is increased observational capability throughout the country and the world.

And secondly, the ability to use, on an objective basis, the large computer for simulating and calculating the character of the atmospheric changes. And there is good quantitative evidence that the predictability of the atmosphere, from the standpoint of serving the citizens of this country, has improved.

We will be glad to furnish you the record of the quantitative measures on that subject.

Senator DOMINICK. I don't suppose my recent letter has come to your attention, containing a report on the Weather Bureau predictions of temperatures for eastern Colorado during the month of January 1966. On 4 days you were within maybe 5 degrees. The rest of the time you were off between 20 and 30 degrees on both high and low temperatures.

Dr. HOLLOMON. I haven't seen your letter. We will take a look at the problem.

Senator DOMINICK. I sent it to Dr. Cressman and made some suggestions in it.

Dr. HOLLOMON. I would not claim we are completely accurate. Now, as to the value of the predictions. I just find it very difficult to believe that the general predictions that the Weather Bureau makes with respect to hurricanes, are substantially inaccurate four-fifths of the time. I think there is clear evidence that over a period of time, there has been great reduction in loss of life and property, for example, in the case of hurricanes and tornadoes.

One of the serious problems here is not only the prediction in these cases of severe storms, but the adequacy of the warning systems, getting the information to the proper people at the proper time.

Senator DOMINICK. That is correct. I think your observational techniques are excellent all of the way through.

Dr. HOLLOMON. Now, the situation on improving the dissemination and advising the people, this year's Weather Bureau budget includes a substantial increase for providing an improved nationwide natural disaster warning system. We are serious in the fact that there have been deficiencies in this, and we want to correct them and provide much better warning services of all kinds in a more effective way than we have in the past.

Senator DOMINICK. Dr. Holomon, are you a flyer?

Dr. HOLLOMON. Only as a passenger. I don't have a license.

Senator DOMINICK. I am an amateur flyer. I have been flying for 30 years, and I can assure you that the pilots of this country do not share your enthusiasm for weather predictions.

Dr. HOLLOMON. I tried to indicate this fairly, that it had improved, that they were not perfect, but they had improved, and they need substantial improvement. I honestly don't think that we are differing. I only say they are better than they were. I think they can be improved and I further believe that we can take the steps to do so.

Senator DOMINICK. In your statement, you say that when any particular type of weather modification becomes fully operational, the decision to modify the weather in a given instance will depend in a large measure on the prediction of what the weather will be.

Dr. HOLLOMON. That is right.

Senator DOMINICK. I gather that there are systems of getting rid of cold fog right now?

Dr. HOLLOMON. That is right.

Senator DOMINICK. You don't need any weather predictions on that, because you have your installations ahead of time; do you not?

Dr. HOLLOMON. That is right. It is a local phenomenon, and you can go out and see it. But, in that condition the prediction is clear. It is not a case of whether rain will or will not occur, a storm will or will not occur. It is a short-term problem, and it is perfectly clear in the case of cold fog, in a sense. You don't need the prediction. You wait until it is there.

Senator DOMINICK. When you are doing ground generation to increase precipitation, the target area has been pretty carefully examined ahead of time and the generator is set up largely from the prevailing wind system, and so forth?

Dr. HOLLOMON. That is correct.

Senator DOMINICK. Is it not true that having these reasonably well set up, depending upon wind changes you could then wait until the required type of storm from an observational point of view would come over the area, which you could properly seed?

Dr. HOLLOMON. Or from a prediction point of view, either one.

Senator DOMINICK. It would be helpful to alert the people, if you could predict it a day ahead of time.

Dr. HOLLOMON. And also that the likelihood of rain from that storm would not be high, with or without the seeding. We would like to know that too.

Senator DOMINICK. But these are observational techniques of storms as they are moving in; is this not true?

Dr. HOLLOMON. Cloud systems as they are moving in, yes; or that might change as a result of the other climatic conditions, yes; that is correct.

Senator DOMINICK. Do you have some comments on that, Dr. White?

Dr. WHITE. No, Mr. Chairman.

Senator DOMINICK. So there are, at the present time, weather modification techniques which are available in certain types of weather, which are not necessarily reliant on accurate predictions.

Dr. HOLLOMON. No; but they are certainly reliant on accurate observations; and, depending on the size of the area, on the character of the weather one is trying to modify, they depend to a greater or lesser degree on prediction.

Senator DOMINICK. To what degree has the Weather Bureau analyzed the difference between their weather forecasting techniques and the techniques used by other forecasters?

Dr. WHITE. We generally do not conduct evaluations of the forecasts of private forecasters. We do conduct extensive evaluations of our own forecasts, which are published.

Senator DOMINICK. Would it be helpful on an experimental basis to determine whether others might have techniques which are an improvement on the ones now in operation?

Dr. WHITE. Well, the problem of evaluating forecasts is a very, very difficult one. There are almost as many schemes for evaluating forecasting as there are meteorologists, and it is very difficult to decide upon an acceptable one.

Senator DOMINICK. The best one, it seems to me, is to forecast what is going to happen tomorrow and then find out what happens tomorrow.

Dr. WHITE. Yes, if you can get meteorologists to agree this a proper way. There are many private groups who are making forecasts. If they have forecasts which they wish to submit to the scientific journals, to illustrate the accuracy of their forecasts, this is the normal way in which this is done. And the normal way in which the forecast evaluations are presented.

Senator DOMINICK. I am not quite clear on this. It would seem to me, if the forecasting ability of the Weather Bureau is under question, that it might be helpful to run an experimental program, side by side with the private forecaster, and determine which one has the techniques to more accurately predict the weather.

Dr. HOLLOMON. Isn't it true, Senator, that any private forecaster, as well, relies, to some degree at any rate, upon both the total observa-

tions and the central forecasting calculations of the Weather Bureau?

Senator DOMINICK. I am absolutely positive they rely on the observations prepared by the Weather Bureau all over the world.

Dr. HOLLOMON. Also, the calculations of what the essential weather fronts are throughout the world?

Senator DOMINICK. I assume this is part of the observational techniques.

Dr. HOLLOMON. It is more than that. It is a question of applying dynamics to these operations in terms of the kinds of analyses we have available now. It is my understanding, I believe to be correct, that all private parties, use, if they are professionally sound, the total observation and basic predictions that are made out of the weather central operation here in Suitland.

Now, the question I think is, the comparative degree of accuracy with which local weather is predicted by the Weather Bureau or by private parties. I believe that everybody uses now the very sophisticated wind patterns, pressure patterns, temperature patterns, and so on, that are not just observations but which are calculations from observations and the forecasting of how these will change in time. These are generally available to everyone and serve, I believe, as the core of this problem.

Senator DOMINICK. If they are so used and they come up with different results, it would seem to me that maybe the techniques of interpretation of those would be worthwhile exploring.

Dr. HOLLOMON. On a local basis, particularly.

Senator DOMINICK. Local basis is what the purpose of the prediction is surely designed for. It just occurs to me that perhaps this is one way of finding out whether the interpretive process is correct.

Dr. HOLLOMON. I was only trying to make the point that there are several interpretive processes that take place, interpretive processes that take into account of calculation of the total airmass, the total motion of that airmass, its effect on local weather, and so on.

I know of no private parties that carry on that kind of very broad scale calculation of the total motion and types of flow of airmass over the United States or over the world.

I think the question, at least from my observation of it, is a question of the degree to which that information now is interpreted with respect to the detailed variations from the local areas. It is to that kind of predictability that I refer in my comments. It seems to me the way to get at this problem, if there are private parties who do believe that they have better prediction capabilities than the Weather Bureau is to publish the results. And I think they can be fairly evaluated.

Senator DOMINICK. That is what I am talking about. Run them side by side.

Dr. HOLLOMON. I see no reason why this evaluation can't take place by the full publication of both sets of results and let's see what happens.

Senator DOMINICK. In general, you don't believe that there is any usefulness in doing this, because there would be the same results.

Dr. HOLLOMON. No, that is not what I am saying. It seems to me that the meteorological literature offers an adequate forum for the publication of technical literature on the predictability of the weather in relation to anybody who makes these predictions.

Senator DOMINICK. Isn't it the responsibility of the Weather Bureau to use the most advanced techniques they can to find out if their predictability is accurate?

Dr. HOLLOMON. Without question.

Senator DOMINICK. This is one way of getting at it.

Dr. HOLLOMON. The data have to be published in some fashion.

Senator DOMINICK. It can be published in the daily newspaper, side by side with the Weather Bureau prediction.

Dr. HOLLOMON. It seems to me that does not provide the basis of a very scientific evaluation. What needs to be published is the record over a period.

Senator DOMINICK. That is what I mean; a year or more, whatever you want to do.

Dr. HOLLOMON. I have difficulty finding out what stops a private person from publishing at this moment—and he is encouraged to do so—the results of weather prediction, contrasting his prediction of pressure, temperature, and so on, as against what actually happened. It seems to me this kind of information—there are journals, media for publishing this kind of evaluation. I just don't know what the problem is.

What you are implying is——

Senator DOMINICK. I know what the problem is and I think you do, too. The problem at the present time is getting any kind of an evaluation, side by side, with the Weather Bureau report. What we are trying to do is to see if the mode of interpretation is different from what the Weather Bureau's doing, and if the other mode is more accurate.

I can't see anything wrong with trying that.

Dr. WHITE. The Weather Bureau reports are published and open and available to anybody, and, if there is a desire on the part of someone to make comparisons, these data are available to him. He can make such comparisons and he can publish the results he obtains from these.

Dr. HOLLOMON. Conversely, it seems to me, if the results of private parties are made public, we certainly can make the comparisons as to what the relative accuracy is over a long period.

Senator DOMINICK. But you are opposed to the idea of giving an experimental contract to anybody to do this, side by side, with the Weather Bureau?

Dr. WHITE. I would have to know the particular circumstances of the contract, the proposal in detail, before I would want to make a decision on it.

Dr. HOLLOMON. It is certainly not a decision I would make.

Senator DOMINICK. I was interested in your recommendations on Nos. 3 and 4, which you said we ought to think about. In No. 3 you say the Secretary of Commerce might be given the appropriate authority to assess all private and State research and operational programs to preclude endangering the public safety.

Do you feel that these programs are or might endanger the public safety as they are now conducted?

Dr. HOLLOMON. I don't believe that is the case at the present time. I don't think the technical evaluation, as far as I hear it and read about

it in the various reports that have been issued, that this is currently a problem. That is why I don't make a recommendation in this area.

I think this is a matter, though, that the Congress and we should keep under careful study. As you know, if we really learn to modify the characteristics of hurricanes, as an example, this kind of question could arise, particularly if private parties also attempted to make the same modification.

Senator DOMINICK. Are any State or private groups now engaging in either hurricane or tornado modification?

Dr. HOLLOMON. I know of none at the moment.

Senator DOMINICK. So your recommendation is against No. 3; is that what I understand you to say?

Dr. HOLLOMON. No, sir. We made certain specific recommendations on the preceding page as to what should be included in the legislation now. What we are suggesting on page 22 are questions which the committee now and in the future should consider, and we stand ready at a future time to give our views on these various problems, but we are at this stage simply presenting them as questions for the committee's consideration.

I am not ready, certainly, to take a position on the matter at this moment.

Senator DOMINICK. The National Science Foundation discussed some of the problems which might result both from an ecological and sociological point of view if large-scale weather modification programs were put through.

Who should conduct that kind of research?

Dr. HOLLOMON. Regarding the effects of climate on living systems, particularly the effect of climate on the general character of man's activities, I think that should be conducted by ESSA. Where you have a problem with the effect of microclimate, and other changes on, let's say, agricultural activities, I think it ought to be conducted by the Agriculture Department in cooperation with ESSA.

Senator DOMINICK. Is the Agriculture Department now engaged in weather modification research?

Dr. HOLLOMON. You can correct me, Bob, if this is wrong. There are certain joint programs underway on the effect of microclimate, small-scale changes in climate, in Agriculture and between Agriculture and ESSA. There are certain programs, I think I am correct, on lightning suppression in the Agriculture Department. Is that correct?

Dr. WHITE. That is correct.

Senator DOMINICK. As you know, this country in selected areas at the present time—and undoubtedly in selected areas in the future—will have sharp problems with regard to having enough water to keep going even with what it now has.

Dr. HOLLOMON. Yes, sir.

Senator DOMINICK. Do you feel that we are presently in a position where applied research could be put into effect to try and increase water in those areas?

Dr. HOLLOMON. I feel clearly we are in a position to lay out programs to determine the best way to increase the water content in those areas, and that we should proceed to evaluate them and we have the techniques now; we should proceed to operate.

Senator DOMINICK. And this would be true, I would gather, in the northeast section of the country?

Dr. HOLLOMON. I don't think we are ready there yet. I think we have to do some experiments in that area to determine the consequences of seeding.

Senator DOMINICK. Do you think we are ready to do it in the Colorado Basin?

Dr. HOLLOMON. Experiments are now planned for a Colorado River Basin.

Senator DOMINICK. On an applied basis?

Dr. HOLLOMON. Certainly they are planned now, broadscale experiments to evaluate carefully the consequence of seeding, how it should be done and what the results are. This is by the Bureau of Reclamation.

Senator DOMINICK. I am talking about putting into operation now existing techniques that are known, with the probability of increasing, by at least 10 to 15 percent, the precipitation in an area.

Dr. HOLLOMON. I think my position is that we are ready to go to the stage of determining the engineering feasibility, the technical steps one has to specify in order to do that accurately and that program is under way.

Senator DOMINICK. As you probably know, there has been substantial discussion in Congress of the need for importing water from streams not being entirely used into other areas of the country.

Dr. HOLLOMON. I know something about this. I am not thoroughly familiar with it.

Senator DOMINICK. It strikes me that if we could get going on a weather modification program, we might be able to produce more water at a much cheaper price.

What are your comments on that?

Dr. HOLLOMON. I think this is the kind of question that needs to be asked, as to what the trade-off costs are between the various alternatives and in order to do that we have to know the efficiency and effectiveness of the weather modification in these areas. I think that is an appropriate question to ask and we should seriously ask it.

Senator DOMINICK. Recently the National Science Foundation issued regulations compelling State, local, and private cloud seeders to furnish information on their weather modification activity, together with advanced notice of an intention to seed and after-the-fact reports.

Dr. HOLLOMON. Yes.

Senator DOMINICK. Are these being received?

Dr. HOLLOMON. I cannot tell you at the moment. That regulation went into effect—it is dated December 21. It is to become effective January 1. And I can't tell you whether they are being received at the moment or not.

Senator DOMINICK. Under what authority were those regulations issued?

Dr. HOLLOMON. They were issued by the National Science Foundation under the authority in—do you have the references, Mr. Christenson?

Mr. CHRISTENSON. The act of July 11, 1958 (Public Law 85–510; 42 U.S.C. 1872a) is the authority of the National Science Foundation for issuing the regulations.

Senator DOMINICK. This is not then under the authority of any existing weather modification law that Congress has passed. It is an executive order.

Dr. HOLLOMON. Oh, no. This is the authority in the law which is in the National Science Foundation's legislation.

Mr. CHRISTENSON. It refers specifically to weather modification.

Senator DOMINICK. Will these reports be coming to the National Science Foundation or to ICAS?

Dr. HOLLOMON. The present situation is that these reports will be coming into the National Science Foundation, and the substance of their analysis will certainly be made available to ICAS and other interested agencies.

Senator DOMINICK. I wonder if we could have the staff find out who will be doing the evaluation of these reports and to what extent they will be available to the general public?

(Material requested follows:)

NATIONAL SCIENCE FOUNDATION,
OFFICE OF THE DIRECTOR,
*Washington, D.C., March 16, 1966.*

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

DEAR MR. CHAIRMAN: This is in further response to your letter of February 28 and our acknowledgement of March 7 concerning the additional information on weather modification reports which you and Senator Dominick have requested.

You ask to be informed as to what group is processing the weather modification activity reports required by the Foundation, and to what extent the reports are made public and circulated within the Government. You also requested to be informed as to the use to which the information contained in the activity reports is being put and a few samples of the type of information being received.

As you know, effective January 1, 1966, the Foundation requires in accordance with 45 CFR 635.1–635.7 that all persons engaged in weather modification activities provide advance notice to the Foundation of intention to conduct such activities, submit monthly progress reports, and maintain logs and keep records. A copy of the regulation is enclosed for your convenient reference. A significant difference between the current and past requirements is that the present regulation provides that those engaging in weather modification must initiate reports of the activities they intend to undertake and the progress thereunder rather than requiring the Foundation to seek out those conducting weather modification activities and to request annual and periodic reports from them after the projects have been started. This will provide current information to any Government agency desiring to check with NSF on the possibility of contamination of any proposed field site by the planned activities of others.

In early January 1966 when the Foundation announced the new regulation to the appropriate officials of all the States and to all the weather modification researchers and operators known to us, we stated that this new procedure would undergo a pilot analysis over a period of approximately 1 year, and upon conclusion of this study the Foundation contemplated the development of a procedure for distributing information on active and intended weather modification field operations. Since these new reporting requirements have been in effect for only a period of a little over 2 months, we believe that at the present time there is not sufficient experience with the new reporting system to make decisions as to how this information should be disseminated to the public and as to the manner and frequency of publication for its best use by the scientific community and in the general public interest. In the meantime, this information will be of value to the Foundation and other agencies in planning and carrying out their programs of weather modification research, in helping to judge the extent of work underway or being planned, in assuring that they are not supporting duplicating or interfering efforts in the field, and in permitting the Foundation to warn other groups in the field that their programs may interfere with one another.

The Division of Environmental Sciences of the Foundation, which is responsible for processing the weather modification reports, has received enough reports

to enable us to provide you with copies of some representative reports in order to respond to your request for a few samples of the type of information being received. Three copies of reports are enclosed. When we have been able to make a meaningful and helpful analysis and study of our experience under the new weather modification reporting system, we will inform you accordingly. In the meantime, if we can be of any further assistance, please do not hesitate to call upon us.

Sincerely yours,

(Signed) LELAND J. HAWORTH, *Director*.

[Federal Register, vol. 30, No. 250, Dec. 29, 1965]

TITLE 45—PUBLIC WELFARE

Chapter VI—National Science Foundation

PART 635—KEEPING OF RECORDS AND FURNISHING OF REPORTS IN CONNECTION WITH WEATHER MODIFICATION ACTIVITIES

AUTHORITY: The provisions of this Part 635 issued under 72 Stat. 353 and sec. 11(a), 64 Stat. 149, 153.

**§ 635.1 Purpose.**

The purpose of this part is to develop information for use in carrying out the responsibility of the National Science Foundation to support a program of study, research and evaluation in the field of weather modification as authorized by the National Science Foundation Act of 1950, as amended. Section 14(f) of the Act authorizes the Director of the Foundation to obtain, by regulation, subpoena, or otherwise, such information in the form of testimony, books, records, or other writings, to require the keeping of or furnishing such reports and records, and to 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 carry out this responsibility, where adequate and authoritative data is not available from any Federal agency. The information required under this regulation is not so available and therefore must be obtained from individuals and organizations engaged in weather modification activities.

**§ 635.2 Application of part.**

This part applies to any person, and to any organization, whether commercial or nonprofit, engaged in or intending to engage in, any weather modification activity (including research) intended to modify the atmosphere through artificial means. Such activities include, but are not limited to, any of the following:

(a) Intentional seeding of clouds and fog to alter drop size distribution, produce ice crystals, produce coagulation of droplets, or in any way to influence the natural development cycle of the cloud or its environment by dispersing into in any material or gas such as silver iodide, lead iodide, carbon black, dry ice, ammonia, etc.

(b) Intentional initiation of large heat sources or fires to influence convective circulation or evaporate fog.

(c) Intentional modification of solar radiation exchange of the earth or clouds through the release of gases, dusts, liquids, or aerosols into the atmosphere.

(d) Intentional modification of the energy transfer characteristics of the earth's land or water surface by dusting with powders, liquid sprays, or dyes.

(e) Intentional release of electrically charged particles, radioactive particles or ions into the atmosphere to alter its electrical field pattern or produce localized electrical field anomalies.

(f) Intentional application of shock waves, sonic energy sources, or other explosive or acoustic sources to the atmosphere to influence cloud growth, dissipation, or precipitation patterns.

**§ 635.3 Reporting requirements.**

(a) *Prior notice.* Each individual or organization intending to engage in any weather modification activity on or after February 1, 1966, shall give not less than 30 days advance notice to the Foundation of intention to engage in such activity. Such notice will be submitted on a Foundation report form, copies of which will be made available upon request from the National Science Foundation, Washington, D.C., 20550. Where intention to engage in a weather modification activity develops less than 30 days prior to the planned activity, the required report shall immediately be forwarded to the Foundation by airmail and shall

be accompanied by a statement explaining why the 30-day requirement could not be met.

(b) *Activity reports.* After the weather modification activity reported pursuant to § 635.3(a) of this section has commenced, each person or organization engaged in such activity shall submit to the Foundation an activity report on field operations on a quarterly basis. This report will be submitted on the form referred to in § 635.3(a) of this section.

**§ 635.4 Maintenance of logs.**

Each individual or organization engaging in a weather modification activity shall maintain a daily log of such activity. The log shall contain all relevant facts, including the following:

(a) Daily Log of Ground Weather Modification Activities (including Seeding Releases):

(1) When readily available to project personnel during observational period, description of meteorological situation in target area and control area such as types of clouds, percent cloud cover, temperature, humidity, appearance of lightning, hail, funnel clouds, severe rain, snow and unusual radar patterns should be recorded.

(2) Quantitative meaurements of precipitation obtained from nonfederally operated sources such as rain gauges, snow pillows, radar, optical transmissometers and streamflow gauges, in target and control areas.

(3) Any pertinent remarks on unusual results or significant events in the progress of the project should be entered in the log if they would contribute significantly to the technical evaluation of the project.

(4) In the case of the operation of a ground silver iodide generator or other dispenser of particles, aerosols or gases, the daily log shall include:

(i) Location of each weather modification device or generator in use.

(ii) Name of individual responsible for turning each weather modification device or generator on or off.

(iii) Time each weather modification device or generator was turned on and turned off.

(iv) Basis or criteria for turning on or off each weather modification device or generator.

(v) Type of material dispersed by each weather modification device or generator.

(vi) Rate of material release of each weather modification device or generator during operation.

(vii) Total material released by each weather modification device or generator during each operational period.

(b) Daily Log of Airborne or Mobile Weather Modification Activities (including Seeding Releases):

(1) Complete log of each aircraft flight or mobile generator run including, but not necessarily limited to, ground track, altitude, air speed, times over check points, release points of seeding or other charges, temperature, average wind direction and speed at release altitude, and, for aircraft, specify type of aircraft, airport or airports used and names of crew members.

(2) All other pertinent information as listed above for ground weather modification activities.

**§ 635.5 Retention of records.**

Records required to be maintained by this part, including logs, shall be available for inspection upon request of the National Science Foundation for a period of not less than 5 years after the date of entry. Such records shall not be required to be produced at any place other than the place where normally kept, provided a true copy of such record is made available to the Foundation, as may be requested, or there is agreement as to the information contained therein.

**§ 635.6 Disclosure of information.**

Information developed as a result of the reporting procedures set forth herein shall be made publicly available on a periodic basis by the Foundation. This information will not include trade secrets or other data required to be kept confidential under section 1905 of Title 18 of the United States Code, except where the Director of the Foundation determines that the withholding of such information would be contrary to the purposes of sections 3(a)(9) and 14 of

the National Science Foundation Act of 1950, as amended. Individuals and organizations reporting weather modification activities may request that information which they consider to be included within the scope of 18 U.S.C. 1905 be withheld from public disclosure and the Foundation will give due consideration to granting such requests.

**§ 635.7 Penalty.**

Any person willfully failing to meet the requirements imposed by this regulation shall, upon conviction, be fined not more than $500.

*Effective date.* This part shall become effective on January 1, 1966.

Dated: December 21, 1965.

LELAND J. HAWORTH,
*Director, National Science Foundation.*

[F.R. Doc. 65-13879; Filed, Dec. 28, 1965; 8:48 a.m.]

---

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C.

REPORT ON WEATHER MODIFICATION OPERATIONS

Public Law 510, 85th Congress

(See instructions)

NSF File No. 66-67.

This report is supplement to notification of intent.

Dates covered by this report: Continuing.

1. Project designation: Project Screen Test.

2. Name and address of sponsoring agency: National Science Foundation, Washington, D.C.

3. Purpose of operation: To run a screening test on certain chemical reagents as ice nucleants in supercooled clouds.

4. Target area: (attach map showing target and control areas and location of all ground generator sites, rain gages, radars, etc.). No specific target or control areas will be used. The opportunity to seed will be determined by the location of clouds within the area on the accompanying map.

Approximate size of test area 10,000 square miles.

5. Description of equipment and seeding agents or other modification technique employed (see instructions):

Aircraft: 310 Cessna equipped with manual release equipment.
Reagents: Urea, AgI, phloroglucinol, hydrophobed silicates.
Dispenser: "Optional use" of impact pulverizer.

6. Operating summary for quarter: (See instructions).

7. Where may log book information be obtained if required? Robert Knollenberg, Univ. of Wisconsin, Meteorology Department, 404 Science Hall.

8. Where may a copy of the summary report be obtained at completion of project? Univ. of Wisconsin, Meteorology Department.

CERTIFICATION. I certify that the above statements are true, complete, and correct to the best of my knowledge and belief, and are made in good faith.

ROBERT KNOLLENBERG,
*Junior Investigator, University of Wisconsin Meteorology Department, Madison, Wis.*

FEBRUARY 7, 1966.

INSTRUCTIONS

One copy of NSF Form 9B-13 is to be submitted 30 days or more prior to actual modification operations and box checked indicating "modification of intent." At 90-day intervals thereafter, one copy of form 9B-13 is to be submitted and box checked indicating "quarterly activity report" until project is completed. "Dates covered" should indicate estimated starting and completion date for field operations when "notification of intent" is checked. For quarterly reports, "dates

covered" should indicate reported months and year. Form should be mailed to NSF no later than 1 month after end of reported quarter.

Item 1. Enter project designation or designation.

Item 2. Enter name and address of sponsoring company, organization, or individual.

Item 3. Enter type and purpose of weather modification operations: i.e. rainfall increase, hail suppression, etc.

Item 4. For "notification of intent," map should be attached showing target area, control area, coded number and location of each ground generator and coded number and location of key rain gages, radars, or other precipitation measuring devices. Also location of airport for airborne operations.

For quarterly activity report, reference can be made to original submission, unless a significant change has occurred during the reporting period.

Item. 5. Describe type of ground or airborne generators used, type of seeding material dispensed, rate of dispensing material in grams per hour or other appropriate units, type of precipitation gages used in target and control area, and any other pertinent information such as type of radars, type of aircraft employed, etc.

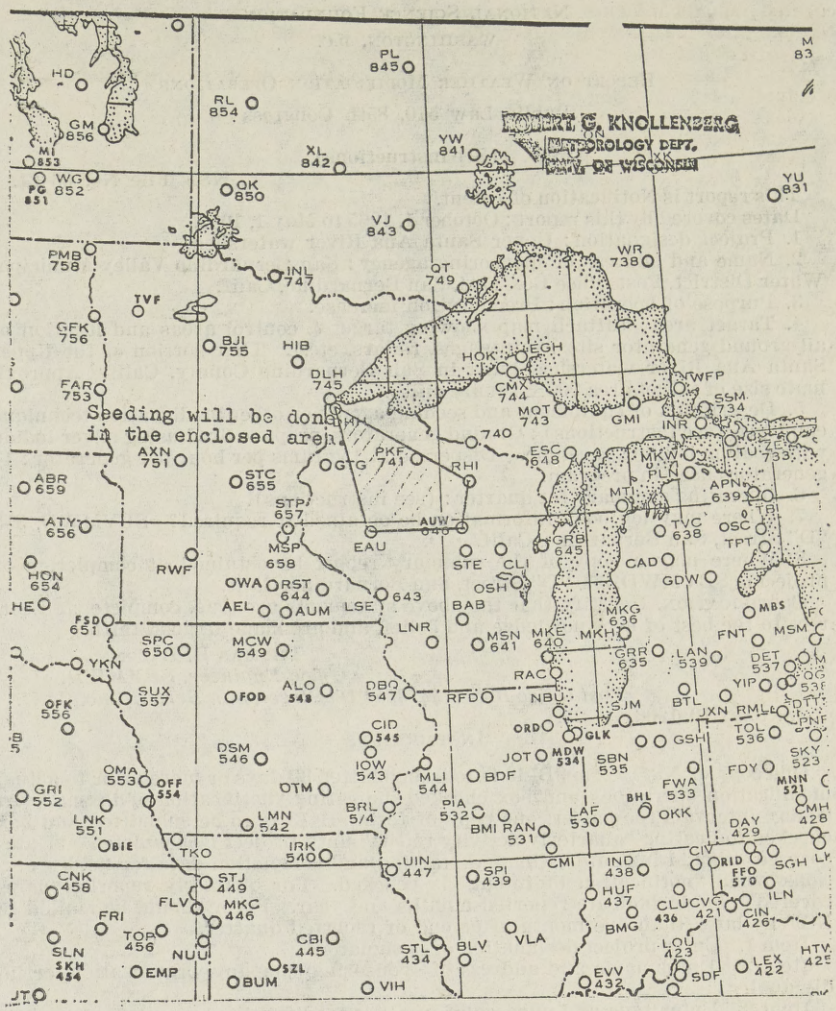
For quarterly activity report, reference may be made to original submission, unless a significant change has occurred during the reporting period.

Item 6. For quarterly reports, report total hours of operation and total material dispensed for each coded generator location on map of item 4 for reported quarter. For airborne operation, specify altitude, date and times of release of seeding material specifying ground check points over which release took place for each seeding flight. Also specify total quantity of material released on each flight.

Item 7. List name and address of responsible individual from whom logbook entries may be obtained or examined. Phone number should be included if possible.

Item 8. List name and address of responsible individual from whom an evaluation of results may be obtained after the completion of the project. The final quarterly report should indicate estimated date when final summary report will be available.

Attach additional sheets if necessary.


Seeding will be done
in the enclosed area.
ROBERT G. KNOLLENBERG
METEOROLOGY DEPT.
UNIV. OF WISCONSIN
PL 845
RL 854
HD
GM 856
MI 853
WG 852
PG 831
XL 842
OK 850
YW 841
YU 831
VJ 843
PMB 758
INL 747
OT 749
WR 738
TVF
GFK 756
BJI 755
HIB
DLH 745
HOK
EGH
CMX 744
MOT 743
GMI
WFP
SSM 734
INR
FAR 753
AXN 751
PKF 741
OGG
RHI
740
ESC 648
MKW
PLN
BTU
ZEL 733
ABR 659
STC 655
MTI
APN 639
TBI
STP 657
ATY 656
AUW 646
TVC 638
OSC
TPT
MSP 658
EAU
GRB 645
STE
CLI
CAD
HON 654
RWF
OWA
RST 644
OSH
GDW
AEL
AUM
LSE
643
BAB
MKG 636
MBS
FSD 651
LNR
MSN 641
MKE 640
MKH
FNT
MSM
SPC 650
MCW 549
GRR 635
LAN 539
DET 537
YKN
RAC
YIP
SUX 557
FOD
ALO 548
DBQ 547
RFD
NBU
BTL
OFK 556
SJM
JXN
RML
ORD
GLK
TOL 536
CID 545
GSH
DSM 546
JOT
MDW 534
SBN 535
SKY 523
OMA 553
OFF 554
IOW 543
BDF
FDY
GRI 552
OTM
MLI 544
FWA 533
MNN 521
BRL 5/4
PIA 532
BHL
OKK
LNK 551
LMN 542
BMI
RAN 531
LAF 530
DAY 429
OBIE
TKO
IRK 540
UIN 447
CMI
IND 438
CIV
RID
FFO 570
SGH
CNK 458
STJ 449
SPI 439
HUF 437
ILN
FLV
MKC 446
CLUCVG 421
CIN 426
FRI
BMG
TOP 456
CBI 445
VLA
LOU 423
SLN
SKH 454
NUU
EMP
SZL
STL 434
BLV
EVV 432
SDF
LEX 422
BUM
VIH

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C.

REPORT ON WEATHER MODIFICATION OPERATIONS
Public Law 510, 85th Congress

(See instructions)

NSF File No. 66–21.

This report is Notification of Intent.

Dates covered by this report: October 1, 1965 to May 1, 1966.

1. Project designation: Upper Santa Ana River watershed.

2. Name and address of sponsoring agency: San Bernardino Valley Municipal Water District, Post Office Box 1144, San Bernardino, Calif.

3. Purpose of operation: Precipitation increase.

4. Target area: (attach map showing target & control areas and location of all ground generator sites, rain gages, radars, etc.). That portion of the Upper Santa Ana River watershed lying in San Bernardino County, Calif. Approximate size of target area 900± square miles.

5. Description of equipment and seeding agents or other modification technique employed (see instructions): Ground generators, propane fired using silver iodide with sodium iodide in acetone. Dispersed at 15 grams per hour per generator; 17 generators used in program.

6. Operating summary for quarter: (see instructions).

7. Where may log book information be obtained if required? SBVMWD, 355 "D" Street, San Bernardino, Calif.

8. Where may a copy of the summary report be obtained at completion of project? SBVMWD, 355 "D" Street, San Bernardino, Calif.

CERTIFICATION. I certify that the above statements are true, complete, and correct to the best of my knowledge and belief, and are made in good faith.

THOMAS R. BACON,
*Office Engineer, SBVMWD,*
*Post Office Box 1144, 355 "D" Street, San Bernardino, Calif.*

JANUARY 19, 1966.

INSTRUCTIONS

One copy of NSF Form 9B–13 is to be submitted 30 days or more prior to actual modification operations and box checked indicating "notification of intent." At 90-day intervals thereafter, one copy of form 9B–13 is to be submitted and box checked indicating "quarterly activity report" until project is completed. "Dates covered" should indicate estimated starting and completion date for field operations when "notification of intent" is checked. For quarterly reports, "dates covered" should indicate reported months and year. Form should be mailed to NSF no later than one month after end of reported quarter.

Item 1. Enter project designation or designation.

Item 2. Enter name and address of sponsoring company, organization, or individual.

Item 3. Enter type and purpose of weather modification operations: i.e. rainfall increase, hail suppression, etc.

Item 4. For "notification of intent," map should be attached showing target area, control area, coded number and location of each ground generator and coded number and location of key rain gages, radars, or other precipitation measuring devices. Also location of airport for airborne operations.

For quarterly activity report, reference can be made to original submission, unless a significant change has occurred during the reporting period.

Item 5. Describe type of ground or airborne generators used, type of seeding material dispensed, rate of dispensing material in grams per hour or other appropriate units, type of precipitation gages used in target and control area, and any other pertinent information such as type of radars, type of aircraft employed, etc.

For quarterly activity report, reference may be made to original submission, unless a significant change has occurred during the reporting period.

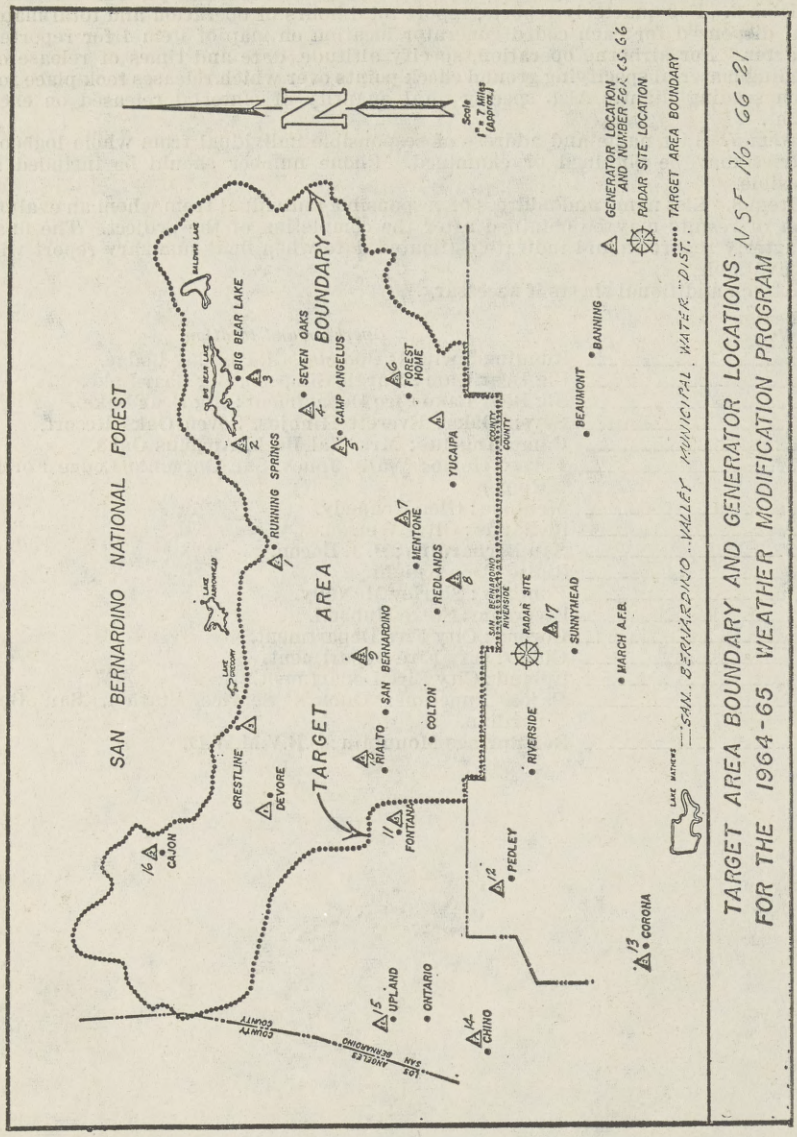
Item 6. For quarterly reports, report total hours of operation and total material dispensed for each coded generator location on map of item 4 for reported quarter. For airborne operation, specify altitude, date and times of release of seeding material specifying ground check points over which releases took place for each seeding flight. Also specify total quantity of material released on each flight.

Item 7. List name and address of responsible individual from whom logbook entries may be obtained or examined. Phone number should be included if possible.

Item 8. List name and address of responsible individual from whom an evaluation of results may be obtained after the completion of the project. The final quarterly report should indicate estimated date when final summary report will be available.

Attach additional sheets if necessary.

| *Generator No.* | *Operator and location* |
|---|---|
| 1 | Running Springs: Bob McCall, Holiday Lodge. |
| 2 | Big Bear Dam: Margie Simpson, Big Bear Lake. |
| 3 | Big Bear Lake Fire Department: Big Bear Lake. |
| 4 | Seven Oaks: Everett Hinojos, Seven Oaks Resort. |
| 5 | Camp Angelus: Mrs. Val Beck, Angelus Oaks. |
| 6 | Forest Home: Wally Jones, San Gorgonio Lodge Forest Home. |
| 7 | Mentone: Glen Kennedy. |
| 8 | Redlands: Olive Wenzel. |
| 9 | San Bernardino: P. J. Bacon. |
| 10 | Rialto: Don Knight. |
| 11 | Fontana: Shirley McNelly. |
| 12 | Riverside: Steve Hubbell. |
| 13 | Corona: City Fire Department. |
| 14 | Chino: City Fire Department. |
| 15 | Upland: City Fire Department. |
| 16 | Cajon Junction: Odom's Service Station, San Bernardino. |
| 17 | Box Springs Mountain: S.B.V.M.W.D. |




TARGET AREA BOUNDARY AND GENERATOR LOCATIONS NSF No. 66-21
FOR THE 1964-65 WEATHER MODIFICATION PROGRAM

Senator DOMINICK. Now, Doctor, you have been here on the Washington scene long enough now and you know as well as I do that one of the problems that we as a committee are going to face is the question of what agency is going to have the major responsibility for advancing the general technology of weather modification, I gather you think it ought to be incorporated in Commerce?

Dr. HOLLOMON. That is correct, sir.

Senator DOMINICK. Do you anticipate that legislation of this type would receive pretty sharp reactions from the other agencies?

Dr. HOLLOMON. I do not, sir.

Senator DOMINICK. That is encouraging. And I hope you are right.

Dr. HOLLOMON. I also pointed out—I don't know whether you were here—I pointed out in my statement that there is under consideration a reorganization plan to transfer the responsibilities from NSF to the Department of Commerce.

Senator DOMINICK. How long have we been using weather observation satellites?

Dr. HOLLOMON. On an operational basis, and by this I mean routinely on an operational basis, from the standpoint of systematic continuous basis we have been using them starting the beginning of this year. The launch hopefully is being counted down for the second operational satellite at this moment. We were supposed to launch it 2 days ago, the second satellite of the operational system 2 days ago, and we hope to have it launched on Saturday. However, there have been since April 1, 1960, experimental satellites which have provided cloud cover observations——

Senator DOMINICK. Is this the Tiros satellite?

Dr. HOLLOMON. Right. The Tiros system provides cloud observations particularly, and on a more or less routine basis. There have been periods in which we haven't gotten coverage. It was an experimental program. Each satellite was somewhat different from the preceding one, and so on.

The first operational satellite was launched about 2 weeks ago, February 3. This will be a continuous operational program.

Senator DOMINICK. This is being coordinated, I gather, with the Navy, in its work in the oceans on reporting buoys and things of that kind?

Dr. HOLLOMON. No; this satellite is for the purposes of cloud observations.

Senator DOMINICK. I understand that, but is this being coordinated with the Navy?

Dr. HOLLOMON. The data we get from the buoys feeds into the same system the satellite feeds into, which is weather central in Suitland.

Senator DOMINICK. This is the computer system you referred to previously?

Dr. HOLLOMON. Not only the computer system, but then the satellite information is used to monitor the computer system, where this cloud cover information can give us, particularly over areas of the world—this is one of the serious problems about weather prediction—over areas of the world where we do not have adequate observations, particularly the Southern Hemisphere, and the Pacific, we just don't have

adequate observations. This satellite gives us qualitative, not quantitative, information, over these areas. And this is used to moderate, as much as possible, the observation and prediction capabilities of the central weather information, to make it more accurate.

Senator DOMINICK. Would either one of you be able to render even a guess as to where weather starts?

Dr. WHITE. It starts everywhere, in a sense. Disturbances are continuously being formed in the atmosphere at various places. There are preferred places where these disturbances are formed. For example, one of the preferred places is in the Gulf of Mexico, or off Cape Hatteras. But, literally, weather forms and stops just about everywhere.

Senator DOMINICK. From the point of view of the continental United States, does weather start, as far as observational techniques and interpretation, largely from the Northwest Pacific, plus the interaction from——

Dr. WHITE. Generally, weather moves from West to East, and it is very vital, therefore, that you have data and observations to the West, and in our continent, also to the North. So if I had a choice for just one observation point, if I were in the middle of the United States, I would choose a point in the Northwest.

Senator DOMINICK. Thank you very much, gentlemen. We appreciate it. As far as I am concerned, if I have any more questions, I will drop you a line and see if you can give me some answers.

Dr. HOLLOMON. Thank you very much, Senator.

Senator DOMINICK (presiding). We will now hear from Dr. Thomas Bates, science adviser to the Secretary, Department of the Interior.

## STATEMENT OF DR. THOMAS F. BATES, SCIENCE ADVISER TO THE SECRETARY, DEPARTMENT OF THE INTERIOR; ACCOMPANIED BY DR. ARCHIE KAHAN, DIRECTOR OF THE OFFICE OF ATMOSPHERIC WATER RESOURCES OF THE BUREAU OF RECLAMATION, DENVER, COLO.

Senator DOMINICK. Dr. Kahan, it is a pleasure to have you with us, too.

Do you have a prepared statement?

Dr. BATES. Yes. And with your permission, I would like to read it for the record.

You already know, I believe, Dr. Kahan who is director of our Office of Atmospheric Water Resources of the Bureau of Reclamation, headquartered in Denver, Colo.

Mr. Chairman and members of the committee, the Department welcomes this opportunity to present its views on legislative proposals which, if enacted, would affect the management and wise use of the Nation's water supply. This Department bears the major responsibility for the management of the Nation's natural resources; and of all of these, water is the most indispensable.

Surface and underground water, sea water and atmospheric water all play their part in meeting the total water requirements of our growing population. Science and engineering can help increase exist-

ing supplies of water by expanding and perfecting the techniques of desalination, by teaching us how to recharge underground reservoirs, by developing effective evaporation controls, and by unlocking the clouds in one region without depriving another area of its normal precipitation.

As President Johnson said last spring:

> The development of methods for altering weather and climate to the benefit of mankind is a subject of quickening interest in the Congress and the executive branch of the Government of the United States, as, indeed, it is to all of the human race. We recognize that achievement of such a capability would mean vast economic and social gains for human life on this earth. I believe it is both symptomatic and symbolic of the character of the American people that we are now engaged in first steps toward this goal, not for any narrow national purpose, but in the confidence that such benefits will be shared as a mutual blessing with all of our fellow men.
>
> The scientific and engineering obstacles that must be overcome rank in magnitude with those encountered in developing peaceful uses of nuclear power and compare with those now being encountered in our attempts to place a man on the moon. * * * Substantial progress had been made. * * * But the pace has been slow. To advance the rate of progress, an effort of larger scope and direction is needed both in conducting basic research and in developing means to put the knowledge to work.

To meet the challenge expressed so effectively by the President will require the cooperative efforts of universities and industry, of communities and States, and most certainly of the various Federal agencies charged by the Congress with responsibilities that involve research, testing, and operations in weather modification.

One of the most pressing of these responsibilities, that of assuring adequate water supplies to meet the growing needs of the Nation, involves the Department of the Interior. This Department would be delinquent in its duties if it did not actively plan and work to make proper use of all components of the water resource system. Atmospheric water is the most important of these components.

For this reason it is particularly important that Interior be involved from the outset in the planning and execution of any weather modification program related to its mission. Thus, to the extent that weather modification may be used to manage precipitation, not only should major operational responsibilities rest with the Department of the Interior, but also this Department must determine and be responsible for much of the research and development work that must precede the employment of any particular operational procedure.

At the same time the research, testing and operational programs in the area of weather modification which are required for the accomplishment of the missions of other major governmental agencies, such as the Department of Defense and the Department of Agriculture, are best performed by those agencies.

Our further remarks, both with respect to our own programs and with respect to the relationship of these goals to the proposed legislation, S. 2916 and S. 23, should be viewed against this background.

The Congress recognized several years ago that weather modification may be one of the important tools required by the Department of the Interior for its management of America's water resources. We are pleased to report that the congressionally assigned program of the Department is being directed and enlarged to meet the President's

challenge by developing ways to put our knowledge of weather modification to work to improve the management of our water resources.

From a beginning of only $100,000 in 1962, the program has been increased by the Congress to almost $3 million in 1966. We have engineering research contracts in effect with seven educational institutions, five private organizations, one State agency, and five other Federal agencies. Associated with this program is an advisory committee of leading experts on water resources and weather modification.

The reports issued last month by the Special Commission on Weather Modification of the National Science Foundation and the Panel on Weather Modification of the National Academy of Sciences clearly support the need for mounting a much larger effort in all fields of weather modification. These reports recognize the need for the mission-oriented weather modification programs of agencies such as the Departments of Agriculture, Defense, and the Interior.

But we emphasize that such expansion of our program in atmospheric water resources complements and does not in any way conflict with the weather modification research and operation of other mission-oriented agencies. Thus, the hail research efforts sponsored by the National Science Foundation, the fog dispersal work of the Air Force, the hurricane research of the Navy and the severe storms work of Commerce should continue at an accelerated pace.

The Department of the Interior's principal concern and interest is in the increase, decrease, or relocation of precipitation as significant means of providing for our overall management of water resources. The National Science Foundation Special Commission points out in its report that the following factors tend to favor assignment of responsibility for weather and climate modification to the Department of the Interior:

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

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

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

In further support of these views, let me point out how varied and how complex are the responsibilities of the Department of the Interior for water resources management. Last year, the Congress established the Cabinet-level Water Resources Council to plan the best use of this Nation's portion of our planet's water. The Water Resources Council is composed of the Secretaries of the Interior; Agriculture; Defense; Health, Education, and Welfare; and the Chairman of the Federal Power Commission. President Johnson has designated the Secretary of the Interior as the Chairman of the Council.

While water for most of us is a simple and familiar item, in reality water uses are now highly complex, interrelated, and even conflicting.

The water management programs of the Department of the Interior recognize this complexity and interrelationship.

Our water projects serve many purposes including navigation, recreation, fish and wildlife, quality of water, power production, irrigation, municipal and industrial uses, and flood control. Indeed, this Department has explored and developed many new techniques of water management in the public interest.

Our Office of Saline Water has a dozen years of productive work in research under its belt and is making great strides toward salt water desalination as an economic and competitive source of fresh water.

The Office of Water Resources Research provides support for basic and applied research and the training of graduate students at each of the 51 Water Research Institutes. A few of the projects are in the area of weather modification and all are designed to provide increased knowledge and capabilities needed for the proper management and utilization of our water resources.

For the past 64 years, the Bureau of Reclamation has made irrigation facilities available and provided water service to more than 9 million acres of land suitable for sustained irrigation and municipal and industrial water for 11 million people. The value of crops and forage produced on these lands over the years now stands at almost $22 billion.

While irrigation was the initial factor in reclamation work, other water uses are making increasing demands on reclamation projects. This Bureau has also been conducting experiments for a number of years on suppression of evaporation from reservoirs, a program intended to significantly increase usable water supplies throughout the Nation.

Bureau interest in weather modification began in 1947 and led to establishment of the formal program of engineering research referred to previously. The activity is now centered in the Office of Atmospheric Water Resources, directed by Dr. Archie Kahan, who is appearing with me today.

The U.S. Geological Survey has long been responsible for the measurement and evaluation of this Nation's underground and surface water supplies both as regards quantity and quality. Most major decisions regarding possible action to be taken in meeting short-range flood or drought emergencies or long-range flood or drought emergencies or long-range water resource problems are based upon the data and evaluations provided by this agency.

Other agencies in the Department of the Interior participating in water resource programs include the Office of Coal Research, Fish and Wildlife Service, Bureau of Indian Affairs, Bureau of Land Management, National Park Service, Bureau of Outdoor Recreation, Office of Territories, Bonneville Power Administration, Southeastern Power Administration, Southwestern Power Administration, and a number of other organizational units.

Despite such concentration of expertise dedicated to the solution of the Nation's water problems, no Federal agency is self-sufficient. The Department of the Interior needs the continuing help and support of other Federal agencies in carrying out its growing program. In its atmospheric water resources, it already has working agreements that

can be expanded with the Weather Bureau, and with agencies of the Department of Agriculture and the Department of Defense.

We wish to underline our support of the statement in the NSF Special Commission report that:

> The National Science Foundation should continue and expand its support of research in the atmospheric sciences, including its program directed at providing a satisfactory scientific basis for weather and climate modification. This should be carried on primarily at universities and colleges and should include maintenance of the National Center for Atmospheric Research as a facility for the conduct of basic research on a scale beyond that feasible for individual university investigators. The degree of continuing and special attention given by the Foundation to the support of the physical sciences, engineering, the biological sciences, and the social sciences aspects of weather and climate modification should be reviewed from time to time in the light of the progress of the overall national program.

We also strongly concur with the recommendation of the NSF Special Commission that Federal agencies should be free to conduct and support such research and development and undertake such operational activities in the weather modification area as are required for the effective discharge of their missions.

This recommendation is consistent with what the Department of the Interior has been doing in its atmospheric water resources program for the past 4 years.

We emphasize that the important contribution of a weather modification program to water augmentation and to other major objectives of other Federal agencies can best be accomplished by making essential units of that program a part of the operating missions of those organizations. It is against that standard that we need to appraise S. 23 and S. 2916.

Senate bill S. 23 introduced by Senator Anderson in the 1st session of the 89th Congress is identical to S. 1020 introduced by Senator Anderson in 1963. Both bills would authorize $20 million for a period of 8 years during which the Secretary of the Interior and the National Science Foundation would undertake to conduct engineering and meteorological studies and investigations of physical methods for cloud seeding to increase precipitation, and techniques of controlling snowpack storing and runoff. Subsequent to the introduction of S. 1020, the atmospheric water resources program of the Bureau of Reclamation has been greatly expanded.

Before the Congress directed the expansion of atmospheric water activities by the Bureau of Reclamation hearings were held by the Senate Committee on Interior and Insular Affairs which reviewed various proposals for stepping up the Bureau of Reclamation's program. Under the authority of reclamation law, the Bureau of Reclamation is now conducting an expanding program of investigation and applied research aimed at augmenting water supplies through the inducement of precipitation at a number of locations. The Bureau operated these activities on a budget of $1,126,000 in fiscal year 1965, $2,980,000 in fiscal year 1966, and has a proposed budget before the Congress for $3 million in fiscal year 1967. In all of these activities, this Department is working closely with other Federal agencies including the National Science Foundation.

In view of what has just been stated to you, we believe that the objectives of S. 23 are being adequately met by the present operations

of the Department acting through the Bureau of Reclamation. We fail to see any need for enactment of such a bill at the present time.

We believe that S. 2916 as written is deficient in a number of respects. For example, it fails to reserve unequivocally the right of agencies to perform operational missions which the Congress has assigned. We believe that the act as written could be interpreted as giving to the Secretary of Commerce the sole or predominant responsibility for research and development work needed to augment or modify precipitation in the area of water resource management. We are not alone in this interpretation.

Science magazine for February 18, 1966, states:

> Apparently, under the concept entertained by Magnuson and the Commerce Department, agencies with an interest in weather modification would either confine their programs to the application of operational techniques developed for them by ESSA or follow ESSA's guidance in developing the techniques themselves.

We believe that it is essential that agencies needing operational techniques be permitted to do required research and development.

We believe that the proposed authority of the Secretary of Commerce to regulate commercial enterprise in the field of weather modification should be specifically limited to exclude private contractors performing assignments from other Federal agencies.

We believe that coordination of Federal agency programs in weather modifications should be carried out in the Office of Science and Technology rather than in the Federal Council for Science and Technology. We support the report of the NSF Special Commission in this regard.

In conclusion, Mr. Chairman, while we are heartily in favor of legislation which would encourage progress in weather modification, we consider that S. 2916 must be extensively revised before it will accomplish that goal in the most effective manner.

Senator DOMINICK. Dr. Bates, thank you for your statement. As you probably know, when I was on the Interior Committee, I was instrumental in getting an appropriation for weather modification research through the committee and through the Appropriations Committee and into the hands of the Bureau. So I have a great deal of sympathy for your testimony.

I do have a couple of questions that I think might point it up. Mr. Dominy, or someone in the Interior Department some time ago produced some figures showing what 1 inch of additional water in the Upper Colorado River Basin would produce in terms of acre-feet down through the river. Do you have any recollection of what those figures were?

Dr. BATES. I was not on deck at that time. We can get them for you and insert them in the record.

Senator DOMINICK. I think that would be helpful, because it is my recollection that it was a fantastic amount of additional water that would be available for that whole river system.

(The information follows:)

ATMOSPHERIC WATER RESOURCES PROGRAM OF BUREAU OF RECLAMATION, U.S. DEPARTMENT OF THE INTERIOR

**It is estimated that an additional inch of precipitation above Glen Canyon Dam on the Colorado River would produce a runoff of 575,000 acre-feet of water. This extra amount of flow through Federal powerplants could boost income from**

**hydroelectric power production, using established power rates, by $2.5 million. This additional water would also be available for agricultural, municipal, and industrial uses. Allowing for losses in runoff, this additional inch of precipitation could still provide 500,000 acre-feet of water for irrigation which could produce an annual gross crop income in excess of $25 million. Use of part of this additional supply for municipal and industrial uses would of course substantially increase the value of this extra precipitation.**

**The additional water supply would also provide benefits to recreation, fish and wildlife, and improvement of water quality. Discussion of water quality is an important consideration in our relations with Mexico concerning international aspects of the Colorado River.**

Senator DOMINICK. If we were able to do this, and on the assumption it would produce a lot of water, what would be the international effect?

Dr. BATES. It seems to me since we are linked directly with the problems of Mexico and of Canada from the standpoint of the agricultural production of these countries and the ability to sustain populations in these areas, that any benefits that accrue from the standpoint of improving our own situation in arid areas adjacent to Mexico and Canada would have overlapping effects in these countries. I do not know enough about interchange between the nations in this area to say what the direct effect would be here.

The other indirect effect, of course, is that by doing these things effectively in our own Nation we will be producing scientific and engineering knowledge that can be used very effectively either in coordinated efforts involving the United States and other nations or by those other nations themselves.

Senator DOMINICK. I think Dr. Kahan is aware of this. One of our problems, at the present time, is producing enough water to take care of the Mexican treaty obligations and particularly water that is not saline in its characteristics. This would be of help in that; would it not?

Dr. KAHAN. Yes, sir.

Senator DOMINICK. I wonder if you could give me an estimate of the cost that would be required to try and implement a program which would produce additional precipitation in the Upper Colorado River Basin?

Dr. KAHAN. To go into operational application of things we know now would require money of the order of millions of dollars, if you were to try it for the whole area at once. An appropriate way to start would be on a pilot plan basis and this could be done with additional funds of a fraction of a million dollars.

Operational application at the present time could be undertaken. It would contain an element of risk as to what the Government was getting for its money. The further we go toward evolving the operational systems, the less that risk should be. It is my personal opinion that widespread application should wait until we pin down some of the operating criteria that are now coming to light, so that we do not have operations going on under circumstances when you might decrease the precipitation instead of increase it.

Senator DOMINICK. The National Science Foundation has submitted evidence which would indicate that research up to now discloses that clouds of cold temperatures are amenable to weather modifica-

tion programs for additional precipitation better than clouds with warm temperatures. Would this mean then that your operations would probably be in the mountainous areas?

Dr. KAHAN. Yes, sir. The meteorological circumstances that lend themselves to seeding in light of our present knowledge occur in mountainous areas. In regard to this matter of cold and warm clouds, there is such a thing as the clouds getting too cold to be effective, in that the effectiveness of freezing nuclei is a temperature dependent thing and if the air gets cold enough, nature provides enough particles that are effective as freezing nuclei, so you have a range of optimum temperature for man to be able to be effective, that is, colder than some of the freezing temperatures, but you can go too far in this cold direction.

Senator DOMINICK. Where you have nothing but ice crystals in clouds, yes. Do you feel we have existing techniques now which would make meaningful an applied research experiment in the Upper Colorado River Basin?

Dr. KAHAN. Yes, sir, I do.

Senator DOMINICK. A couple of questions, Dr. Bates.

The Bureau of Reclamation is the primary agency of the Department of Interior involved in weather modification.

Dr. BATES. That is right.

Senator DOMINICK. It operates largely in the Western United States?

Dr. BATES. That is right.

Senator DOMINICK. Does it in fact operate east of the Mississippi?

Dr. BATES. Only through the making available of its expertise to other agencies in that area.

Senator DOMINICK. Do you think the agency with responsibility in this field, should be the Department of Interior and not the Department of Commerce?

Dr. BATES. That is right.

Senator DOMINICK. This sounds to me as though we are right in the middle of one of the things I commented on a few minutes ago, which I suspected would be the case.

Dr. BATES. If I might, I would like to say that the reason we are in the middle, I think, is because we are talking about the water resources responsibilities of the Department of Interior. The Bureau of Reclamation's authority relates to the 17 Western States. Nevertheless, from the standpoint of responsibilities of the Geological Survey, the Office of Water Resources Research, and the many other areas in the Department of Interior concerned with water resources—they all operate nationwide.

Senator DOMINICK. Do I understand from your statement that the Department of Commerce is not represented on the Water Resources Council?

Dr. BATES. That is correct.

Senator DOMINICK. You mentioned Interior, Agriculture, Defense, HEW, and the Chairman of the Federal Power Commission.

Dr. BATES. That is the case, I believe.

Senator DOMINICK. Would it be helpful to add Commerce to the Water Resources Council in view of its work in weather modification and in weather forecasting, good, bad, or indifferent?

Dr. BATES. I don't know that it is my place to make such a statement. I think that depends a great deal on how the present discussions in which we are engaged come out.

Senator DOMINICK. Is the Interior Department a member of ICAS?

Dr. BATES. Yes, sir. I am the representative on that committee.

Senator DOMINICK. And Commerce is?

Dr. BATES. That is right.

Senator DOMINICK. In your statement you refer to engineering research contracts in effect with certain institutions and organizations. I wonder if you would be kind enough to submit those organizations for the record?

Dr. BATES. We would be glad to.

(The information follows:)

ATMOSPHERIC WATER RESOURCES PROGRAM OF BUREAU OF RECLAMATION, U.S. DEPARTMENT OF THE INTERIOR

| *State* | *Contractor or subcontractor* |
|---|---|
| South Dakota | South Dakota School of Mines and Technology: Atmospherics, Inc.; Thomas J. Henderson, president. Weather Science Inc.; Dr. Ray Booker, president. |
| Wyoming | University of Wyoming. |
| Nevada | University of Nevada: North American Weather Consultants; Robert B. Elliot, president. |
| Colorado | Colorado State University: E. Bollay Associates; Eugene Bollay, president. |
| Utah | University of Nevada: North American Weather Consultants; Robert B. Elliot, president. |
| California | Taft College. Fresno State College. Naval Ordnance Test Station, China Lake. Precipitation Control Co.; Dave Merrill, president.[1] |
| Washington | Weather Modification Board, State of Washington: E. Bollay Associates; Eugene Bollay, president. Battelle-Northwest Laboratories, Richland. |
| Arizona | Meteorology Research, Inc.; Dr. Paul MacCready, president. |
| New Mexico | New Mexico State University[1] (also participation by New Mexico Institute of Mining and Technology). U.S. Geological Survey. U.S. Soil Conservation Service. U.S. Weather Bureau (ESSA). U.S. Forest Service. |

[1] Agreement under consideration.

Senator DOMINICK. You say that under the authority of reclamation law, the Bureau of Reclamation is now conducting an expanding program of investigation and applied research aimed at augmenting water supplies through the inducement of precipitation at a number of locations. Would you supply us with those locations?

Dr. BATES. We would be very glad to, sir. We could list them now if you wish.

Senator DOMINICK. That would be helpful if you have them.

Dr. KAHAN. In South Dakota, the South Dakota School of Mines and Technology is conducting experiments, at two experimental sites.

In Wyoming, the University of Wyoming is conducting cap cloud experiments.

In Colorado, E. Bollay Associates is conducting applied research project in the Steamboat Springs area of the Park Range.

In Flagstaff, Ariz., Meteorology Research, Inc., has been conducting research in cumulus clouds.

In Utah, Utah State University is developing a radio reporting network and is planning a seeding experiment.

In Nevada, the University of Nevada Desert Research Institute has a comprehensive program including both instrumentation and system development and a randomized seeding experiment.

In the Pacific Northwest we have recently begun instrumentation for a precipitation relocation experiment study. This is with the State of Washington Weather Modification Board, which, incidentally, has done some experimental work on its own previously.

In California, we have the beginning of planning of the coordination of existing programs aimed at trying to increase the learning that will result from them.

Senator DOMINICK. Thank you, Doctor.

Last year through the cooperation of Senator Allott and Senator Mundt and myself we were able to get an additional sum appropriated for the specific purpose of applied research. Although the bill itself did not say so, it was intended for the Upper Colorado River Basin, for the purpose of starting an applied research program for precipitation in that area.

Has anything been done along those lines?

Dr. KAHAN. We feel that the program that we are doing is applied research. If your meaning is the application of existing techniques for the actual production of water, it was our understanding of the legislation as it came out that we were precluded from spending any of the money for actual application of existing techniques.

Senator DOMINICK. That certainly was not my intention when we put it in. I frankly admit that I don't remember what the conference report eventually came out with in wording on that, but I thought it was left broad enough so you could do this.

Dr. KAHAN. It contained words that none of the increase should be applied for operational seeding.

Senator DOMINICK. You feel, however, that existing techniques are adequate to do meaningful applied research from the point of view of trying to induce additional precipitation?

Dr. KAHAN. Doing additional applied research; yes, sir.

Senator DOMINICK. Are those programs coordinated with FAA or Weather Bureau?

Dr. KAHAN. Yes, sir. In two ways. We have an advisory committee on which there is Weather Bureau and ESSA representation. We also have made a presentation to ICAS about our program in detail.

Senator DOMINICK. On the assumption that we should be successful in these programs, it occurs to me that predictability of weather from the normal pattern might be changed. And I wonder when this information is passed on to the Weather Bureau to be put into their computer, what effect it may have on weather.

Dr. KAHAN. I think by good communication between agencies, the knowledge and experience and the things that one agency is doing can be made available to another.

Senator DOMINICK. You don't know whether that is being done now?

Dr. KAHAN. At the present time we don't feel that we are doing anything that affects the weather on a scale that would be of interest to the Weather Bureau in determining their forecasts. Our actual seeding operations are on a quite limited scale. In the park range area, for example, the target area is on the order of 100 square miles. And the things that we are doing are not of a nature that the Weather Bureau would ordinarily forecast.

Senator DOMINICK. There is no difficulty in getting this information to the Weather Bureau, however, when these techniques are being put into application?

Dr. KAHAN. No, sir.

Dr. BATES. I might add one of the Federal agencies involved in the Bureau of Reclamation program on a contract basis is the Weather Bureau, so we have a very close liaison.

Senator DOMINICK. The National Academy of Sciences stated, "to anticipate the downwind effect upon, say, the Colorado River Basin or the Plains States due to massive seeding of the winter snowpack along the Sierras and Cascades requires quantitive knowledge of national patterns of flux convergence across these orographic bearings."

Does this suggest that the time for large-scale programs is still pretty far in the future?

Dr. BATES. I would like the meteorologist to answer that.

Dr. KAHAN. I think, as I indicated earlier, there would be considerable risk in undertaking large-scale programs, risks of wasting a good deal of the taxpayers' money.

The question of downwind effect needs to be looked at a lot more carefully than it has been. There is a tendency to apply an analogy with surface water and the appropriation of upstream moisture that is not nearly so applicable in the atmosphere. You can increase precipitation on the western slopes of the Colorado Rockies without affecting in any major way what happens on the eastern slope of the Colorado Rockies, because the two regions don't get their import precipitation from the same moisture source. The precipitation on the eastern side predominantly results from gulf air, air coming up from the Gulf of Mexico and not from air that has been dried out by coming across the Rockies from the Pacific.

Senator DOMINICK. Yesterday, the witness from NAS stated that the problem of so-called rain shadow, in the downwind area, was pretty well dissipated and really wasn't a problem.

Would you comment on that?

Dr. KAHAN. I think that it has been a fear, as I say, based on this surface-water analogy. I think the evidence to date of a downwind effect is certainly not impressive. I believe the studies performed in ESSA, to check this out, revealed that downwind for some 150 miles there was evidence of an increase rather than a decrease.

Senator DOMINICK. Doctor, you have been involved in weather modification for quite a long period. I know your background.

How many private organizations under contract would you feel are really using valid techniques in trying to accomplish additional precipitation?

Dr. KAHAN. I can think of about a dozen that would certainly come into that category. There may be others whose techniques I am not familiar with.

Senator DOMINICK. How large an area, in general, do they try to cover?

Dr. KAHAN. This depends on the circumstances of a particular operation. But, in general, it is in the hundreds of square miles. Some commercial projects were undertaken which began as units for the benefit of groups of counties; a west Texas county would run 30 by 30 miles and three or four of these might have gotten together to pool their interests in supporting the work. One might be talking about hundreds or even thousands of square miles in some commercial projects.

But they range downward to individual drainage basins for a particular dam.

Senator DOMINICK. So that commercial operations now are actually being conducted on a fairly big science scale as the term was used yesterday by the National Academy of Sciences?

Dr. KAHAN. They are certainly being conducted over large geographical areas. I didn't use the term and would suggest that the term "big science" ought to apply to the amount of knowledge involved rather than the dollars.

Senator DOMINICK. I was talking about scale of operations.

Dr. KAHAN. Yes, they certainly operate on a large scale.

Senator DOMINICK. The staff informs me in the early 1950's approximately 10 percent of the Nation was being seeded. Is that what you would also compute?

Dr. KAHAN. There were seeding contracts in effect for most of the Western States, sometimes over large areas. I would have said that the fraction of the Nation was larger than 10 percent.

Senator DOMINICK. Now is that still true or have these private operators dropped back in their operations?

Dr. KAHAN. The areas under treatment at the present time are much smaller than was the case then.

Senator DOMINICK. The National Science Foundation report also states:

> All weather modification experiments of a scale large enough to have important biological consequences, such as those currently envisioned for the upper Colorado River Basin, should be preceded and accompanied by careful ecological monitoring and computer simulation studies.

What is your comment on that?

Dr. KAHAN. I think the author of that statement may have known more about what is envisioned for the upper Colorado River than I do. We do not at the present time have plans for wide-scale seeding in the upper Colorado.

We are aware of the importance of ecology in this field. We have considered that it is possible to keep the impact on ecology in mind in experimenting and operating without necessarily affecting it adversely.

We are, for example, doing seeding in the upper elevations of a portion of the Colorado Rockies where there is now already heavy snow accumulation. The effect on the ecology of that area, of seeding that 100 squares miles, does not seem to be anything that you could call catastrophic.

We are in conversations with such people as the Forestry Service about the interrelation between ecology and seeding, both from the standpoint of how forest management practices affect runoff and also the reverse, what is going to be the effect of additional precipitation.

In general, I think there is a fear of widespread thoughtless activity here that I don't know that anyone really contemplates undertaking.

Dr. BATES. I would like to add, if I may, Mr. Chairman, that from the standpoint of the interests of the Department of Interior as a whole, as you may imagine, when you consider the responsibilities of the National Park Service, the Bureau of Public Land Management, the Bureau of Sport Fisheries and Wildlife, we are among those very concerned with the ecological relationships. There is a terrific need to establish the state of the situation as of the present time, so that all of the things that men do, not only by weather modification, but by increasing the size of our cities, building airfields, and so on, can be evaluated in terms of an increasing amount of knowledge in this area.

Consequently one aspect of an increased weather modification program that I believe we would all welcome would be the increased emphasis that it should give to such activities.

Dr. KAHAN. If I may add, Mr. Chairman, the present technology, the increases apparently possible, fall well within the range of natural variation, so it is difficult to see that animals and plants that have adapted themselves to the natural variation would be greatly affected by the important but still relatively small increases we are now looking at, the 10-percent increase.

There is no area I know of where the natural experience runs along so steadily that a 10 percent, or a much-greater-than 10-percent variation doesn't exist in natural experience.

Senator DOMINICK. The NAS report, Dr. Bates, also says: "The question of acceptable statistical design and evaluation of atmospheric experiments must be resolved." What has prevented the formation of adequate statistical design for this? Is it because of the lack of knowledge of what actually is going to be produced, or lack of knowledge of the formations to start with?

Dr. BATES. I think both of those factors are involved, Mr. Chairman. Just as we have been growing in this field with regard to the techniques that need to be employed, we have also been growing from the standpoint of how to deal with data, the improvement of statistics and the use of computers to do the things that we must do.

I believe that one aspect of the present program of the Bureau of Reclamation is to relate very directly to the state of the art, not only from the standpoint of the techniques used for cloud seeding, but the techniques relative to operations, research systems analysis, and statistical design.

Senator DOMINICK. Is that being carried forward?

Dr. BATES. Yes.

Senator DOMINICK. By your agency?

Dr. BATES. That is right. I am sure Dr. Kahan can speak specifically on that.

Dr. KAHAN. Some of the contracts which we have let have been let with improvements of evaluation techniques primarily in mind. One of the important aspects of the park range program is the trying out of a totally new approach to detecting or evaluating effective seeding.

Senator DOMINICK. One of the things that those of us who have been interested in this subject have had as a kind of rule of thumb is that you can't produce precipitation or rain when you don't have the necessary clouds or storms to produce it from. And I am wondering whether the experiments that have been conducted, or your own knowledge, would lead you to believe that over a period of time we could induce storms into a drought area, in order to relieve the drought. Otherwise, if we have clear skies, you won't get any more rain no matter what you do.

Dr. BATES. I personally believe that in the long-range view this is a very important reason to get this total program going. Obviously, in the present state of the art, we are purposely working in local situations where we can measure individual storm systems and clouds in sufficient detail to know whether to seed or not to seed.

But, looking at the long-range picture, it seems to me quite possible to envision that we should, one day, be able to look at the storms coming in over the Pacific and relate our increased knowledge as of that day, whenever it is, to be problems that you are speaking directly about, not just from the standpoint of the local area in California or Arizona, but from the standpoint of the Gulf Stream or the clouds forming in the Pacific and so on.

This is one reason I consider this such a tremendous opportunity that we have today, because of the very important potential that none of us can really see today.

Senator DOMINICK. It might be possible then to move storm clouds and by seeding them at the right time prevent them from dropping rain and moving them to an area where you need the rain?

Dr. BATES. I think there are a lot of things possible that we simply can't predict in the present state of our knowledge. I consider the challenge to be tremendous.

Senator DOMINICK. Is there a shortage of qualified people in this field?

Dr. BATES. As of the present situation, I do not frankly believe that there is. I believe as we go ahead and improve the image, if you wish, of work in the atmospheric sciences relative to meeting more specifically than we have done in the past the needs of man, we will benefit by people from other groups, other sciences, coming into this area.

This does not mean that we will not, as time goes on, when we develop a large program, have to do the same thing they have done in other areas; namely, encourage, through contracts of the type we now have with the universities, graduate students to work in these areas, bring them into these fields and increase the total number of people as the program grows.

Senator DOMINICK. Do you have a feeling that any of the bills which are presently before committees, whether this one or other committees,

will have any stimulating effect on producing more scientists in these fields?

Dr. BATES. I think a lot will depend on whether these bills are passed and implemented with regard to the funds involved. I do feel as I have looked at the whole field—I must say I am a geologist, not a meteorologist, so I have come in a little from the outside—I feel that even the work of the Bureau of Reclamation for the past 4 years together with the work of these high level NSF and academy committees, has already brought to the attention of my colleagues back in the universities an area that is going to be extremely important, and knowing how universities work, I am sure they are going to be very alert relative to what has already happened and looking toward further participation.

Senator DOMINICK. Dr. Bates, I wish you or Dr. Kahan would comment on the statement made by the Commerce witnesses that predictions are necessary to weather modification or accurate weather modification programs.

Dr. BATES. Let me just give a general statement and perhaps Dr. Kahan can add something. As I think was brought out in that testimony, some of this problem is a matter of semantics. Prediction as opposed to observation.

I think in our program, and Dr. Kahan can verify this, we need to establish for a cloud or storm system coming into our area of interest, whether or not it is ripe for seeding. Now this is observation, in my analysis, but it borders on the prediction aspects.

Let me say also that I think the roots of both these, prediction and weather modification, are based in the same need for knowledge. Whether we are going to make accurate prediction or whether we are going to do a job of weather modification, we must have the data required for both.

I cannot see a much more direct relationship between prediction and modification, except that obviously the group that is responsible for making predictions must be in very direct real time communication with the people who are doing the weather modification work, if they are going to make appropriate predictions.

Senator DOMINICK. Is the latter situation now true?

Dr. BATES. I don't believe so, to the extent it should be.

Senator DOMINICK. What would you recommend to improve this coordination and availability of prediction?

Dr. BATES. I would say the National Science Foundation program of obtaining information is the start of this. I have not studied this question and so I can't say how this should be expanded, but I believe something needs to be done to establish a more formal and real time communication in this area.

Senator DOMINICK. The Central Weather Forecasting Bureau of the Commerce Department presumably would be available at all times, would it not, for the operators of any weather modification program?

Dr. BATES. I assume so.

Senator DOMINICK. I am just wondering how we are going to do it any faster than that.

Dr. KAHAN. Mr. Chairman, the relation of prediction to weather modification has been mentioned frequently. There is no question but

what an ability to know what is going to happen arms a person to proceed with wisdom. It is not, however, necessary, as your questions earlier indicated, that all weather modification be based on predicted weather.

The principal thing that we are doing now in weather modification is adding to the supply of freezing nuclei. To my knowledge there are no systematic observations of the natural nuclei concentration being made on a wide scale, and I think this is something that has to happen.

So that the thing that is happening most directly, the insertion into the atmosphere of freezing nuclei at the present time doesn't play any role in any prediction system. To the extent that you are producing precipitation which affects the atmosphere, it would certainly be desirable for a prediction agency to know what was going on in the way of operational efforts.

An understanding of what is happening in the atmosphere is important, important to forecasting, important to attempts to modify the atmosphere.

The scale of operations that are presently going on are such that the forecasting involved needs to be done on a very local scale and is not the sort of thing that you get from the general weather forecasting service, although you do base your decisions about the future on data and analyses prepared by them.

So there is an involvement in prediction here that is of a fine scale, and there is an involvement on a gross scale. For anyone to make the case that you don't need good prediction would be ridiculous, but it should not be assumed that operations for weather modification have to be placed in direct organization juxtaposition with forecasting agencies.

Senator DOMINICK. Then the previous statements that I made to the Department of Commerce; namely, that you don't need accurate forecasting for the dispersal of cold fog, or for additional precipitation, would be reasonably accurate?

Dr. KAHAN. Yes, sir.

Senator DOMINICK. Fine. I appreciate both of you coming up. I think you have been very helpful as far as this overall testimony is concerned.

We will adjourn the meeting at this point and we will resume the hearings on March 7, 1966, in this room.

(Whereupon, at 1 p.m., the committee recessed, to reconvene March 7, 1966.)

# WEATHER MODIFICATION

MONDAY, MARCH 7, 1966

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

The committee reconvened, pursuant to recess, at 10:08 a.m., in room 5110, New Senate Office Building, Hon. Daniel B. Brewster, presiding.

Senator BREWSTER. The Commerce Committee will come to order.

This morning's hearing on weather modification is the fifth of the current series. At previous hearings this year the committee heard testimony from the National Science Foundation, the National Academy of Sciences, and several other Federal agencies.

At this morning's hearings, witnesses from the Department of State, the Department of Agriculture, the FAA, and several private parties will be heard.

The hearings today and tomorrow will add to the diversity of the testimony previously taken by this committee.

Much of the discussion and most of the projects to date have dealt with increasing precipitation. Active programs of fog dispersal and lightning suppression, however, are being conducted.

The commercial operators probably constitute the largest single group in terms of projects working in weather modification.

These and other factors will be highlighted this morning and tomorrow.

Now, is Dr. Wallace Joyce present?

## STATEMENT OF J. WALLACE JOYCE, ACTING DEPUTY DIRECTOR, INTERNATIONAL SCIENTIFIC AND TECHNOLOGICAL AFFAIRS, DEPARTMENT OF STATE

Dr. JOYCE. Yes, Mr. Chairman.

Senator BREWSTER. Dr. Joyce, will you please take the witness stand here?

Dr. Joyce is the Acting Deputy Director, International Scientific and Technological Affairs of the Department of State.

Dr. Joyce, we have a prepared statement from you, but please proceed as you wish, sir.

Dr. JOYCE. Mr. Chairman, I appreciate very much the opportunity to present material to the committee. I shall be glad to read the statement if you wish me to, since it is a rather brief one.

Senator BREWSTER. Please proceed.

Dr. JOYCE. The United States has 13 bilateral agreements with countries predominantly in the Western Hemisphere and particularly



59-528—66—pt. 1——16

in the Latin American area (Mexico, Peru, Chile, Colombia, France, French West Indies, Netherlands, Netherlands Antilles, Barbados, Cayman Islands, Trinidad, Jamaica, Dominican Republic, New Zealand, and Canada).

These agreements are based on exchanges of notes between the U.S. Government and the governments concerned. The agreements generally include provision for the United States to supply certain meteorological equipment and to train local personnel to enable them to operate this equipment.

For their part, the participating countries provide a site for the installation of the equipment, including necessary shelters. They also make all data obtained available to the United States, and additionally to all countries belonging to the World Meteorological Organization.

Through these agreements the United States has direct and rapid access to meteorological data in the areas involved, data required to improve our ability to predict weather and for other purposes.

In addition, the United States is a signatory to the World Meteorological Organization Convention which provides for formal participation in the affairs of this specialized agency of the United Nations. Through this means the United States is an active participant in the special communication circuits and in the data acquisition activities required for the preparation of meteorological forecasts on a hemispherical basis.

In regard to agreements dealing with the problems which weather modification will pose, there is one agreement which has recently been consummated by an exchange of notes between the U.S. Government and the Government of New Zealand to undertake preliminary testing of constant-level weather balloons, which ultimately might form a component of a worldwide weather reporting system combining satellites, balloons, and ocean buoys.

The New Zealand agreement is a first step in making possible type tests to determine the suitability of constant-level balloons to be used as a component of the ultimate system.

No additional agreements concerning weather modification have as yet been undertaken. The Department of State clearly recognizes the need to develop suitable agreements which will make possible the necessary research and the orderly participation of the United States as a leader in any worldwide system that develops when large-scale practical applications of weather modification techniques are realized. At this point in time, however, the details of such agreements are still under consideration.

Senator BREWSTER. Thank you very much, sir. I have a question or two.

I have just returned from Geneva, Switzerland, where I gained the impression—I hope erroneously—that U.S. participation in the World Meteorological Organization was pretty limited and that some of our men that we had assigned to this organization were disappointed with the support they had received from the State Department. Would you comment on that?

Dr. JOYCE. Mr. Chairman, I am sorry to hear this. I am not aware of any specific requests that have been received from these people. I assume these are Americans who are on the staff at the WMO?

Senator BREWSTER. That is correct.

Dr. JOYCE. I shall certainly be happy to investigate and see what the difficulties may be.

(The material follows:)

Further inquiries have failed to reveal the basis for the individual's remarks. The record clearly confirms U.S. policy to fully support the World Meteorological Organization.

Senator BREWSTER. To the best of your knowledge, is our policy to support the WMO?

Dr. JOYCE. It certainly is, sir. Yes, sir.

Senator BREWSTER. Has this caused us any problems in international affairs?

Dr. JOYCE. Not to my knowledge, Mr. Chairman.

Senator BREWSTER. Now, speaking of problems, have our weather modification activities caused us any international problems with any of our neighbors?

Dr. JOYCE. To my knowledge they have not as of this date. I think we realize the steps that must be taken to avoid such problems, and these, of course, will be one of the things that will have to be taken into account in agreements.

Senator BREWSTER. We are both aware that cloud-seeding and associated activities have raised a storm of protest in some areas of the United States, and it is entirely possible that activities here could cause some concern in Canada or Mexico.

Dr. JOYCE. We fully understand this and appreciate it; yes, sir.

Senator BREWSTER. Will you now describe for us the existing coordination and communication between Moscow and Washington in this area of endeavor and what link, communications link, we use here?

Dr. JOYCE. Mr. Chairman, to my knowledge, a great deal of the interchange occurs through the WMO. There is in addition, of course, the direct line, the so-called "weather line," between Washington and Moscow which was set up and went into operation in September 1964.

This came about as a result of an agreement between Dr. Dryden, the late Deputy Administrator of NASA, and Professor Blagonravov on the Soviet side.

The line was established for the interchange of weather satellite data.

It is still in operation on the assumption that eventually satellite data will flow. As you know, the Russians to this day have not orbited weather satellites, and therefore there is no satellite data coming from Moscow.

Senator BREWSTER. Do we provide them with any satellite information?

Dr. JOYCE. We do not, Mr. Chairman.

Senator BREWSTER. Is the line used for other weather purposes?

Dr. JOYCE. The line has been used for standard weather data simply to keep it in operation and to make certain it is functioning properly.

Senator BREWSTER. Is it used on a working daily basis, or is it just for periodic tests?

Dr. JOYCE. As I understand it, it is on a working daily basis.

Senator BREWSTER. Is the State Department involved in the World Weather Watch?

Dr. JOYCE. We will be involved in any agreements or arrangements that are necessary to carry out the U.S. activities primarily through the WMO but not in a substantive way, of course. I think the agreement that I spoke of with New Zealand is an example of our activities in this regard.

Senator BREWSTER. Now, I have a quote here from the National Science Foundation. I would like you to comment on it. They say:

It would be highly desirable for the United States to issue a basic statement as to how it views the relationship of this new national effort to the interests, hopes, and possible apprehensions of the rest of the world.

Is any such basic paper being prepared by the State Department?

Dr. JOYCE. I am not aware of such a paper at the present time.

Senator BREWSTER. Well, would you direct an inquiry to the Department to see if anything is being considered?

Dr. JOYCE. I will certainly do so; yes, sir.

(The information follows:)

It seems premature to issue a statement at this time on the relationship of the program on weather and climate modification to the interests, hopes, and possible apprehensions of the rest of the world.

We are considering proposals that we might make on this subject to the Fifth Congress of the World Meteorological Organization which convenes in Geneva next year.

Steps are already being taken to exchange research information with other countries both at the scientific and the governmental level. Further efforts will be made to promote the international exchange of information relating to weather and climate modification.

Since future progress in weather and climate modification will depend in a critical way on progress in understanding the atmosphere and in extending our capability for predicting atmospheric phenomena, every possible step should be taken to encourage and further the program of the World Meteorological Organization for a World Weather Watch. This program will greatly improve our understanding of the atmosphere and our ability to predict atmospheric phenomena.

Senator BREWSTER. I thank you very much, sir. You are excused with our thanks.

Dr. JOYCE. Thank you.

Senator BREWSTER. Is Dr. Byerly here?

## STATEMENT OF THEODORE C. BYERLY, ADMINISTRATOR, COOPERATIVE STATE RESEARCH SERVICE, DEPARTMENT OF AGRICULTURE; ACCOMPANIED BY JACK BARROWS, FOREST SERVICE

Dr. BYERLY. Senator Brewster, accompanying me is Jack Barrows of the Forest Service, who has participated in that Service's Operation Skyfire since 1953, in case there are technical questions that require response.

Senator BREWSTER. We are very happy to have you with us, sir.

Dr. BYERLY. Mr. Chairman, I appreciate the opportunity to appear before this committee to present the views and some of the activities of the Department of Agriculture concerning weather modification and control.

Weather modification is of major importance to agriculture and forestry. The production of food and fiber, the protection of crops and forests, the full utilization of agricultural and forest resources,

and the well-being of rural communities are all strongly influenced by weather and climate. Any program which may result in modification of weather and climate and in turn may influence agricultural and forestry activities is of interest and concern to the Department of Agriculture.

The Department endorses the development of research programs which will advance scientific knowledge and the technology for weather and climate modification. We believe, however, that the basic objectives and purposes of S. 2916 can be obtained under existing authorities and within the framework of recent recommendations by the Interdepartmental Committee for Atmospheric Science and of existing and developing plans within the executive branch.

We plan to continue to strengthen our mission-oriented research in this field, which includes the following:

(1) Modification of lightning storms to reduce the occurrence and severity of lightning-caused forest fires.

(2) Modifications of hailstorms to reduce damage to crops and other agricultural and forestry resources.

(3) Energy-exchange processes in the earth-air interface and the modification of these processes by the management of vegetative cover on agricultural and forest lands.

(4) Biological responses to weather modification with particular emphasis on ecological monitoring and computer simulation studies to predict effects on complex ecological communities of plants and animals found in forests and on other agricultural lands.

The need for continuation and expansion of such mission-oriented research is emphasized by the recent reports of both the National Science Foundation Special Commission on Weather Modification and the National Academy of Sciences Panel on Weather and Climate Modification.

In the performance of such research the Department has a long history of cooperation with the Weather Bureau of the Department of Commerce and, more recently, the Environmental Sciences Service Administration of the Department of Commerce.

We also cooperate closely with the National Science Foundation. The program of the National Science Foundation is of direct benefit to the weather modification research being done by the Department of Agriculture.

We cooperate, too, with the Bureau of Reclamation in the Department of the Interior in its research program for increasing precipitation.

These very beneficial cooperative relationships should continue and be strengthened.

The Department of Agriculture is making significant progress in weather modification research. The major research activity has been in the modification of lightning storms to reduce the occurrence and severity of lightning-caused forest fires. This research, known as Project Skyfire, is being performed by the Northern Forest Fire Laboratory of the Forest Service at Missoula, Mont. The research is focused on the severe lightning-fire problem in western forests.

Some 10,000 lightning-caused forest fires occur annually in the United States. These fires cause millions of dollars in forest resource

damages and fire-control costs. Project Skyfire is determining whether special weather modification techniques can reduce these great losses and costs.

Although Project Skyfire is a program of very modest size, it may be one of the most definitive research activities in weather modification. This research is doing the following:

(1) Developing physical models of mountain thunderstorms.

(2) Identifying and measuring the special characteristics of fire-igniting lightning strikes.

(3) Developing working hypotheses for the modification of lightning discharges through the introduction of seeding agents in cloud systems.

(4) Testing working hypotheses and basic theories of lightning, using both laboratory and field experimental methods.

(5) Developing special instrumentation and equipment for the measurement of lightning discharges and the generation of silver iodide nuclei.

(6) Developing special mathematical, statistical, and physical evaluation methods for the analyses of lightning modification through cloud seeding.

(7) Performing field experiments in the modification of lightning discharges from thunderstorms over mountainous forest areas.

While much of this work is of a pioneering nature involving heretofore unexplored fields of research, the progress is encouraging. New knowledge has been gained of the basic mechanisms of fire-igniting lightning strikes and of the action of ice-forming nuclei on cloud electrification processes.

High-output, ram-jet-type silver iodide smoke generators have been developed for use on aircraft and at ground stations. Now technology has been developed for delivering large quantities of silver iodide nuclei to thunderstorm cloud systems and for measuring and evaluating the results. Data from 3 years of cloud-seeding experiments in a specially instrumented test area show more than 30-percent reduction in cloud-to-ground lightning from treated storms.

This research is providing the essential foundation for a strengthened research effort and for the planning of larger scale experiments in lightning modification.

The second weather modification research area of major interest to the Department of Agriculture is hail suppression. In 1963, farmers in the United States purchased more than $2.8 billion of protection against hail. In 1962, farmers collected $81 million on their hail insurance. In the Plains and Mountain States, hail is an important adverse factor in the production of grain and forage crops. Production and quality of fruit and vegetable crops in many regions of the United States are influenced by hail. Entire crops can be wiped out by severe hailstorms.

The results already achieved by Project Skyfire in lightning modification provided some of the background for projected Department of Agriculture research in hail suppression. Hail is often an element in lightning storms, and some of the technology for modifying either phenomenon may involve similar approaches.

Project Skyfire scientists have found that there is a relationship between hail occurrence and frequency of lightning discharges, the

flash rate, and storm duration. More than twice as much lightning has been recorded during storms with hail than those without hail. Storms that produced the largest hailstones also produced the most lightning.

The Skyfire results suggest that if cloud seeding reduces the size and amount of hail, it may also reduce the amount of lightning produced by the storm.

For these and other reasons, the research in modification of lightning and suppression of hail has common interests. The weather modification technology for either element may call for so-called overseeding. Very high concentrations of seeding agents may be required. The concentration of silver iodide nuclei effective at $-15°$ C. being introduced by Skyfire seeding technology into small cumulus clouds is about $3 \times 10^4$ per liter and in a typical thunderstorm about $5 \times 10^3$ per liter. These concentrations are greater than those believed needed to date in typical precipitation-increase seeding activities.

As summarized in the report of the NAS–NRC Panel on Weather and Climate Modification, "overseeding" is one of the possible approaches to hail suppression. The Department of Agriculture expects to enlarge upon its already developed technology for "overseeding" in developing experimental approaches for reduction of hail damage.

With very limited exceptions, the results of hail suppression research in the United States and in several other countries have not been conclusive. Well designed and carefully controlled hail modification experiments are needed. The Department hopes that such experiments may be performed at an early date in the Plains States or in other major agricultural areas where hail is an important factor.

Fundamental to progress in hail suppression research is better knowledge of the hailstorm itself. As in the case of lightning modification activities, there is a need for both basic and applied research in the hailstorm problem. The Department believes that the performance of its mission in this area of weather modification requires strong efforts in both types of research.

Also, as in the case of lightning research, we expect to work closely with the National Science Foundation in the overall aspects of this research program. The assistance of the Weather Bureau and the Environmental Sciences Service Administration of the Department of Commerce will be needed in the weather forecasting and some applied research aspects of the problem.

A third area of mission-oriented weather and climate modification research of particular concern to the Department of Agriculture is investigation of the energy-exchange processes in the earth-air interface. Management systems on agricultural and forest lands may have profound influences on weather and climate.

For example, the arrangement and character of agricultural crops and forest stands can influence the convective activity which is part of cloud growth processes. Also, the vegetation itself makes an input of moisture back to the atmosphere.

At the earth-air interface, a complex set of interactions occur which affect both vegetation and the atmosphere. Here is where solar energy is incorporated into plant materials and thus enters the food chain. Agricultural research is aimed at obtaining the most efficient energy

exchange through modifications of various elements of the environment in this zone.

Changes in albedo, surface roughness, the geometry of field crops and forest stands, moisture relations and other factors have a significant effect upon the production of food, fiber, and water. Studies underway include such things as wind movement, air turbulence, and energy budget as related to evapotranspiration, snow accumulation and melt, and photosynthesis.

The biological consequences of weather modification are of great concern to the Department. The best available information in the field of plant and animal ecology indicates that any significant large-scale modification of weather would be likely to result in extinction of some natural plant and animal communities and to increase weed species and insect and disease pests.

The Department has a particularly strong background of competency and experience in the scientific disciplines that should be brought to bear in determining the biological effects of weather modification. A strengthened research program in this regard should be undertaken concomitant with the research directed at learning how to modify weather and climate. This is particularly urgent to avoid unforeseen, deleterious, and irreversible effects upon plant and animal communities.

Because of the apparent imminence of increasing success in weather modification, it is imperative that a major program of research be directed at the biological consequences of such activities. Research should include a well-conceived program of computer simultation studies. This would allow the maximum use of ecological information now available from different environments to develop functional relationships between soils, plants, animals, site, and weather. It would probably provide the most rapid way to obtain a first approximation of weather modification effects.

At the same time, a well-financed, sustained program of studies of natural plant and animal populations, communities, and ecosystems as related to changes in the environment should be launched.

Thank you, Mr. Chairman.

Senator BREWSTER. Thank you very much, Dr. Byerly. I have a question or two here.

As you know, in many of our agricultural communities we have substantial opposition to any weather modification activities. In my State of Maryland, section 110(a) of article 66(c) of our code absolutely prohibits any type of weather modification activity whatsoever until 1967 when this policy of Maryland will be reviewed, and other States have similar limiting statutes.

Where you have those State statutes, does the Department still carry on any experimental activity?

Dr. BYERLY. I think the Department has no experimental activities in the State of Maryland that would be in violation of the statute.

Senator BREWSTER. Is it the Department's policy to cooperate with State statutes where you do have State limitations?

Dr. BYERLY. It is.

Senator BREWSTER. Going all the way from Maryland to Moscow. Excuse me, Mrs. Neuberger.

Senator NEUBERGER. Senator, that just brings a question to my mind. What if there is such activity in Virgina and some of it kind of floats over into Maryland? What happens?

Dr. BYERLY. May I say, Mrs. Neuberger, Madam Senator, that at the moment our major activities are in the Northwestern States. We do have some activities of a laboratory scale at Beltsville, theoretical studies, simulation studies, things of this sort.

But we are not I think in any hazard of impinging upon the State of Maryland.

May I point out that this problem of preemption by the Federal Government with respect to States is one of the unresolved problems that still requires a good deal of study.

Mrs. NEUBERGER. Thank you.

Senator BREWSTER. The Russians have claimed that by using rockets and/or artillery they have been very successful in the suppression of hail. Do you have any knowledge of this?

Dr. BYERLY. We hope they are right, the point being this—and I will ask Mr. Barrows to verify if I deviate from what we think is the case:

They are, in fact, as far as we know, entering into the base of the clouds at the same point with this means that we are with our Operation Skyfire, so that is why I say we hope they are right.

The difficulty comes that insofar as we know they do not have adequate controls or at least have not given us adequate control information.

If they say, "Here we have suppressed a hailstorm," well, what is the yardstick? How do we compare these things?

We say we hope they are right. They may be.

Senator BREWSTER. I now direct your attention to lightning suppression. When an attempt is made to suppress lightning, do you get any side effects such as hail, snow or rain?

Dr. BYERLY. May I ask Mr. Barrows to respond.

Mr. BARROWS. Mr. Chairman, we have looked for side effects from our seeding to date. We have observed some of these effects. Most of the storms that we work with in Project Skyfire are typical midsummer, relatively dry lightning storms. We have observed to date no differences in precipitation. However, we are not examining precipitation in a control area adjacent to our instrumented area.

We have observed a reduction in hail when we get a reduction in lightning. These two seem to go together.

Senator BREWSTER. Still on this same lightning subject, are you doing anything to protect aircraft from being hit by lightning? Is this in your field of endeavor?

Mr. BARROWS. No, sir. This is not in our field of research.

Senator BREWSTER. Is there any difference in the lightning that causes forest fires and other types of lightning?

Mr. BARROWS. This has been one of the questions that we have been most curious about. We believe that we have identified the type of lightning stroke that is most likely to start forest fires.

Lightning strokes vary widely in their characteristics. The type of stroke which we believe is most apt to start forest fires is one that has a long, continuing surge of current.

Senator BREWSTER. A special commission of the National Science Foundation recently stated, and let me quote from them:

> Larger scale operations, such as an attempt to increase the rainfall of any substantial part of this country, should not be undertaken from a biological point of view.

Would you comment on this statement by the National Science Foundation?

Dr. BYERLY. The reason why we have placed emphasis on the ecological studies is exactly responsive to this quote. We do not feel that we can withhold intervention in so important a matter as weather modification until we have all of the ecological information, but we do believe that we should obtain concurrently and through computer simulation estimates of the probable impact of increase of precipitation either prior to or concurrently with such modification attempts.

Senator BREWSTER. Senator Neuberger.

Senator NEUBERGER. No questions.

Senator BREWSTER. Thank you very much, Dr. Byerly.

## STATEMENT OF JOSEPH D. BLATT, ASSOCIATE ADMINISTRATOR FOR DEVELOPMENT, FEDERAL AVIATION AGENCY

Senator BREWSTER. We are very happy to have you here, Mr. Blatt.

Mr. BLATT. Thank you, sir.

Senator BREWSTER. Mr. Blatt, do you have a prepared statement?

Mr. BLATT. Yes, Mr. Chairman.

Mr. Chairman, Senator Neuberger, I appreciate the opportunity to discuss with you weather modification and the Federal Aviation Agency's interest in it from an aviation viewpoint.

At Senator Magnuson's suggestion in his letter to the Administrator, I will read only a summary of my prepared statement. The prepared statement may be in your record.

In designing the national airspace system, a system being implemented to provide for the safe and efficient utilization of our Nation's airspace, we have considered the problem of coping with the weather in the following three ways:

1. By designing an adequate weather forecasting and reporting subsystem.

2. Through the development of an all-weather landing system to permit aircraft operations regardless of prevailing airport conditions of ceiling and visibility.

3. Through weather modification. While there is not now a weather modification technique developed to the point where it can be included as a reliable part of the national airspace system, we believe that usable techniques for the dissipation of supercooled fog at airports may be possible for inclusion in the not too distant future in the system.

Supercooled fogs can be modified to permit landings and takeoffs at airports by improving the visibility by dispersing the fog. This is done by seeding of the fog from an airplane. Dry ice pellets are dispersed from the airplane in a technique similar to crop dusting. The dry ice causes the fog to change its character, and the ice crystals which are formed fall to the ground.

Ground-based techniques for dispersing supercooled fog have been tried and have achieved limited success.

The technical problem still unsolved is the modification of all types of fog, particularly warm-type fog. At present, in spite of considerable experimentation, the solution to this warm-fog problem is not at hand. Consequently, we have not included such a method in our national airspace system design.

When an acceptable technique is developed, it of course can be included in the national airspace design.

Mr. Chairman, as to the desirability of the enactment of either S. 2916 or S. 23, we defer to the departments that would be directly charged with responsibility under those bills.

Thank you.

(The full text of Mr. Blatt's statement follows:)

STATEMENT OF JOSEPH D. BLATT, ASSOCIATE ADMINISTRATOR FOR DEVELOPMENT, FEDERAL AVIATION AGENCY

Mr. Chairman and members of the committee, the Federal Aviation Agency's interest in weather modification is directed at those benefits to be derived from applying weather modification techniques to further assure the safety of aviation operations and to improve the efficient movement of air commerce.

I. WEATHER MODIFICATION AND ITS PLACE IN THE DESIGN OF THE NATIONAL AIRSPACE SYSTEM

In designing the national airspace system of the next decade, the problem of coping with weather has been considered in the following three ways:

*1. The aviation weather forecasting and reporting subsystem*

The best way of satisfying the varied requirements of the users of aviation weather information is by designing an adequate aviation weather forecasting and reporting system, which delivers the information required within the necessary time period, as one portion of the overall national airspace system. This subsystem, which closely interrelates to the Weather Bureau's basic meteorological system, will rely on improvements to be made in each of its four portions: data acquisition, processing, communication, and display. An adequate aviation weather forecasting and reporting subsystem is not dependent on weather modification.

*2. All-weather systems*

The FAA has been conducting a research program for the development of a so-called all-weather landing system which would permit aircraft operations regardless of prevailing airport conditions of ceiling and visibility. We undertook development of the all-weather landing system after a study indicated that U.S. air carriers could lose $67 million in 1963 alone because of delays, cancellations, and diversions due to weather. The all-weather landing system will complement the aviation weather forecasting and reporting subsystem by permitting additional operations, and would be required even if we had perfect forecasts. At those terminals which are being equipped with special-instrumentation aircraft carrying specified equipment will be able to land safely even though the pilot cannot establish visual reference with the approach light lane until he descends to 100 feet above the plane of the runway, and can see only 1,200 feet ahead of him as he touches down on the runway. Our development is continuing to the next phase which will control the aircraft to touchdown without visual reference on the part of the pilot.

*3. Weather modification*

The third way of coping with the problem of weather in the future aviation system could be to employ weather modification techniques either large scale or at individual terminals.

These techniques are not now included in the national airspace system since one of the ground rules for incorporation into that system is that the equipment

and techniques selected must be within the state of the art. Thus the remote acquisition, transmission via telephone line, and display of information on aircraft targets along with their identity and altitude is accepted and planned as part of the system. Display of weather information from weather radars is also accepted and planned as part of the same system. Weather modification techniques, on the other hand, have not been developed to a point whereby they might be economically applied or depended on to be reproduced with enough certainty to be included in any future system. When significant improvements in the state of the art of weather modification are attainable, they can be incorporated into the system. The one weather-modification technique that seems to offer the best possibility for future use in the national airspace system is the dissipation of supercooled fogs.

Since Langmuir and Schaefer successfully demonstrated seeding techniques some 20 years ago, considerable effort has been expended in attempting to develop an operational system for dissipating supercooled fog. The Army's Cold Regions Research and Engineering Laboratories, the Air Force Cambridge Research Laboratory, and United Air Lines and others have demonstrated that supercooled fogs can be dissipated over an area large enough to permit aircraft to land and take off. The technique employed uses dry ice as the seeding agent and an aircraft as the platform. The dry ice is dropped into the fog. Ice crystals are formed which grow in size and fall to the ground, thus improving visibility. The Air Force has employed large aircraft like the KC–135, while United Air Lines in their tests throughout the past season in the Northwestern United States used light aircraft, under contract.

Attempts at developing ground-based techniques have been made by both the Air Force and the Army with limited success. The problem is one of distributing the seeding agent along the aircraft approach path. Thus the employment of tethered balloons, small rockets, or vertically oriented blowers may be effective at one spot, but the difficulties in locating these devices on the ground along the approach path are immediately obvious. Aircraft approaches to many of our major terminals are either over communities or over water areas. These ground-based techniques as well as those using drones all have limitations because of their potential interference with aircraft operations and safety of persons on the ground. Nevertheless because the technique of supercooled fog dissipation has been demonstrated as feasible, continued development of ground-based seeding mechanisms appears warranted.

II. PRESENT ACTIVITIES OF THE FEDERAL AVIATION AGENCY IN WEATHER MODIFICATION

The current weather-modification programs of FAA are modest.

We have the University of California at Berkeley under contract to investigate the capabilities of the "fog chamber" at the university as a facility to be used for weather-modification experimentation. The decay rate and the physical characteristics of the fog produced in the chamber are being measured and analyzed.

The FAA Systems Research and Development Service evaluate proposed fog-dispersal techniques which come to our attention from industry or from the public. We are an active member of the Interdepartmental Committee for Atmospheric Sciences (ICAS) through which our weather modification activities are coordinated with other Government agencies. ICAS has requested that FAA recommend a technical plan for cold fog dispersal. That plan is currently being developed.

Senator BREWSTER. Thank you, Mr. Blatt.

Senator Neuberger, do you have any questions?

Senator NEUBERGER. No questions.

Senator BREWSTER. Mr. Blatt, I understand that the United Air Lines now has a program testing the effectiveness of fog-dispersal techniques. Is this done under a license from the FAA or what is the FAA's connection with the United Air Lines program?

Mr. BLATT. This is not done under any license agreement. This is a venture purely on the part of private industry to better the conditions that they are experiencing along their route, specifically in the northwest portion of the United States where they do experience supercooled fog conditions.

There is no agreement with United Air Lines. We participate with them to the extent of receiving information with respect to their procedures, techniques, and their success.

Senator BREWSTER. Do you know what success they have achieved, if any?

Mr. BLATT. Yes. They have had considerable success. They have reported that with respect to their operations they are getting a benefit-to-cost ratio of 5 to 1. That is, the cost of seeding, the cost of dispersal, is approximately one-fifth their estimated cost of the diversions that would have been created had they not done this type of weather modification work.

Senator BREWSTER. In the second paragraph of page 2 of your summary, you used the words "achieved limited success." In those words do you refer to the United Air Lines program?

Mr. BLATT. No. That is with respect to ground-based techniques. United Air Lines techniques are all with respect to the seeding from an aircraft. The techniques referred to in that paragraph were ground based, such as tethered balloons, rockets, vertical-facing blowers, things of that nature.

Senator BREWSTER. Well, with ground-based activities have we actually opened an airport that would otherwise be fogbound?

Mr. BLATT. Yes, we have. But the success has been extremely limited. The size of the hole created in the fog varies greatly. The movement of the hole, being able to place the hole in a position so that the winds will move the hole over the approach area, is too restricted with ground-based aids. You have much more variability and flexibility with respect to aircraft seeding.

Senator BREWSTER. The statement has been made with reference to aircraft seeding that FAA regulations are far too restrictive and companies or airlines are not able to carry out programs they want to because of your restrictions. Would you comment on that?

Mr. BLATT. Our regulations do restrict operations in questionable weather conditions. However, this, is of course, for the safety of the aircraft and aviation as a whole. However, the regulations do permit waivers for experimentation purposes and for the furthering of these techniques.

So I would have to comment by saying that I do not feel that the regulations restrict the operations unduly.

Senator BREWSTER. Are you aware that the statement in the National Science Foundation reports, and I quote:

> FAA and Air Force regulation is overly restrictive in testing various possible fog dissipation techniques?

Mr. BLATT. I am aware, yes, sir. I do not believe that our regulations are overly restrictive.

Senator BREWSTER. Now, sir, one last question. In your full statement at the bottom of page 4 you say that the ICAS has requested that the FAA recommend a technical plan for cold fog dispersal and then conclude by saying that plan is currently being developed.

Is that some form of "government-ese," or where is this plan now and when will somebody see it?

Mr. BLATT. The Interdepartmental Committee on Atmospheric Sciences has charged the Federal Aviation Agency with the responsi-

bility of developing a coordinated Government-wide plan for the application of the techniques for cold fog, supercooled fog dispersal. We in the Federal Aviation Agency are at the present time developing such a plan and are coordinating the plan with other governmental agencies concerned.

We hope to be able to submit this plan to ICAS early in the fall of this year.

Senator BREWSTER. Thank you very much, sir.

Senator Neuberger.

Senator NEUBERGER. No questions.

Senator BREWSTER. Thank you very much.

Mr. BLATT. Thank you, sir.

Senator BREWSTER. Do we have Mr. Howell here? Mr. Wallace E. Howell, president of W. E. Howell Associates, Inc., of Lexington, Mass.

Mr. Howell, welcome to this hearing. We are very happy to have you here, sir.

## STATEMENT OF WALLACE E. HOWELL, PRESIDENT, W. E. HOWELL ASSOCIATES, INC., LEXINGTON, MASS.

Mr. HOWELL. Thank you very much, Senator Brewster.

I am Wallace Howell, president of W. E. Howell Associates, Inc., a private meteorological firm specializing in cloud physics and weather modification, and president of the Mount Washington Observatory, Inc., a private nonprofit corporation in New Hampshire.

In the past 16 years I have been involved in some 60-odd weather modification programs chiefly concerned with reducing weather modification to a useful practice and applying it in situations where its economic leverage overcomes the uncertainties involved.

These operations have been mostly in eastern North America, Latin America, and the Philippine Islands.

I have three points that I would like to make before this committee, premised on the start already made on a weather modification program and on its potentialities being such as to deserve national concern. My three points are:

1. The importance of a pluralistic approach to a national program of weather modification.
2. The importance of private initiative in reducing weather modification to useful practice.
3. The importance of separating the regulation of weather modification from its operation.

With regard to the first point, the national program should pursue a pluralistic approach under flexibly coordinated guidance with simultaneous drive toward several coordinate goals.

Unless the objectives that we now have in view fail completely, this Nation is committed unavoidably to an undertaking in the field of modification of which the operational, economic and social magnitudes will tremendously overshadow the seminal role of pure science.

In this, science alone is not a sufficient guide.

If in testing the scientific foundations we neglect the other foundations of this undertaking, we risk our best chance to build a well balanced and effective national program.

Already some others have noted gaps. Dr. Schaefer submitted to this committee, I understand, a paper in which he noted that the engineering phase cannot wait for a perfect understanding of the scientific phases.

Dr. Malone also noted that the development and evaluation of techniques of applied research are an outstanding gap.

The evaluation of applications is something that I believe must be undertaken in the round with reference to all the impacts on all the various end uses.

In the area of science the channeling of adequate support to a few major research efforts should not be allowed to deprive alternative ideas not in accord with the majority view of encouragement.

Ten years ago, when this subject was last heard before a committee of the Senate, the idea that cloud seeding might be effective over flat ground through indirect effects on the clouds was discounted by recognized bodies of scientific opinion. Today this is one of the hottest ideas in the weather modification.

At that time it was recommended that we must know exactly how silver iodide forms ice crystals if we are to know how to use it. Today we recognize that it does form ice crystals even though we do not completely understand how, and the fact that it does is being recognized as something that we must investigate through use.

These are but two examples of cases where oddball ideas have turned out to be the most valuable, and some of those that have been officially most encouraged have perhaps not developed as well as hoped.

Reduction of weather modification to useful practice should encompass many climatic settings, many practices, many techniques, many end uses, through which and to which it may be exercised.

In the cases that I have been personally connected with, we have seeded clouds from midcontinent to midocean, from subarctic to the Equator, from plains near sea level to mountains over 18,000 feet high, from deserts to one of the world's rainiest jungles. Not only the settings but the purposes have been equally varied: to fight forest fires, protect banana trees from blowdown, carry a sugar crop through a dry season, supply water to hydroelectric plants, some of these uses very occasional, some of them covering a great deal of the time.

A single program may involve many different kinds of impacts. In 1950 when New York City conducted an experimental program and asked me to direct it, a country club complained it did not want its guests scared away by rain. The Palisades Amusement Park offered me double pay to stop the rain. But I went ahead with the point of view of learning what could be learned—here a trial for one specific purpose, to alleviate shortage.

There are perhaps hundreds of different uses that need to be explored. This trial was carried out in one place, the Catskills under one unique set of conditions. How many other thousands of combinations of conditions, locations, and uses are there that need to be investigated before we know where it is appropriate to use weather modification—and techniques as well, bringing in skill as another factor?

This operation ran into one particular conflict of interest, one set of social and political circumstances. How many others need to be

explored before we know how a national program should be developed and how are they to be explored other than through use?

Explicit recognition should be given to the value of international cooperation in both basic and applied weather modification by authorizing support of selected programs through foreign aid and other international channels.

I am leaving early tomorrow morning for a conference in Bogotá and another in Lima with reference to what are the actual uses to which weather can be put in actual settings, not in the idea of setting up a weather service because it is a good idea to set up a weather service, but to find out who is actually using weather forecasts, in what way.

These explorations with reference to weather modification need to be developed in many places, because some places are peculiarly advantageous to one use or another, and all the information gained in such experiences feeds back to the development of our own national program.

The diverse interests of the Government, the scientific community, private initiative, and social and political entities outside the Federal Government should all be directly represented in the top advisory board responsible for guidance of the national weather modification program.

Nearly 9 years ago, in 1957, with the recommendation for passage of S. 86, the message with which the Senate committee recommended this passage recognized very clearly the partnership between pure research, basic science, and applied research.

The program of applied research envisaged in that message was never realized. Why not? I think Dr. Haworth the other day gave a substantial part of the answer when he said that by the time it came to institute this program the only general agreement that could be obtained within the scientific community was that there should be basic research.

Furthermore, the task was given to the National Science Foundation which had itself said that it was interested in basic and not applied research.

But what is this scientific community of which Dr. Haworth spoke? My own belief is that when the Advisory Committee on Weather Control disbanded, the breadth of experience, the breadth of outlook in practical meteorology which it represented was lost and has not yet been restored.

I note that, of the scientific committees listed at the back of the NSF seventh annual report, confirmation of the list of committees I have drawn up in my statement here, none of these committees carries representatives of the point of view of applied meteorology, the task of developing experience through useful applications.

Included in this statement are—

Committee on Atmospheric Sciences of the National Academy of Sciences.

Panel on Weather and Climate Modification of the National Academy of Sciences.

Advisory Panel on Weather Modification of the National Science Foundation.

Special Commission of the NSF.

University Committee, now University Corp. for Atmospheric Research.

Executive Committee for Meteorology of the AGU.

Committee on Cloud Physics of the AGU.

Committee on Cloud Physics of the American Meteorological Society.

Committee on Weather Modification of the American Meteorological Society.

These committees constitute the consensus of the scientific community, but they have not represented a broad point of view with respect to the development of what I visualize might be a national program in weather modification.

I believe, therefore, that legislation should provide specifically for restoration of this balance through representation of the point of view that I believe is going to be extremely necessary in future developments.

So much for my first main point of a pluralistic approach.

A second main point is the role of private initiative in reducing weather modification to useful practice and in the exercise of this practice should be given explicit recognition and encouragement.

When I read the statements that have preceded mine, I feel a bit like the princess resting on top of 17 thick mattresses of statements, and under the 17 I feel that there is a pearl of great value not a pea.

About $5 billion was spent in 1965 by U.S. industry on research and development. Up to 1957 an increasing share of this was flowing toward weather modification. By the statements developed at that time, the attitudes of government developed at that time, this trend was reversed, and the flow of these funds was reduced to a trickle.

And yet it is that trickle, carried on by private industry as best it could under the circumstances, that provided the conclusions which Dr. Hollomon speaking here the other day was able to refer to as having been verified by the National Academy of Sciences report as demonstrating positive values from weather modification.

The NAS did indeed verify these reports, but it was not brought out in my opinion that the work sprang from private initiative carried on despite discouragement and disparagement from official sources and that the verification was the right word—that they did find the conclusions reached from these private experiences were substantially correct.

And so it is my opinion that private entities when they undertake to integrate their own efforts to reduce weather modification to a useful practice, with the purposes and requirements of a national weather modification program, should be specifically recognized as playing an organic role in the national weather modification program, and as such they should receive compensation in certain specific forms:

1. Scientific advice of the best that can be given.

2. Support for additional scientific observations and operations not a normal part of an operational program.

3. Evaluation by an appropriate public and disinterested agency of the scientific, economic, and social results of the operation.

59-528—66—pt. 1——17

4. Reimbursement of expenses with respect to periods when operation is suspended; for example, for randomization of seeding trials.

5. Indemnification for legal liability arising out of such weather modification operations.

It is this, the private drive to investigate all possible rewarding uses, that can provide an unmatched motivation for thorough investigation of the great range of questions that I referred to earlier.

Furthermore, one of the disadvantages of the past dissociation of operational from research work has been a good deal of duplication of effort. University organizations have spent time developing apparatus that they should not have had to develop. Private organizations have spent time developing methods of evaluation that they should not have to develop. Each one should support the other in a well-rounded national program.

From my own experience I can add that private entities engaged in this share of the national weather program should be protected from capricious or arbitrary regulation by State and local governments and from arbitrary or capricious impositions of liability and should have the benefit of uniform requirements for qualifications and for responsibility, uniform requirements of all weather modification operators throughout the United States and its possessions.

I believe you are familiar with—you have already spoken of it—some of the background of my experience in that, so I will not go into detail at this point.

Going back to my previous point, I believe that this role of private initiative is so important that it deserves specific representation, direct representation, on all top regulatory and advisory boards having to do with planning and execution of a national program.

My third point: Regulation of weather modification should be lodged in an independent board dissociated from all operational interests and representative of a broad viewpoint of public policy.

It is unfortunate, but true, that the line between the regulation of and regulation on weather modification is already blurred. The regulation on weather modification issued by the National Science Foundation overlaps in a very difficult manner to pin down, but nevertheless a somewhat operative manner, into operation in regulation of weather modification.

Yet, in expressing this viewpoint, I must express it before the same body—in fact, even before the same person—to whom I must talk if I wish to propose a program of research for NSF sponsorship.

In the present instance, my differences of opinion regarding this regulation are truly trivial, and yet there are the seeds here for a most unpleasant situation.

I feel that legislation establishing a regulatory board should preempt to the Federal Government all authority for regulation, including establishment of qualifications and responsibilities of weather modification.

There is nothing tentative in my mind about the present need for Federal preemption of the power to regulate. A power vacuum exists that is being partially filled by inconsistent State and local legislation, in some instances capricious and ill-advised. And you know the background.

I feel that the authority of this regulatory board should extend to the power to resolve conflicts of interest that may arise out of interference between projects, whether these projects be public or private. And in my opinion the public interest would be best served by an agency that can impartially weigh the public and the private contributions to the national program.

In closing, my neck is already a good distance out, but I will stretch it out a little further.

Earlier I mentioned that exceptions to the general lack of Federal programs—no, I did not, because I did not read my statement all the way through. I noted in my statement that nearly all programs that had developed as a result of S. 86 were programs of basic research and not applied, with two exceptions.

As of 1 year ago, shortly before the results of independent appraisal of commercial operations began to become known in the scientific community, Government weather programs in applied weather modification as listed in the report on this subject by the Committee on Government Operations included an Air Force project with limited objectives of developing a capability to disperse low stratiform clouds and fog, a Forest Service project with the limited objective of mitigating lightning-set forest fires, both of which had their origins before 1957, a Project Stormfury, a joint Navy-Weather Bureau project to study the possibility of modifying hurricanes, and, finally, the only project of a broader scope, the Bureau of Reclamation project with the objective of controlling water resources in various watersheds through the optimum use of dams.

Of these, only the last mentioned is precipitation-oriented, and only that one has developed a program specifically aimed at taking advantage of the capabilities in the private field of meteorology through contracts with some of the leading commercial firms.

Incidentally, I do not hold a contract with them.

And it is this project that has had the greatest difficulty in justifying its existence before the consensus of scientific opinion.

Weather forecasting is clearly the weatherman's province. But, just as education of the young is too important to leave to teachers alone, so weather modification in my opinion is too important to leave to meteorologists alone.

The nature of the Federal program designed to encourage and coordinate exploration and exploitation of a multitude of specific individual situations, with a supporting program of scientific research, with regulation, greatly transcends the present capability of existing agencies. And yet the experience and commitments of existing agencies constitute an important source of strength that should not be wasted.

Since completing my prepared statement, I have studied some of the statements previously made and discussed my own statement with several persons whose opinions I value highly. As a consequence, I will present suggestions differing from those in my prepared statement.

First, I suggest establishment of an independent Weather Modification Board perhaps modeled on the CAB, charged with regulation of weather modification by all agencies, public and private, to which the regulatory power of States and lower political entities should be preempted.

Second, I suggest that the major task of formulating and carrying out a national weather modification program should rest with a weather modification commission outside the present Government agencies.

Specifically, I suggest that the commissioners should be chosen in equal numbers from public and private life and should give direct representation to a broad spectrum of viewpoints from which the concerns of applications for useful purposes and of our social institutions should not be omitted.

The commission should be provided with a staff capable of maintaining close working liaison with the entire field of weather modification both here and abroad and of carrying out detailed background and planning studies.

The commission should be charged with putting the national weather modification program into effect in part by utilizing the capabilities, suitably expanded, of the National Science Foundation and the National Center for Atmospheric Research and the several Government departments, each within the domain of its most suitable utilization, and in part by creating its own operating arm to carry out specifically those major programs of field experimentation that have been recommended by the National Academy of Sciences Panel report but lie outside the basic research domain of the National Science Foundation.

Third, I suggest that other agencies of the Government be authorized to carry out under the general guidance and coordination of the commission both researches and applications pertinent to the special missions of these agencies.

I am well aware that the proliferation of Government agencies poses a serious problem and that establishment of a new one is not as simple a solution as it might appear nor something to be taken lightly. Yet I am moved to speak for it.

A nonexistent agency obviously lacks a voice of its own, and if anyone is to speak for it he must arise from outside the Government or else speak against his own agency.

Also I feel that a voice from outside is necessary to counterbalance the tendency I have noted in some agency statements to overaggrandize their roles somewhat at each other's expense but mostly at the expense of accomplishments outside the Government whose authors have no organized voice.

My suggestion for a new weather control commission rests on the following observations:

First, the initial form in which a national weather modification program is cast will be crucial for its future development, and to temporize by allocating it to an agency not fully suited to the task would be to risk its lasting deformation.

Second, the task transcends the boundaries of existing agencies no less than it transcends State boundaries.

It corresponds to an entirely novel relationship between government and the governed.

Its lines to the Executive and especially to Congress should be freed from the inadvertent influences that would be unavoidable if the function were appended to those of an existing agency.

Third, in this particular present, where our past imperfect meets the future, and in terms of the actualities of top-level leadership, of

depth of commitment and breadth of mission, no one of the existing agencies nor all of them together can furnish a home that is both congenial and adequate for the people on whom we must and should be depending for the performance of this task.

And, finally, of all the Government agencies that have touched this field in the past, the Advisory Committee for Weather Control provided in relationship to its resources by far the most constructive leadership and the most creative program. It provided a demonstration of the effectiveness of this approach in organizing the many separate elements, public and private, into a productive national program that has not been forgotten.

(The full text of the statement follows:)

STATEMENT BY WALLACE E. HOWELL ON LEGISLATION FOR A NATIONAL WEATHER MODIFICATION PROGRAM

*1. Introduction*

I am Wallace E. Howell, president of W. E. Howell Associates, Inc., a private meteorological firm specializing in cloud physics and weather modification, and of the Mount Washington Observatory, Inc., a private nonprofit corporation in New Hampshire. In the past 16 years I have been involved in some 60-odd weather modification programs chiefly concerned with reducing weather modification to a useful practice and applying it in situations where its economic leverage overcomes the uncertainties involved. These operations have been mostly in eastern North America, Latin America, and the Philippine Islands.

I am a professional member of the American Meteorological Society, and hold the society's consulting meteorologist certification, and my company is a member of the Weather Control Research Association, a group of 50 members drawn from governmental, research, and business entities concerned with this field.

I have three points to make before this committee, premised on the start already made on a weather modification program and on its potentialities being such as to deserve national concern. They are:

1. The importance of a pluralistic approach to a national program of weather modification;
2. The importance of private initiative in reducing weather modification to useful practice; and
3. The importance of separating the regulation of weather modification from its operation.

*2. The national weather modification program should pursue a pluralistic approach under flexibly coordinated guidance with simultaneous drive toward several coordinate goals*

Unless the scientific objectives now in view fail of ultimate realization, we are already committed unavoidably to an undertaking of which the operational, economic, and social magnitude will tremendously overshadow the seminal role of pure science. Science alone is not a sufficient guide. If in testing the scientific foundations we neglect the other foundations of this undertaking, we risk our best chance to build a well-balanced and effective national program.

In the history of science, the pure and applied aspects have always cross-fertilized each other. In weather modification, experience with applications is an important source of ideas and intuitions for basic research. Both of these involve potential direct impact on the social and political communities to an unprecedented degree, for the weather is everybody's. The exploration of applications and impacts is as important as exploration of the pure science itself.

The need for a broad viewpoint in the guidance and development of a national weather modification program is an immediate one.

(a) *In the area of science, the channeling of adequate support to a few major research efforts should not be allowed to deprive alternative ideas not in accord with the majority view of encouragement.*—Ten years ago, the notion that cloud seeding might be effective in cumulus clouds over flat ground through its indirect effect on the dynamics of these clouds was discounted by recognized bodies of scientific opinion: today it is one of the hottest ideas in weather modification. Ten years ago, these same bodies of opinion stressed the necessity for fully under-

standing the ice-forming action of silver iodide if we were ever to use it successfully for weather modification: today, though little progress has been made toward that understanding, the empirical importance of the fact that it does indeed modify clouds is recognized beyond question. These are but two examples of the fact that some of the brightest ideas in weather modification have blossomed outside the garden plots laid out for official cultivation, and some of the most assiduously cultivated plots have so far proven rather barren.

We must, then, nourish the volunteers outside the fence, even though these may at first look rather weedy, and even though it will require a vast expansion of our effort to bring to full fruition those starts that have already blossomed promisingly.

(*b*) *Reduction of weather modification to useful practice should encompass many climatic settings, many practices and techniques, and many end uses, through and to which it may be exercised.*—The 60-odd weather modification programs I have been connected with have ranged from the subarctic to the Equator, from midcontinent to midocean, from plains near sea level to mountains over 18,000 feet high, from deserts to one of the world's rainiest jungles. The purposes served by the modifications have been almost as varied: to fight forest fires, protect bananas from blowdown winds, carry a sugarcane crop through the dry season, supply water to hydroelectric plants, come to the rescue of a city with practically dry reservoirs, help cover a ski slope with snow. Often a single program has involved many different facets. In 1950 New York City desperately needed more water, and asked me to seed clouds over the Catskills. The Nevele Country Club didn't want its guests scared away by the prospect of perpetual rain and sued to enjoin the city. The Palisades Amusement Park offered me double pay to keep rain away. I went ahead in the Catskills, using the seeding occasions to learn all I could about its effects.

Here was a trial of weather modification for one specific purpose—to alleviate shortage in the reservoirs. There are hundreds of uses for weather modification that may be more or less apt, and in the future there may be thousands, and we need to know how to do cloud seeding for other uses as well. This trial was carried out in one particular place—the Catskills—under one unique set of weather conditions. But we need to know how to do cloud seeding in a thousand other places, and in a thousand different weather situations, as well. This was carried out by one particular technique—silver iodide seeding from the ground. But we need to know the effectiveness, for particular purposes, in particular places under particular conditions, of many other techniques as well. This operation ran into one particular conflict of interests, in one particular legal, social, and political context. But what would be socially, politically, legally, advisable or possible in any of a thousand other contexts?

These questions call for vigorous exploration through the actual impact of them on people and situations. We cannot hope to be suddenly wise enough to prescribe the shape of a national weather modification program. It will grow. Indeed we cannot keep it from growing. But we can and should encourage and shape its growth at the levels of operational, economic, political, and legal experience in the field.

(*c*) *Explicit recognition should be given to the value of international cooperation in both basic and applied weather modification by authorizing support of selected programs through foreign aid and other international channels.*—The atmosphere is our laboratory. We cannot easily isolate the phenomena we wish to study. But sometimes we are lucky enough to find a setting where the phenomenon we wish to study is relatively free from interfering disturbances. For instance, on the west coast of South America there is a natural laboratory for studying sea-breeze phenomena free from middle-latitude storms, unmatched in the United States and its possessions.

In Colombia, we have used cloud seeding to alleviate damage from local thunderstorm winds. The result is experience, information, and insights applicable to some purely scientific problems and to some problems of reducing weather modification to practice in the United States.

At Bogotá, the capital of Colombia, there is an exceptionally attractive opportunity to study the formation and possible artificial dissipation of ground fog in the context of a useful application to keep the country's principal airport open for commercial use. Knowledge gained there would be immediately applicable to similar problems in the United States.

This story could be repeated many times over. Aside from the assistance given to our neighbors by such endeavors, aside from leadership in a prime field

of international collaboration, aside from the obvious fact that weather management is bound to become an international matter, it is in the immediate interest of our own national program to take advantage of natural and human resources wherever they exist to help contribute answers to the many questions facing us.

(*d*) *The diverse interests of the Government, the scientific community, private initiative, and social and political entities outside the Federal Government should all be directly represented in the top advisory board responsible for guidance of national weather modification program.*—In 1957, nearly 9 years ago, the Senate Committee on Interstate and Foreign Commerce recommended the passage of S. 86 in this language:

"Congressmen—and Federal agency representatives emphasized the importance of and the need for legislation establishing a program of basic and applied research in the field of weather modification.

"Testimony from non-Government witnesses indicated further need for research in both the basic and applied aspects of the program.

"Presently in charge of basic research programs for the Government, the National Science Foundation seemed to be the logical agency to carry out the program.

"Therefore, provisions in the bill would permit the National Science Foundation to execute the program. The National Science Foundation would also be able to arrange with other governmental agencies for handling of the applied or field research aspects of the program.

"It is expected that the National Science Foundation would establish a special commission for formulating an overall research program. This group will recommend which portions of the field should be investigated from a basic aspect, and which should be applied for field research. The National Science Foundation would determine the best possible division of the applied research program and arrange responsibility for this portion of the program.

"Thus, your committee recommends a research program that will yield scientifically verifiable answers to the many questions in the important field of weather modification."

Despite the very evident intent of the Senate committee that basic research should be teamed with applied research, and with two exceptions that I shall note later on, the anticipated program of applied research never materialized. Why not?

Between 1953 and 1957, leadership was provided by the Advisory Committee on Weather Control, composed of six Government members and five members from private life, selected for their sound scientific grounding and for their broad experience in applied meteorology. It was on the basis of their report that the Senate committee made its recommendation. The breadth and balance of outlook lost when the Advisory Committee disbanded in 1957 has not yet been restored.

You may examine the makeup of the following committees, and I do not know how many others, without finding the name of a single person who has been identified with the application of weather modification to useful ends and scarcely anyone identified with applied meteorology in general:

Committee on Atmospheric Sciences, National Academy of Sciences.

Panel on Weather and Climate Modification, National Academy of Sciences.

Advisory Panel on Weather Modification, National Science Foundation.

Special Commission on Weather and Climate Modification, National Science Foundation.

University Committee for Atmospheric Research.

Executive Committee for Meteorology, American Geophysical Union.

Committee on Cloud Physics, American Geophysical Union.

Committee on Cloud Physics, American Meteorological Society.

Committee on Weather Modification, American Meteorological Society.

Between 1957 and 1965, the consensus of these bodies that applied research on weather modification was inadvisable and premature effectively blocked the development. Until about a year ago, this consensus regarded the experiences of commercial operations in reducing weather modification to useful practice as being without scientific value and unworthy of their further consideration. It was only as a consequence of outrageously provocative official disparagement of commercial operators that this situation was finally altered. The belated recognition of the positive results accumulated by commercial operators brought

about a complete reversal of this attitude on the part of the Panel on Weather and Climate Modification. In terms of the experience that might have been gained if this recognition had been more timely, the delay has been a costly one.

Restoration of balance between scientific and practical viewpoints in the guidance of official policy is an urgent matter; it should be brought to bear on plans being made now. Indications are against the supposition that balance will restore itself spontaneously: appointment of the American Meteorological Society's Committee on Weather Modification was announced subsequent to publication of the National Academy of Sciences and National Science Foundation reports recommending applied research, yet nobody identified with this activity was placed on the committee. Appointment of a top-level steering committee along the lines of the Advisory Committee on Weather Control could go far toward restoring breadth and balance.

*3. The role of private initiative in reducing weather modification to a useful practice and in the exercise of this practice should be given explicit recognition and encouragement.*

In a free enterprise system, the sum total of private initiatives is the most thorough and the most perspicacious investigator, tester, and evaluator of new ideas. Let us make it our ally in weather modification.

From the beginning, industries and large-scale agriculture having an economic interest in the use of water have held the leading role in sponsoring applied weather modification experimentation. I testified in 1957 at the Senate committee hearings on S. 86. "There is no danger that scientific or commercial progress in weather modification will cease for lack of Federal support. From our experience with more than a score of industrial clients, we know the advantages of weather modification are attractive enough to hold and expand the interest of the industries concerned."

Yet the flow of industrial support did slow to a trickle. The reason was one I had not foreseen: not lack of Federal support, but the chill of official disparagement of applied weather modification as being unscientific and premature. How many board chairmen could tell their stockholders they were bucking that kind of advice from the purest of horses' mouths?

Applied weather modification slowed to a trickle, but it did continue to trickle in despite everything. It carried out on its own, as best it could under the circumstances, the 1957 Senate committee recommendations on applied research. And it accumulated the evidence that finally turned the official viewpoint about-face, once the panjandrums of science could be persuaded to examine it.

There remains in the private sector an enormous and largely untapped reservoir of interest and concern regarding useful application of weather modification, a reservoir that needs only to be thawed out after its long deep-freeze treatment, a reservoir capable of substantially supplementing and perhaps even outdoing the levels of public support so far mentioned. Here are private dollars ready and able to carry a great share of the load that the taxpayer would otherwise bear. Should not this power be harnessed to the national weather modification program?

(*a*) *Those private entities that undertake to integrate their own efforts to reduce weather modification to a useful practice with the purposes and requirements of the national weather modification program should, in recognition of the value to the public of such undertakings, receive compensation in the form of—*

(1) *Scientific advice for the design of operations in such manner as to yield maximum values both scientific and practical;*

(2) *Support for such additional scientific operations and/or observations not a normal part of the operational program as may be practical and of scientific value to the national weather modification program;*

(3) *Evaluation by an appropriate public agency of the scientific, economic, and social results of the operation;*

(4) *Reimbursement of expenses with respect to periods when operation of the program is suspended for nonoperational reasons, especially for "randomization" of seeding trials; and*

(5) *Indemnification for legal liability arising out of weather modification operations.*

One of the great disadvantages of the past dissociation of governmental and university research from commercial operations has been that the research organizations have spent much time and effort developing equipment and carrying out experimental operations for which equipment and techniques had already been developed by commercial companies, while the commercial operators had not the means of carrying out desirable experimental observations and programs for lack of support for other than the immediate concerns of their operations.

It seems obvious that integration of these two types of operation will bring many advantages to both by making the most apposite facilities and abilities of each available to the other for pursuit of their joint objectives. The results of a questionnaire circulated to industrial entities concerned with the sponsorship of weather modification operations, plus my own conversations along this line, lead to the conclusion that industrial sponsors as a rule will not object to the restrictions that certain of the scientific procedures, such as randomization of operations, will impose on their operations, and will cooperate fully in conforming their operating practices and qualifications to the requirements of an integrated program, provided that there are reasonable compensations, especially in the direction of more rapid perfection of weather modification practices for useful application.

In return, this arrangement will make available to the scientific community a wealth of weather modification experience obtained under adequate scientific control, adaptable to the testing of a wide variety of scientific hypotheses in both basic and applied branches of the work.

There is a further advantage to be gained by making the advantages of these undertakings available to all who wish to undertake them. In this manner, the exploration, on an equal footing as far as considerations of policy are concerned, of all the operational, economic, and social opportunities for exploitation of weather modification will be encouraged, rather than the selection of a privileged few as might occur if only certain private entities were allowed to operate in this manner.

(*b*) *Private entities engaged in reducing weather modification to a useful practice should be protected from capricious or arbitrary regulation by State and local governments and from arbitrary or capricious impositions of liability, and should have the benefit of uniform requirements for qualification and responsibility of weather modification operators throughout the United States and its possessions.*—Several townships in Pennsylvania have ordinances forbidding operations intended for modification of the weather, even though expert testimony has established that cloud seeding done within these townships would ordinarily be expected to have its effect in other townships. Also in Pennsylvania, a State law permits the county commissioners of the individual counties to outlaw weather modification activities in their counties, and the commissioners in at least two have done so, despite the fact that counties like townships are too small to contain the expected effects of a cloud-seeding operation. Another State, Delaware, has outlawed all cloud seeding for another two seasons, through September of 1967. These actions were taken on the mistaken supposition that cloud seeding was being done for the purpose of destroying rainclouds and that it had led to intensification of the drought, whereas independent studies of the cloud-seeding operation involved have indicated that it probably increased the rain, as reported in the National Academy of Sciences Publication 1350.

Several other States have laws claiming sovereignty over the moisture contained in the atmosphere over these States. Though no case involving these supposed sovereign rights has been adjudicated, circumstances where one sponsor or one weather-modification operator might have operations in one of these States and also in another State upwind of it could lead to difficulties.

In yet another of the States having laws with respect to weather modification, the laws provided for licensing of operators having no professional qualification in meteorology whatsoever, and I know personally of at least one instance where a licensee in one of these States has misrepresented himself as a meteorological expert and sought business as such, on the basis of his holding a weather modification operator's license.

In relation to the Delaware law, I might recount that when I recently had cause to seed the clouds in southeastern Pennsylvania, I had smoke generators operated in parts of West Virginia, Virginia, and the District of Columbia, bordering on Maryland, in such a manner that the expected effect leapfrogged the State of Maryland.

There are many other instances in my personal experience when I have operated generators in one State for effect in another. The indications of a recent Weather Bureau study that precipitation increases appear to extend as much as 150 miles downwind from the intended target underline the interstate character of most weather-modification operations, whether commercial or experimental.

I know of no other field of endeavor where the interstate character of the operation is so obvious, and where it would be so difficult to assure limitation of the effects to a single State. The case for Federal preemption of the right to regulate weather modification activities and to prescribe regulations necessary to assure its conduct in a responsible manner is clear cut.

It seems equally obvious to me that, where we now stand on the road toward weather modification, all operations are in a position to add useful knowledge to our slender store. A public policy that encourages such operation while at the same time providing necessary public safeguards would serve that end.

(*c*) *The role of private initiative in reducing weather modification to a useful practice should be explicitly recognized through direct representation of it on all top regulatory and advisory boards having to do with planning and execution of a national weather modification program.*—If public policy is to make effective use of private initiative in a national weather modification program through integration of privately supported endeavors with research efforts, it is both fitting and advisable that top-level regulatory and advisory boards have the benefit of direct expression of the points of view involved. Such representation would also measurably increase the readiness of private concerns to take a part in the national program.

*4. Regulation of weather modification should be lodged in an independent board, dissociated from all operational interests and representative of a broad viewpoint of public policy.*

Even though many of the scientific conclusions regarding weather modification are tentative, the principles of science on which the investigation rests are firmly established. In the same sense, even though the form of regulations required for protection of the public interest and advancement of public policy in weather modification can now be only tenatively discerned, the principles on which such regulations are to rest are already firmly established. One of the most basic of these principles is the separation of regulatory from operational functions.

It is unfortunate but true that I and others in the same boat are already caught in ambiguous crosscurrents involving regulation. Although the recent regulation promulgated by the National Science Foundation purports to be a regulation on weather modification, there is no clear line distinguishing this action from regulation of weather modification, which in my opinion it in some degree affects but which is specifically outside its authority. Yet in raising this question I must plead the matter before the same organization, and indeed before the identical individual, before whom I must also appear if I wish to offer research proposals for sponsorship by the Foundation. The actual matter is trivial, but it holds the seeds of a thoroughly unsatisfactory situation.

(*a*) *The makeup of the board should give explicit recognition to the concerns of the Government, of the scientific community, of social and political entities outside the Federal Government, and of private initiative concerned in the reduction of weather modification to useful practice and the exercise of this practice.*—I have, I think, given sufficient space to the reasons why I believe that the breadth of viewpoint that I believe to be essential in this regulatory body cannot simply be taken for granted.

(*b*) *Legislation establishing the regulatory board should preempt to the Federal Government all authority for regulation, including establishment of qualifications and responsibilities of weather modification operators and all questions of sovereignty over the weather.*—There is nothing tentative about the present need for Federal preemption of the power to regulate. A power vacuum exists that is being partially filled by inconsistent State and local legislation, in some instances capricious and ill advised. Let me quote the recent resoluton adopted by the board of county commissioners in Franklin County, Pa.: "Weather modification activities are detrimental to the welfare of the county * * *." And an editorial opinion of this action from the Chambersburg (Pa.) Public Opinion. "The commissioners would have been in a much stronger position if they had been more candid with their public. They recognized the weakness of the State

enactment and of any resolution they might pass under its authority, and on a predominantly scientific subject they elected the negative, not the positive, approach. * * * It was a sad and weak performance."

(c) *The authority of the board should extend to the power to resolve conflicts of interest that may arise out of, for example, interference between projects, or out of different objectives within a single area.*—At the present time no machinery exists for resolution of conflicts of this sort except where in certain instances they might be intrastate in nature.

CLOSING REMARKS

I have a feeling that my neck is now out about a yard, but in closing I would like to stretch it out still further with some observations on the means of carrying out these suggestions through agencies of Government, even though I lack experience in the legislative field and lack also the courage of complete ignorance.

Earlier I mentioned exceptions to the general lack of Federal programs in applied weather modifications. As of 1 year ago, shortly before the results of independent appraisal of commercial operations began to become known in the scientific community, Government weather programs in applied weather modification as listed in the report on this subject by the Committee on Government Operations included an Air Force project with the limited objective of developing a capability to disperse low stratiform clouds and fog, a Forest Service project with the limited objective of mitigating lightning-set forest fires, both of which projects had their origins before 1957; Project Stormfury, a joint Navy-Weather Bureau project to study the possibility of modifying hurricanes; and finally, the only project of a broader scope, the Bureau of Reclamation project with the objective of controlling water resources in various watersheds through the optimum utilization of dams. The last mentioned is noteworthy in that it is the only one that is precipitation oriented, the only one that has developed a program specifically aimed at taking advantage of capabilities in the field of private meteorology through contract with some of the leading commercial firms—among whom, incidentally, my own firm does not number—and the one that has had to sail most strongly against the wind to get where it is now.

Weather forecasting is clearly the weatherman's province. But just as the education of the young is too important a matter to leave to schoolteachers, so weather modification is too important a matter to leave to the meteorologists, especially to those who have for the past many years so exaggerated the false hopes on the periphery of the problem and so completely overlooked false gloom at its heart. The nature of the Federal program designed to encourage and coordinate the exploration and exploitation of a multitude of specific individual situations, with a supporting program of scientific research, and with regulation, greatly transcends the present capability of existing Government agencies, and yet the experience and commitments of existing agencies constitute an important source of strength that should not be wasted. To take advantage of these strengths I suggest the following allocation of functions:

First, an independent Weather Modification Board, perhaps modeled on the Civil Aeronautics Board, restricted to a regulatory capacity; preempting the present authority of State and local governments;

Second, a Weather Modification Advisory Council administratively within the Environmental Science Services Administration but composed of representatives of all the Government agencies concerned with weather modification and of an equal number of representatives drawn from private life; this Council to provide overall guidelines and coordination for orderly development of the national weather modification program, and empowered to direct the implementation of its program through the two agencies next mentioned below;

Third, statutory assignment to the Environmental Science Services Administration of the principal role in basic scientific research in support of the national program, to be accomplished through in-house, contract, cooperative, or coordinated activities under the guidelines established by the Council;

Fourth, statutory assignment to the Department of the Interior of the principal role in the reduction of weather modification to useful practice not only within the present area of interest of the Bureau of Reclamation and the Office of Water Resources Research but also within an expanded domain covering all applications for useful purposes with authorization to carry out this assignment through in-house or contract activities and with specific authorization for cooperative agreements with private entities along the lines I have recommended earlier; and

**Fifth, authorization for other agencies of the Government to carry out, under the general guidance and coordination of the Council, both researches and applications pertinent to the special missions of these agencies.**

Senator BREWSTER. Thank you very much, Mr. Howell.

It is obvious that you are a true expert in this field. Your testimony is very helpful to the Senate Commerce Committee.

I have a few questions, and in part they will be repetition, but I would like to pin you down on some of the points you made.

In establishing this Weather Modification Board along the lines of CAB, would it be possible to place this under or within the structure of one of our existing departments?

Mr. HOWELL. I would like to defer to a more experienced political scientist. I am not sufficiently familiar with the manner in which the agencies interlock. I make only the single point that the regulatory agency should be entirely independent. What it requires to establish independence I do not know.

Senator BREWSTER. The measure, S. 2916, which is before this committee attempts to collect the various Federal activities within the Department of Commerce and give some direction, control, and coordination in this Department. Would this seem to be an improvement under the present lack of coordination and diversified efforts that are taking place?

Mr. HOWELL. It does not seem to me that the placing of the regulatory function within an agency which contemplates a major operational role would be conducive to independence.

Senator BREWSTER. In your judgment, would it be completely impossible to have State regulation of various weather modification operations?

Mr. HOWELL. It would not be impossible given a long enough time. But it seems to me both illogical and impractical in view of the actualities of the situation.

There are, of course, people who interest themselves in uniform interstate legislation, and one of the most interesting hearings held on this topic was before the New York State Committee on Interstate Legislation. However, this path has not been effective to the present time, nor does it promise to be effective within the near future in developing the sort of uniformity that we are now itching for.

Senator BREWSTER. The weather pattern certainly does not respect political boundaries.

Mr. HOWELL. It does not, nor national boundaries.

Senator BREWSTER. We have heretofore discussed the limitations imposed by certain States such as Maryland where you have an absolute bar to any type of weather modification activities. And because of this, because of a lack of coordination, you believe, sir, as you say in your statement, that this entire field without exception should be preempted by the Federal Government?

Mr. HOWELL. This is based not alone on the Maryland situation or the Pennsylvania situation. I have held this opinion for many years and expressed it previously before Senate committees.

Senator BREWSTER. As a private operator in this field, how does the company protect itself from liability?

Mr. HOWELL. In my own case, I carry liability insurance which affords a certain amount of protection. A further amount of protec-

tion comes more or less automatically in that the burden of proof of damage rests on the plaintiff, and so far it has proven extremely difficult to obtain proof that the cloud seeding caused the damage.

Senator BREWSTER. Have any suits to your knowledge been maintained successfully against an operator?

Mr. HOWELL. To my knowledge, no.

Senator BREWSTER. Would you comment, sir, on the present National Science Foundation requirement for reporting? Are the reports effective, are they overly costly, and are they easy to obtain?

Mr. HOWELL. In my opinion, the present reports are certainly effective in obtaining the information that NSF feels it needs. I feel that it has placed the burden of deciding what information is pertinent on the private operator, where I feel that it should have spelled out just what it believes to be pertinent.

I do not feel that under present circumstances the requirements of this regulation are burdensome.

Senator BREWSTER. The National Academy I believe has reported that an average of 10- to 15-percent increase in precipitation is possible. Would you agree with that conclusion?

Mr. HOWELL. I first stated this conclusion in a Senate hearing in 1951. I restated it in 1957. Everything which has happened since confirms my belief that this is essentially the order of magnitude that we are able to achieve.

Senator BREWSTER. Do you have any knowledge of the claims that the Russians have made about their successes in this field?

Mr. HOWELL. Only indirectly through reading reports and through personal conversations with people who have visited Russia.

Senator BREWSTER. Are the Russians or any other sophisticated country more advanced than the United States?

Mr. HOWELL. In the investigation of applied uses of weather modification, I think I can name half a dozen countries that are more advanced than the United States. Certainly among them are Australia, Japan, Russia, Italy, France.

Senator BREWSTER. In your judgment is the United States participating to the full extent that it might in international endeavor in the WMO?

Mr. HOWELL. This is a matter in which I am by no means expert at the present time. I have some opinions regarding the manner in which meteorology and, in fact, other operating organizations of the United Nations have developed over the past 20 years and may develop over the next 20 years, but I am not prepared to make any expert statements.

Senator BREWSTER. Thank you very much. Senator Dominick.

Senator DOMINICK. Mr. Howell, I am sorry I was not here for your testimony. I have had three committee meetings this morning. It is very hard to get to all of them.

I am intensely interested in this subject, as you may have seen from the last series of hearings that we had.

I would like to get a further refresher of your testimony since I have only scanned it briefly.

Mr. HOWELL. I varied the last page of that testimony, Senator. I would be glad to have you look at my manuscript copy here.

Senator DOMINICK. Fine. I will get that a little bit later.

Is my understanding correct that you believe that in any Federal program that is devised an overall board should be set up on which private industry should be represented?

Mr. HOWELL. This is the essence of my statement, yes.

Senator DOMINICK. Now, there have been intimations in past hearings, and the legislation itself would appear to lend substance to it, that the proposal in this particular bill would prohibit private application of weather modification programs wherever it might interfere with a research program being carried out by the Federal Government. What is your attitude on this?

Mr. HOWELL. My attitude is that certainly it is going to be necessary to control such interferences but that their control and regulation should be the function of an impartial agency able to consider all interests involved and that automatic primacy of some perhaps pipsqueak little contractor to the Government over a well organized and historically long-lasting private enterprise should certainly not be automatic.

Senator DOMINICK. I raised questions in previous hearings as to the legal problems involved. Let's take the State of Oklahoma just as an example. Suppose that the Federal Government should decide to conduct a research program in Oklahoma and that the area has in the past contracted for weather modification programs to increase their water resources and would want to in the future. Yet the Federal program would take priority even though the area which was to receive more water might be considered as a control area and end up thereby with not getting any.

Now, what would be the legal effect? You have landowners and municipalities who want more water and who want to contract to bring it about. Yet it is a control area under a Federal research program and therefore no operations can be carried out.

Mr. HOWELL. This is an aspect that I think would be considerably relieved if the private applications, the private investigations in reducing weather modifications to actual useful practice were to be regarded as a legitimate part of the national weather modification program coordinated through a weather modification commission.

This would remove the basis for some of these conflicts and would establish the basis for resolving others in a truly broad view of the public interest.

Senator DOMINICK. Mr. Howell, some years ago I was instrumental in getting an authorization into the Interior bill and then helped in obtaining appropriations of a million dollars for the Government to start work in the weather modification field. We have increased that from time to time. I have been active in all these efforts.

On each occasion I have attempted to make sure that the taxpayers' funds which were being appropriated would be used not only for research but for applied research—in other words, programs that would actually increase precipitation in areas where it is needed.

To the best of my knowledge, this has not been really carried out in that form. It has still been research in all areas up to date. But there have been some private people who have received contracts under this. Do you happen to be in that category?

Mr. HOWELL. No; I do not have a Government contract on weather modification at the present time.

Senator DOMINICK. From your expertise in these fields, how many qualified commercial operators do you feel there now are?

Mr. HOWELL. Well, there are too many levels of qualification for me to give a blanket answer. I would say that there are about half a dozen firms that occupy truly leading positions in this field and perhaps another half dozen or more who have developing qualifications and show promise.

Senator DOMINICK. Has your experience largely been in the East, or has it been on a nationwide basis?

Mr. HOWELL. My operations have extended from northern Quebec down the east coast, out as far as parts of Louisiana and Arkansas, throughout the Caribbean area, and in South America down to Colombia and Peru, and so forth, and out to the Philippine Islands.

Senator DOMINICK. In your work, have you been engaged largely in trying to produce more precipitation?

Mr. HOWELL. This has been the objective of most of my operations but by no means all of them.

Senator DOMINICK. Have you done hail suppression operations?

Mr. HOWELL. Yes; I have. That was the purpose of an operation here not too far from Washington in the central Potomac Valley.

Senator DOMINICK. Have you filed reports on the results of these operations with anyone?

Mr. HOWELL. I have made it a practice to send copies of all evaluation reports that I prepare to the Weather Bureau Library and to Dr. Schaefer who in the early years was really the sort of center of communications in this field, and I have since added the National Science Foundation, the National Academy of Sciences, the National Center for Atmospheric Research, and so forth, to my mailing list.

Senator DOMINICK. Have you received back from these various groups any evaluation of your reports?

Mr. HOWELL. Not until last summer. At that time the National Academy of Sciences Panel on Weather and Climate Modification reviewed a considerable number of my reports and studied some of them in much greater detail.

Senator DOMINICK. From time to time we keep seeing articles in scientific journals and often in newspapers which in effect say that the evaluation reports made by private operators are solely self-serving and have no scientific basis.

I am sure you have seen some yourself. What is your comment on that?

Mr. HOWELL. My comment is that this was indeed the way we in this field were made to feel about the presentation of our reports.

I presented such a report at the International Union of Geodesy and Geophysics in Toronto some years back and again in Denver in 1959. On both occasions there was no discussion from our peers, and we were made to feel pretty much that we were using a podium of science, if you wish to call it that for improper uses.

This was not very encouraging to publication.

Senator DOMINICK. Do you have a feeling that this attitude has changed?

Mr. HOWELL. It has about-faced in the last year.

Senator DOMINICK. This is very encouraging for me to hear, because I found it somewhat exasperating to discover that many locales, many governments, and many private industries were year after year hiring commercial operators and yet the scientists said they were not doing any good at all, that nothing could be proved and that it was a fruitless proposition.

So to change this around, give some recognition to what has been accomplished and to what has been found by the private operators I think is very important in trying to get the general public educated to what we are trying to do.

I make that comment for myself. I think it does have a bearing on this bill.

Have you been involved in forecasting?

Mr. HOWELL. My firm does not do forecasting. I have worked as a forecaster; yes.

Senator DOMINICK. Have you done any research programs for any private industries for purposes of improving forecasting or for developing new methods of weather modification?

Mr. HOWELL. I have not with respect to forecasting, but I have made a number of studies of one sort and another—especially feasibility studies—with respect to weather modification.

Senator DOMINICK. I was interested in your statement where you point out that ground seeding is largely the method by which you conduct your operations. Is this correct?

Mr. HOWELL. This is correct.

Senator DOMINICK. You would be interested to know that I just got a letter from a constituent saying that anybody that does ground seeding and says he gets any results is either a fraud or an idiot. And since I happen to know many people that have been working this way and doing it successfully, I thought this was an example of how some people simply do not understand the situation.

Mr. HOWELL. May I say anyone who contemplates weather modification without being assailed by many doubts is an unfeeling fool.

Senator DOMINICK. I gathered from your answers to questions from the acting chairman that you do not feel that this program should be centralized in a specific agency or at least if you have an integrated overall advisory group, the actual course of programs conducted by the Federal Government should be divided amongst the various agencies.

Mr. HOWELL. I have come to the conclusion which differs from my prepared statement that the principal home of a national weather modification program should be in a weather modification commission independent of the existing agencies but that it should work through the existing agencies where these agencies have special capabilities to be utilized and should develop its own program specifically with respect to the large-scale operational and applied trials that have been recommended by the NAS panel.

Senator DOMINICK. Would you feel that the National Science Foundation as a general coordinator with an integrated industry and governmental advisory committee and with regional coordinating agencies throughout the country would be an effective agency for promoting further activity in the weather modification field?

Mr. HOWELL. It would promote further activity. The degree to

which that activity was a balanced activity would depend on how successful the National Science Foundation would be in expanding its point of view from what has been one basically related to science to one basically related to the investigation of the enormous number of various problems outside of pure science that are going to be involved, in my opinion, in developing a national program.

We are talking about a program which—well, railroading goes beyond the science of the study of friction, and in the same sense the use of a weather modification program is going to dwarf the purely scientific aspects.

Senator DOMINICK. Would you agree with the witnesses who have said before this committee that we are not yet ready for any very large weather modification efforts but that we are ready for what they call big scientific efforts which I gather take in more than a hundred square miles?

Mr. HOWELL. Where one draws the line between small, large, and very large I do not know. I would go along with the statement of Professor Hogan that we should not undertake vast experiments in modification without being able to predict much better than we can now what would eventuate.

But to limit to anything like 100 square miles, when in my own operations we have operated over as much as 30,000 square miles at a time, is going to an extreme in the other direction.

Senator DOMINICK. When you say that you have operated in an area that big, are you talking about trying to increase precipitation in that area, or are you talking about the area that is encompassed by where you set up your generators and a specific target area?

Mr. HOWELL. In this case this was the extent of the specific watershed in which we were attempting to stimulate precipitation.

Senator DOMINICK. In your prepared statement you referred to the fact that in your Catskill operation you had quite a few people objecting rather strenuously to it. What happened then? Were you sued, or did anybody obtain an injunction against you?

Mr. HOWELL. There were two actions undertaken. The Nevele Country Club asked Justice Pecora of the district court for an injunction to stop the city's experimental activity, which Judge Pecora turned down on the grounds that the city's need was a prevailing one and that the Nevele Country Club, if it turned out to have been damaged, had normal recourse in equity.

The second action was brought as a consequence of a severe storm November 27, 1950, which resulted in about 8 inches of rain in some parts of the Catskills, and washouts of bridges. One creek changed its bed in one place. We did seed in this storm.

About $2.5 million worth of suits were brought against New York City by a group of townships acting jointly. But the case never came to trial. It has been off the court calendar now for many years and is in some sort of legal limbo which I do not fully understand.

Senator DOMINICK. Did the city of New York renew your contract on this after 1950?

Mr. HOWELL. No, they did not. There was a change of city administration during the time that I held the contract there, and the commissioner with whom I had originally worked was no longer there at the end of that term.

Senator DOMINICK. Some people have testified here and some comments have been made publicly in magazine articles that you should have at least a 3-year contract to be able to be effective in this field. Does this sound reasonable?

Mr. HOWELL. This is a question which we have not full information to resolve at the present time. One of the most significant points that was discussed in the course of developing the NAS report was the techniques by which we might improve evaluation of field experimentation. Up to the present time there has been a tendency to set forth one fairly simple hypothesis, say, that cloud seeding increased the rain in a certain place, and then set out on an experiment based on this hypothesis and to come up with some data which, after a couple of years, or 3 years is entirely inconclusive when tested by the prescribed procedure.

But since people love to look at their data, they will go back and look at this and discover that perhaps on certain days or in certain relationships between the seeding and the weather there appears to have been an extraordinary effect.

This is outside the prescribed statistical tests. So it may refer only to this specific set of data and may not have any general validity. So then you have to go back, design a new trial, and go through the thing again.

Now, at the present time the recommendation has been made in scientific circles that we should go into the design of experiments much more fully and be able to test many more hypotheses in the course of a single operation so that we can make much more efficient use of our field operations.

Now, whether in the context of the means of evaluation that are within reach we still need to wait so long to test our hypotheses is something which is to be contemplated but not yet proven.

Senator DOMINICK. Well, that was a very careful answer and I appreciate it, but I still am trying to find out whether you think that it is necessary to conduct, in a particular area, programs over 2 or 3 years in order to be able to develop a carefully considered and accurate weather-modification program that can be evaluated for two or three things: (1) the type of clouds that are seeded, (2) whether it brings in additional precipitation, (3) whether it has downwind effects, etc.

Mr. HOWELL. Certainly continuity of support in well-staffed, well-conducted operations is an extremely important factor in getting the greatest value out of them.

Even though we may be able to conclude certain statistical tests in much less than 2 or 3 years by using new techniques, nevertheless, the continuity of a well-designed field program is extremely rewarding in being able to feed back new ideas and to make maximum use of the facility.

Senator DOMINICK. Let me put it a different way. If a private operator has been operating with a hail-suppression program for 11 years in a particular area, would you feel this should have some pretty good scientific evaluation as to whether it has been effective or not?

Mr. HOWELL. Hail is about the most difficult thing to evaluate in that regard, and I would be leery of counting on any reliable indica-

tions even from an 11-year period if one is simply dealing with the raw data of frequency of occurrence of hail alone.

I do feel though that the planned integration of an operational program of that sort with the national weather modification program is a promising means of expanding and taking best advantage of the available field.

I feel that there are many millions of dollars' worth of research and development funds waiting in the wings that have been kept in the deep freeze for past years and that by proper encouragement can be brought forward and made to do much of the work of a national program.

Senator DOMINICK. Mr. Howell, earlier you said Australia, France, Soviet Union, Italy—and I am not sure about Brazil but I think you mentioned Brazil——

Mr. HOWELL. Japan.

Senator DOMINICK. Japan. Were ahead of us?

Mr. HOWELL. As far as applied research in weather modification.

Senator DOMINICK. How do they coordinate this with their governmental agencies—exclusive of the Soviet Union because this is obvious?

Mr. HOWELL. In Australia this is done through the Commonwealth Scientific Industrial Research Organization.

Senator DOMINICK. Is this a part government, part private enterprise setup?

Mr. HOWELL. I think it is entirely government but with relationships, the details of which I do not know, with private industry.

Senator DOMINICK. What about France, Italy, and Japan?

Mr. HOWELL. In Japan it is my understanding that this is carried out by private hydroelectric interests in close coordination with the Government.

In Italy I do not know the details of the organizational aspects at all well.

Senator DOMINICK. From your knowledge of programs in other countries would you say that they are or are not using commercial operators in their applied research programs?

Mr. HOWELL. My impression is that there have been some ties with commercial interests. I do not know of any specific case where a private meteorological firm has been working for government agencies, although I do know in the case of Italy that a private manufacturer has been involved in sponsoring programs for the use of their own products.

Senator DOMINICK. Is it your understanding then that any program which is actually in operation to produce more precipitation is actually conducted by government employees?

Mr. HOWELL. In the case of France I believe that this is conducted by an organization that is loosely affiliated with a university and is sponsored to some degree by a group of insurance companies.

Senator DOMINICK. And you do not know about the others?

Mr. HOWELL. I am not familiar with the details of how these are organized.

Senator DOMINICK. Thank you, Mr. Chairman.

Senator BREWSTER. Thank you very much, Mr. Howell, for a comprehensive statement and some excellent answers to difficult questions, sir.

Mr. HOWELL. Thank you.

Senator BREWSTER. The senior Senator from Oklahoma, Senator Monroney, has been in and out of this hearing several times. I do not see him here now, but I believe Mr. Don McBride of his staff is here.

Mr. McBride, I know that the Senator wanted to introduce the next witness, but perhaps you will do it for him, sir.

## STATEMENT OF DONALD McBRIDE, STAFF ASSISTANT TO HON. A. S. MIKE MONRONEY, U.S. SENATOR FROM THE STATE OF OKLAHOMA

Mr. McBRIDE. Mr. Chairman and Senator Dominick, I am privileged for Senator Monroney to introduce Dr. Ray Booker, whom we have known down in Oklahoma for a good long while.

He was on the faculty of Oklahoma University as a meteorologist and a climatologist, and he has been chasing cyclones and tornadoes over Oklahoma for a good long while. We consider him an expert in his field, probably because it is so complicated that we do not know anything about it.

But, nonetheless, we are very happy to present Dr. Booker to you this morning, and we believe that he can make a very fine contribution to this testimony and this record.

Ray, sit down. May I sit here with you?

Senator BREWSTER. Thank you, Mr. McBride.

Dr. Booker, we are very happy to have you.

I see you have a prepared statement, so please proceed as you wish.

## STATEMENT OF DR. D. RAY BOOKER, PRESIDENT, WEATHER SCIENCE, INC., NORMAN, OKLA.

Dr. BOOKER. Yes, sir, I do. I will submit this for the record. However, in consideration of your time, since it is a fairly short statement, I will not read it but I will attempt to summarize it and to put in perhaps one or two comments which occurred to me since I prepared this statement.

(The full text of Dr. Booker's statement follows:)

STATEMENT ON WEATHER MODIFICATION IN THE UNITED STATES, BY DR. D. RAY BOOKER, WEATHER SCIENCE, INC., NORMAN, OKLA.

The importance of weather modification to mankind has undoubtedly already been expressed many times to this committee. Therefore, I will only say that in my opinion, the ability of man to control his environment, if only to a small degree, ranks in importance with the peaceful uses of atomic energy and the exploration of outer space. The state of the science and technology relating to weather modification has now reached the point where positive beneficial results can be foreseen. We must now mount a substantial effort as a nation to achieve a measure of success in this area.

I am encouraged by the enthusiasm of many Members of the Congress about weather modification as expressed by S. 23, S. 2916, and S. 2875. These bills show an awareness of the urgency of our need to be able to modify our environment. They are in accord with recent recommendations of the National Academy of Sciences and the National Science Foundation Commission on Weather Modification. Both agencies urge a national effort in weather modification. I am in wholehearted support of this as a national goal. We have been too long already in organizing a massive attack on the problems of weather modification.

We have known for 20 years that we could achieve certain changes in clouds. In many cases the changes are strikingly visible. However, we have been slow

to learn how to consistently achieve beneficial results. Many years were wasted in widespread, poorly documented operational cloud-seeding projects, which are too often done by unqualified people. These projects added little to our understanding of the mechanisms involved.

Recent years have brought certain advances which place us in a favorable position to attack the weather modification problem on an adequate scale. We have developed sophisticated and compact instrumentation which can observe atmospheric phenomena on all scales with much more resolution than was possible a few years ago. Equipment is now available for recording and processing the data very quickly and efficiently, even during the life cycle of a particular cloud. We now have aircraft and satellite platforms which can place our instruments at vantage points which would have been difficult or impossible to achieve 2 or 3 years ago. We have computers with sufficient capacity and speed to construct numerical models which resemble very clearly the real atmosphere. Recent research in the A B C's of how clouds live and die has greatly increased our theoretical knowledge of the vital factors in cloud systems.

Every year we bear tremendous economic and human losses due to damaging atmospheric processes. Even slight favorable adjustments of these natural forces would be worth many millions of dollars each year. As technological leaders in the free world, I believe we cannot afford to neglect this opportunity for economic and social advancement for ourselves and others around the world. In this regard, I would like to make the following recommendations:

*1. Regulation of weather modification activities*

Responsibility for regulation of weather modification activities must be separate from any agency which conducts the activity. I suggest a new commission operating under the executive branch but not as a part of any department which now conducts or will conduct activity in weather modification. My interpretation of S. 2916 is that the Department of Commerce would be responsible for conducting large-scale weather modification research and would also control the operations of all other groups in this field. To carry out both of these responsibilities within any one department would require extremely fair-minded administrators. Regulation of the activities of all interested agencies and the private operators should be the sole function of a new commission. It is essential that a voice for private industry also be provided in this commission in order to be fair to those who have established substantial interests in weather modification.

*2. Utilization of existing capabilities*

The Federal program in weather modifcation must take account of the views and capabilities of persons and agencies who have been active in this field in the past. There is an apparent lack of recognition in S. 2916 on the role that private firms and universities could play in weather modification. My review of the literature shows that publications of scientific articles on weather modification by private and university authors outnumber those by Government authors by 10 to 1. If a speedy and economical solution of the problems facing weather modification is desirable, I think it is essential to utilize first the existing capabilities in weather modification rather than building up a large Federal structure to do the work that is now being done outside the Government.

*3. Retention of existing programs*

I think it is a healthy condition to have an active participation in weather modification activities by several Federal agencies. The potential effect of weather modification is as broad and varied as the missions of the several agencies now participating. It is difficult to imagine how a single agency could devote adequate attention to the aspects of weather modification which are important to the overall missions of all of the agencies which have testified before this committee. The transfer of functions now performed by agencies such as the National Science Foundation and the Bureau of Reclamation to the Department of Commerce would not be in the best interest of weather modification. I believe the existing functions of the several agencies in weather modification should be retained and expanded rather than transferring all functions to any single agency.

*4. Funding of weather modification activities*

Far too little Federal support of weather modification has been established in the light of potential benefits therefrom. Appropriations for these activities

should be substantially increased in the near future. Allocations of these funds should go in the direction of demonstrated vigor and competence in this area. Funding should be aimed at adequate long-term support of those organizations which show a competence in weather modification.

*5. Regional aspects*

The climate of the United States is extremely varied. Significant regional research activities should be centered in each area of the United States which is characterized by a particular climatic situation. This could be done through a prime contractor who would be responsible for the overall regional operations and who would be required to subcontract portions of the work to qualified groups.

*6. Liability for weather modification activities*

The Federal Government should assume the responsibility for weather modification activities which will be done for the Federal Government by contractors.

These recommendations are based upon both an extensive personal poll of the feelings of a large number of persons active in weather modification and my own personal convictions.

Dr. BOOKER. Perhaps a brief further introduction of myself, since I am not one of the older fellows in this field, might be in order.

I am from Oklahoma and have been interested in this field for quite some time. I started as an engineer. More recently my work has been at Penn State University where I completed the master's and Ph. D. degrees in meteorology.

More recently, I founded Weather Science, Inc., which has offices in Norman, Okla., and which does research and builds instrumentation for meteorology.

I am involved in weather modification research activities in South Dakota and in Colorado, contracting with universities which are involved in National Science Foundation and Bureau of Reclamation research.

I will not say anything about the importance of weather modification because I know of your interest in this and I notice that it has been pointed out to you many times over already.

I would say that I am in favor of increasing the funding to weather modification and to weather research in general, because weather modification must move forward with related basic research in other areas.

One of the shortcomings, I think, in recent years in many parts of the country has been the operation of research groups on too small a scale, on a scale which does not permit adequate use of weather radars, aircraft, ground observational stations, all of which are essential to meaningful research but all of which have been operated in too many cases on a very, very limited scale so that the results are considerably diluted and not done as efficiently as they could be, say, if they were operated at twice the size.

Further, this work should be done in regional centers I believe distributed around the country. The reason for this is primarily climatological. The climate in the United States varies tremendously, and even within regions varies a great deal, so that work done in one area will not necessarily be duplicated or not necessarily indicate, I should say, the correct answers in another area.

With regard to S. 2916, which has the effect as I understand it of increasing the role of the Environmental Sciences Service Administration in weather modification, I wholeheartedly support this increase. I think ESSA has a larger interest than their current opera-

tions indicate. I think they are interested in increasing their output in this area, and I wholeheartedly support it.

However, with regard to regulation of weather modification activities, I echo the opinions expressed just before me by Dr. Howell, in that I feel that regulation should be divorced from any agency which is actively working in weather modification.

I feel that it is not good government to ask any agency, no matter which agency it is, to conduct a regulation function of itself and other agencies and private industry and university groups at the same time that it performs activities in this area.

I am not an expert in how to run a government, so I cannot make specific recommendations as to where a regulating commission on weather modification should be attached, but I feel that one should be formed because I think it is essential that weather modification regulation and direction be moved to the Federal level.

As Mr. Brewster pointed out earlier, clouds do not respect county boundaries, State boundaries, or even national boundaries, but at least we can work within the national framework much more conveniently.

This commission which I feel should be set up should be charged with the regulation of weather modification activities, both research and operational, should be represented by those agencies which have an interest in weather modification, but I would like to point out also that to be fair to those private firms who have developed a substantial interest in weather modification, there must be representation on this commission or board for private industry, perhaps by university groups.

My own review of the literature in the United States published by U.S. authors indicates that the contributions to the literature by university and private groups outnumber all other sources 10 to 1.

So that there should be, I feel, representation on this commission by these groups.

This agency should be charged with research, but this research should be directed toward learning how to regulate. The legal problems involved in weather modification are so confusing and so involved that no man today is wise enough to know how to regulate this activity. So that an extensive investigation of this area is in order a new commission should be charged with this responsibility.

In order to avoid a conflict of interest this new commission should not conduct any operations for research purposes or for operational, rain increase, hail prevention, tornado prevention or whatever. This should be done by existing agencies.

I do not think it is possible to accumulate all of the responsibilities for weather modification in a single agency, because the missions of several agencies demand an interest in weather modification.

Farmers have a substantial interest in weather modification and can be best represented by the Agriculture Department.

In the field of water resources again I think the Department of Interior should look after this portion of weather modification.

In the field of severe storms I think we have not done enough. The Commerce Department should be charged with the responsibility of intensely pursuing research toward eventual modification of severe storms. I feel the people of Mississippi this week would vote for that wholeheartedly.

And one last point, is that companies or universities doing work on contract to the Federal Government in weather modification of a research nature should be relieved of liability for their actions in performing the research.

At the present time, as I understand the setup of things, this is not true. A private contractor assumes his own liability which may be substantial. Potential litigation perhaps many times the net value of the contract.

This is not a good situation. I do not know the answer, because this is a complicated matter, but it should be studied and studied now.

I think the time when we must solve this problem is getting very close at hand.

I would be glad to answer any questions.

Senator BREWSTER. Dr. Booker, we thank you for coming a long distance to be with us this morning, for your excellent statement, and for giving the members of this committee a chance to have the benefit of your expert opinion.

Senator Dominick.

Senator DOMINICK. Dr. Booker, is Weather Science, Inc., an operator of weather modification programs?

Dr. BOOKER. No. We have no contract with anyone to do weather modification or weather modification research per se. We do subcontract with one or two universities in this area.

Our subcontract is in the nature of our furnishing airplanes, instrumentation, and scientific services in their program, but we have no program of our own.

Senator DOMINICK. Does Weather Science, Inc., have any official relationship with the State of Oklahoma government?

Dr. BOOKER. No, it does not.

Senator DOMINICK. Is it a university group?

Dr. BOOKER. No. It is a private corporation——

Senator DOMINICK. Private corporation?

Dr. BOOKER (continuing). Formed in Pennsylvania and moved to Oklahoma during the last year.

Senator DOMINICK. And what you do is to provide equipment for other groups that are going to be operating?

Dr. BOOKER. This is one of of our functions. We design a whole host of meteorological instruments and put these into a package so that the airplanes become a flying laboratory equipped to measure some 20 atmospheric and aircraft variables.

Senator DOMINICK. But you do not operate anything yourself?

Dr. BOOKER. We do research. We have a program currently going with the National Severe Storms Laboratory in which we are developing a new technique for measuring the air motions associated with severe storms, including tornadoes.

Senator DOMINICK. So you are doing research on a Government contract?

Dr. BOOKER. Yes. We are not directly in weather modification, but I would guess you would call it basic research in thunderstorms.

Senator DOMINICK. And you do also subcontracting work with commercial operators or only with governmental entities?

Dr. BOOKER. With universities and Federal agencies at the present time.

Senator DOMINICK. And you are part of the National Center for Atmospheric Research at Boulder?

Dr. BOOKER. No, sir. We work with them, but we have no direct ties.

Senator DOMINICK. Do you file reports with them and participate in seminar discussions with them on atmospheric problems?

Dr. BOOKER. We participate in discussions, and also, I might point out, we are also involved in Project Hailswath, of which you are aware, for this next summer and in which NCAR is involved. Our function there is to provide one or two aircraft plus instrumentation systems for these aircraft and to provide scientific talent to operate them.

Senator DOMINICK. Have you been asked to do evaluation of weather-modification operations that have occurred in Oklahoma?

Dr. BOOKER. No, not so far.

Senator DOMINICK. I am sure that you have knowledge of the fact that they have been going on.

Dr. BOOKER. Yes.

Senator DOMINICK. I wonder, for the sake of the record here, if you could give us any idea of the scope of the weather-modification efforts that have been made in the State of Oklahoma.

Dr. BOOKER. I do not have a firsthand knowledge of it and probably am pretty unqualified to talk about it.

There have been commercial operations there dating back to the early 1950's, I guess. Recently, there has been very little activity in the State and in the surrounding areas, but a certain amount has gone on of which I am not very knowledgeable.

Senator DOMINICK. Thank you, Dr. Booker.

Senator BREWSTER. Thank you very much, Dr. Booker.

Mr. MCBRIDE. Thank you, Mr. Chairman, for the time.

Senator BREWSTER. Thank you, Mr. McBride.

The committee will meet again tomorrow morning at 10 a.m., to take further testimony on weather modification.

The committee now stands adjourned until 10 a.m., tomorrow.

(Whereupon, at 12:07 p.m., the committee recessed, to reconvene at 10 a.m., Tuesday, March 8, 1966.)

# WEATHER MODIFICATION

---

TUESDAY, MARCH 8, 1966

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

The committee reconvened, pursuant to recess, at 10:05 a.m., in room 5110, New Senate Office Building, Hon. Peter H. Dominick presiding.

Senator DOMINICK. The committee will come to order.

This is the fifth in the present series of weather modification hearings on S. 2916 and S. 23. Today's witnesses are Dr. Bernard Vonnegut and Dr. Roscoe R. Braham, Jr.

In addition to these two witnesses, the committee has received a statement from Dr. Louis J. Battan, professor of meteorology and associate director, Institute of Atmospheric Physics, University of Arizona, and president, American Meteorological Society.

The committee has also received a statement from Dr. Vincent J. Schaefer, director, Atmospheric Sciences Research Center, State University of New York, and Dr. P. E. Church, professor of atmospheric sciences, University of Washington, Seattle, Wash. All three were invited to attend, but prior commitments prevented them from coming. Their statements will be made a part of the record, and copies are available at the press table.

Several other witnesses were invited who were also unable to come. I direct that the record be kept open for 2 weeks so that any statement received from them may be included.

I also wish to announce at this time that hearings on S. 2916 and S. 23 will be resumed on March 31 and April 1 in Denver, Colo.

The first witness today is Dr. Bernard Vonnegut, of Arthur D. Little, Inc., Cambridge, Mass.

Doctor, I am sure I mispronounced your name, so if you will give it to us, I will spare myself embarrassment.

Dr. VONNEGUT. Thank you, sir, you did very well.

I have brought down a statement with me, but if I may, rather than merely reading the statement, I wonder if I might be permitted to say the same material, but perhaps in somewhat different words.

Senator DOMINICK. Doctor, your statement will be included in the record as though read, and you may go ahead in any way that you think best.

## STATEMENT OF DR. BERNARD VONNEGUT, ARTHUR D. LITTLE, INC., CAMBRIDGE, MASS.

Dr. VONNEGUT. Thank you. I have been involved in the study of the atmosphere for sometime now from the early days when Vincent Schae-

fer carried out his exciting first experiments in this field in western Massachusetts. I am concerned, I continue to be concerned in efforts at weather modification with the soundness of the scientific foundation on which these experiments must be based. In other words, weather modification is applied science.

I think that the technology of weather modification will be no better than the fundamental basic information which is necessary to guide it.

In appearing here, I hope that I may help the cause of further scientific research into weather modification. I think, that although some excellent work has been done since the beginning of cloud seeding, that the quality and quantity of the scientific work that has been done is not all that it should be in view of the demands that are going to be made on the scientific background.

I am concerned not only about the quantity of research that has been done, but also the quality. The question, "Can you increase precipitation by cloud seeding?" is a valid, very important question that must be answered, but I would like to point out that this is a social question that is being asked rather than a scientific question.

This is a very complicated question for which we must have some sort of an answer, but when answers to this question are provided I doubt that they are of much use to the scientists. If you tell a scientist, yes, it is possible to increase precipitation or to decrease it, this information that is not of much value to him unless he has a whole lot of other information along with it.

In science, a very important part of the work is to ask questions that are absolutely as simple as possible and then to design an experiment to give you an answer and hopefully you will get a simple answer to a good simple question that will serve as a building block in the next step that you may take.

But if you are careless in asking questions and ask a too complicated one, you are liable to get an answer which, while it may be valuable for some things, is not valuable for science. I think that much of the effort in weather modification has been devoted to these social questions; that is, can we control the weather, and not enough attention has been devoted to the basic effort.

I think another criticism that might be leveled at the scientific effort in the past is that there has not been enough publication of the work that is being done in the field of weather modification. The lifeblood of scientific effort is published scientific information in the technical literature and no matter how good the work is, if it is not published, the science does not thrive, and I urge that there be more publication than there has been in the past.

A further criticism that might be leveled at the scientific work, much of the scientific work that has been going on in the field of weather modification, is that the work that is published is frequently deficient in coming up to the standards that one usually requires of scientific publications.

Many of the technical papers dealing with cloud seeding research devote themselves very exhaustively to the analysis of the results but all too frequently one finds in the scientific publications about weather modification that not enough information is given concerning the nature of the experiment that was carried out.

For this reason if the experiment is a success, it is unfortunately difficult or impossible for anyone to repeat the experiment, because not enough information is given on what was done. On the other hand, sometimes the experiments wind up in failure and there is no change in precipitation or it is actually reduced. Here again we often find we are unable to profit by the experience of the experiment because not enough information is given about the seeding operation.

I hope that in making this statement that I can draw the attention of the committee to the importance of creating a favorable environment for further scientific research that is going to be necessary if weather modification is to grow and if it is to be a useful technology.

It is astonishing how many of the important things that we should know we don't, and I think that in framing legislation that will eventually lead to weather control, one of the most important things is to see that the scientific effort that is carried out is on a scale and of a sufficient quality to lead to weather control.

I think that we can profit by Irving Langmuir's statement about planning research. I am afraid that it is not really possible to plan in detail the research program that is going to be required. About all that can be done is to provide a favorable environment in which research can be conducted.

That is the sum of my statement. If I can be helpful in elaborating on any portion of it, I will be glad to do so.

(Text of full statement follows:)

STATEMENT BY BERNARD VONNEGUT, SCIENTIST, ARTHUR D. LITTLE, INC., CAMBRIDGE, MASS.

My statement is concerned primarily with scientific aspects of weather control. It is intended to convey to the committee my feeling that an expanded scientific effort of the highest quality will be necessary to provide the basic knowledge required for the development of weather control techniques.

I believe that it is worth noting that Schaefer's brilliant laboratory experiments with the cold box, which led to the development of the technology of cloud seeding, were conducted not for the purpose of learning how to control the weather but to answer a good scientific question; how do clouds make snow? There are many more good, unanswered, scientific questions about the atmosphere such as, How do clouds make rain? How do clouds make electricity? How does the air move around in the clouds, and how do clouds make tornadoes? If we mount a strong scientific effort to answer scientific questions such as these, I am confident that the inevitable byproducts will be new and improved techniques for controlling the weather.

I think that it is worth pointing out that there has been, in my opinion, considerable confusion about what constitutes a scientific experiment and that an experiment is not necessarily scientific just because it is conducted by scientists. I refer to the majority of those cloud seeding experiments in which, over a period of time, seeding materials are introduced into the atmosphere to see whether or not more rain results. Such experiments are desirable and should be continued, but it is important to recognize that these experiments are not designed to give a scientific answer but instead a sociological, economic, or a legal answer. This kind of experiment is vitally important to people who must make decisions such as whether or not it is worth investing money for a cloud seeding operation, or what sum of money should be invested for a cloud seeding operation. Valuable though these experiments are for these nonscientific purposes, they are not of much value to the scientist, nor in my opinion will they be adequate to provide for the development of a weather control technology.

Many weather modification experiments fail to meet basic standards that practically all scientists agree should be required of scientific experiments worthy of the name. One of the most important of these requirements is that the experiment be conducted in such a way and be described in sufficient detail that it

can be evaluated and repeated by other scientists. In all too many weather modification experiments, the conduct of the seeding operation is perfunctory and haphazard and often when the results are reported great stress is placed on the results while little or no information is given concerning the details of the operation that presumably was responsible for the results. Experiments of this sort are not good science for they contribute little or nothing to the general store of scientific knowledge. When experiments of this kind achieve their desired result, it is unfortunately quite impossible for others to repeat them, and when the experiments end in failure, often not enough information is provided so that others can avoid repeating the same mistakes.

The primary purpose of a scientific experiment is to answer a scientific question and no matter how elaborate and painstaking the conduct, or how careful the analysis of the results, the experiment is seldom better than the question that it was designed to answer. If the question that is asked is complicated, vague, or meaningless, these qualities are almost invariably reflected in the answers. While "does cloud seeding increase precipitation?" is a good and important question, it is far too general and complicated to be scientific. We must clearly recognize that those experiments designed to answer these kinds of questions will provide little scientific information that can be used in the development of an improved weather control technology.

While recent assessments of the possibility of weather control have emphasized the effects produced by cloud seeding in increasing precipitation, there are some important basic physical considerations which are often neglected that deserve to be emphasized. As a result of many laboratory and field experiments carried out since Schaefer's first experiment, there can be no question that cloud seeding works and that it works every time. If we put dry ice or some other seeding agent into a cloud consisting of supercooled water droplets, this process invariably initiates the transformation of the cloud into ice crystals. Many of the changes brought about in the cloud by cloud seeding are not superficial or trivial but are large and predictable. The cloud particles change from spherical liquid droplets into angular ice crystals that may be thousands or millions of times less numerous but be thousands or millions of times bigger. Heat is released in large quantities and significant changes are produced in the temperature and humidity and, as a consequence, the cloud often changes substantially in size and appearance. I think that it is safe to say on the basis of our entire physical experience that it would be most remarkable and contrary to all previous experience if these changes that we know are caused by seeding failed to produce significant changes in the subsequent behavior of the cloud.

The physics of cloud seeding is now sufficiently well understood that if the cloud-seeding operation fails to produce observable changes in the behavior of the cloud, we are justified in questioning the conduct of the seeding operation or the competence of the observation. On similar grounds, from what we know of the diversity of clouds and the diversity of seeding methods, it is clear that the outcome of a seeding operation will depend in a complicated way on many factors. While there is much we have yet to learn, I think we are quite safe in concluding that the results will vary markedly depending on the cloud and what, when, where, and how much seeding is done, and that the seeding, depending on conditions, can either increase or decrease rainfall. One of the most important goals must be to learn enough about the details of seeding and cloud processes so that we can produce the effects that we desire.

In providing legislation designed to promote the development of weather control technology, I hope that the committee will recognize the importance of more good scientific research. In promoting the scientific research, I hope that it will be guided by Dr. Irving Langmuir's wise statement that you can't plan research, you can only provide a favorable climate for it.

Senator DOMINICK. Doctor, we very much appreciate your thoughtfulness in coming here and giving us this evidence and this testimony. Your position, of course, with Arthur D. Little, which is highly thought of in the entire world, is important to the committee.

I think perhaps some things might be brought in a little broader context and if you don't mind I will ask you a few questions, keeping in mind I am not a scientist.

Dr. VONNEGUT. Not at all.

Senator DOMINICK. First, I think I should say that I don't believe that there is anything in this bill or in the hearings which would negate the need for further scientific research on weather modification or the makeup of weather as such. What we are trying to do is to determine whether or not the focus of the Government's efforts should be concentrated into one agency or one department and exactly how the coordination should go on and how far along we are down the road to being able to conduct weather programs that will have some meaning.

Now first of all, on the scientific research that you were talking about, do you feel that this should be concentrated in the governmental area?

Dr. VONNEGUT. No; I think that it is probably a mistake to try to concentrate scientific research anywhere and I feel that rather than concentrating research, that it should be perhaps even further diversified than is presently the case.

Senator DOMINICK. Should it be funded by the Government?

Dr. VONNEGUT. I am afraid that in the case of research into basic processes in the weather, it is very difficult to see how you can get a payoff. I would regard it as an important investment of funds for a private company or for a private person to try to understand how the atmosphere worked or to attempt to conduct investigations in this field.

In the first place, it is an extremely difficult and expensive thing to investigate the atmosphere, and furthermore, important though these answers are to everyone, it is quite difficult to see how anybody can cash in on them very effectively, particularly a large industry.

For example, the development of cloud seeding at the General Electric Co., I think was more of a headache to them than an asset because it opened up a host of problems. This was a brilliant development, but it was not something that they could capitalize on and I think that we will have to depend on the Government for funds to carry out this research for this reason. It is a good bet if you make a better high-temperature alloy in your laboratory, this will pay off handsomely for a new turbine for some other branch of technology. But in the case of the weather, I think the situation is quite different, that there is no payoff and I am afraid that this is unavoidably going to have to be a function of the Government.

Senator DOMINICK. Now just going into that a little further if I may, there is little or no doubt that there are many areas of this country which are totally dependent on the amount of water that they are able to put to use either by storage for dry seasons or for containment of floods in wet seasons, both in the West and the East.

I would think that industries in those areas would be extremely interested in whatever we can do by way of a program to ameliorate these conditions. Further, I would think that there would be a payoff if we could, to use your term, find proper methods of controlling the weather cycles.

Dr. VONNEGUT. Well, all of us have a great stake in the weather and in the atmosphere. Industry is vitally affected by all aspects of the weather. However, it is such a difficult thing to carry out weather research, it is such a long-rang sort of thing to carry out weather

research, that if I were in a company I would find it difficult to defend to the stockholders putting the big investments that would be required to this end.

Senator DOMINICK. Your company does a considerable amount of this work under contract either with the Government or with private industry?

Dr. VONNEGUT. The Arthur D. Little Co. is a private profitmaking concern and over half of the work we do is for industrial clients. In the course of my experience at Arthur D. Little, we have had problems in funding our research and some years ago we attempted to explore the possibility of getting funds from private industry and from private foundations to carry out work that we wanted to do. And I can assure you that this is a very difficult matter and we met with very little success.

I think that perhaps the one avenue that we did not adequately explore is attempting to get small amounts from a large number of companies who have obvious stakes in the atmosphere. But it is a difficult thing to get funds to do this from private industry.

Senator DOMINICK. Does your company then hold quite a few Government contracts in this area?

Dr. VONNEGUT. Indeed we do. I have been working on problems connected with the atmosphere, primarily with thunderstorms and thunderstorm electricity, and initially the study phases were paid for by Arthur D. Little. However, when it came to getting airplanes and radars to conduct the experiments that we wanted to do, we were unable to do this on our own and we have had support from the Government for this work.

Senator DOMINICK. What areas are you now involved in by way of research on weather?

Dr. VONNEGUT. I am presently involved primarily with the large clouds, large cumulus clouds, what we call thunderstorms, and I am conducting research, attempting to find out how it is that these big clouds can generate electricity that causes them to give lightning.

I am concerned with the effect of this electricity on the behavior of the cloud. And as a result of our work we are beginning to believe that the electricity in a cloud may be a lot more than just an unimportant sideshow. It may be a vital part of the goings on in a thunderstorm, and we think perhaps the lightning itself is an extremely effective rainmaker by electrostatic processes.

I am also interested too in the problem of tornadoes. When you get a big enough and severe enough thunderstorm, they sometimes, as you know, produce tornadoes and this is another one of the mysteries of the atmosphere, and I have been concerned with this too.

Senator DOMINICK. Under what Government agency have you been conducting these experiments?

Dr. VONNEGUT. At Arthur D. Little the original support for our work came from the Office of Naval Research from the Geophysics Branch, and for the past several years our primary support has come from the National Science Foundation.

Senator DOMINICK. Are you engaged in Project Stormfury?

Dr. VONNEGUT. No; I am not. The Weather Bureau has been carrying on Stormfury.

Senator DOMINICK. Are you engaged with the FAA and other agencies in trying to determine the effect of lightning in storms on aircraft?

Dr. VONNEGUT. Yes; I have prepared a report for the FAA, trying to bring together the information that is available on the relationship between thunderstorm electricity and airplanes. Now this, as you know, is a hazard and has caused problems in the past and I did not do so much research on this, that is, uncovering new facts, but I merely attempted to bring the facts from different fields together for the FAA.

Senator DOMINICK. You have not then been involved in the accumulation of additional evidence or lack of evidence as reported, the Air Line Pilot, for February 1966 on the question of whether lightning is in fact a danger to aircraft?

Without objection, this article will be inserted in the record at this point.

[From the Air Line Pilot, February 1966]

LIGHTNING—NUISANCE OR HAZARD?

(By Lt. Col. Jerry Creedon, AWS Liaison Officer, Directorate of Aerospace Safety)

Lightning has long been considered a nuisance, but not much of a hazard, to aircraft in flight. But the Air Force as well as other aircraft operators, the FAA and CAB are beginning to wonder if the hazards of lightning strikes aren't greater than previously thought.

In June of 1964, an F–84 was making a firing pass on a dart towed by another F–84 when both aircraft were struck. The tow pilot received a jolt which knocked his hands off the controls but he was otherwise unaffected. The other pilot almost lost his life. The intensity of the charge blinded him momentarily and the jolt numbed his left arm and leg causing him to lose control of the aircraft, which went into a descending right spiral. Disoriented, he thought the aircraft was in a left spiral. Realizing this pilot's condition, the tow pilot joined on his wing and talked him into a pullout less than 3,000 feet above the ground.

Another case, last August, involved a C–97 which caught fire as the result of a lightning strike. The aircraft was cruising at 17,000 feet over the Rockies when the strike occurred. There was an explosion, and flames appeared near the No. 2 engine. The engine was shut down but the fire, fed by a leaking fuel line, was extinguished only by diving the aircraft at maximum allowable speed. Although the left flap was nearly destroyed by fire, a successful no-flap, three-engine landing was made on a 5,400-foot runway at an elevation of 4,800 feet.

While reports of aircraft damaged by electrical discharges are increasing, it is certain that many more aircraft are damaged than reported, since most occurrences are reportable under paragraph 4d(8) AFR 127–4 as "events considered to be worth reporting as an aid in preventing aircraft accidents." (OHR's are now required on all lightning strikes and electrostatic discharges by par. 29c, AFR 60–16B.) During 1964 there were 45 AFR 127–4 reports, and through May of this year there were 36. Apparently there is no "season" for electrical discharge, consequently it appears 1965 will record an impressive number.

The most common USAF aircraft electrical discharge event consists of the discharge or strike occurring at the nose radome and exiting the aircraft at a wingtip. The top of the rudder and protruding antennae are also frequently struck. C–130's lead the number of incidents with the C–124 running second. As would be expected, most discharges occur in the lower levels (near the 0° C. isotherm), over half occurring at 10,000 feet or lower, with the median at 8,500 feet. The highest altitude reported was 34,000 feet.

STATIC DISCHARGE OR STRIKE?

Frequently it is difficult to say whether an electrostatic discharge or natural lightning strike occurred. Apparently it makes little difference as far as the

effects on an aircraft are concerned, although there is a theory that aircraft-generated discharges cannot produce the energy required to cause damage. Approximately half of the pilots submitting reports state they were in thunderstorm areas. Some reported stratus clouds with no precipitation, however, most indicated precipitation was occurring. Occasionally, discharges occur in the clear, after the aircraft has left a cloud deck.

Lightning phenomena as a hazard to aircraft are continually under study by both governmental agencies and private industry. Early this year a C–130 nose radome was struck while the aircraft was descending for landing. There was an explosion, followed by a fire in a pylon tank. Fortunately, the fire extinguished itself on final approach just prior to touchdown. AFSC is conducting extensive research as a result of this incident. Recently the CAB determined that the probable cause of a commercial jet accident over Maryland in 1963 was a lightning induced explosion in a fuel tank. These incidents serve to remind us of the possible disastrous hazards associated with lightning. Incidentally, it has been estimated that the airlines over the United States experience up to 500 electrical discharges per month.

### GREATEST HAZARD

Fuel tank vents have long been suspect as a path for lightning (or lightning caused flame) to the potentially explosive fuel-air mixture in the fuel tanks. The Lightning and Transients Research Institute (LTRI) considers this to be the greatest explosion danger and recommends that fuel tank vents be located in areas least subject to lightning effects. As noted earlier, most lightning strikes occur near 0° C. where gasoline forms too rich a vapor-air mixture to explode and kerosene too lean a mixture. JP–4 vapor on the other hand, forms a more explosive mixture. Consequently, since a more or less precise combination of factors must exist, JP–4 is significantly more vulnerable to explosion than either gasoline or kerosene. Research in this area is continuing.

Lightning phenomena, while under extensive study, are quite controversial among pilots. LTRI says "Little can be done in the immediate vicinity of an aircraft to control whether it is struck by lightning, since the aircraft, which is relatively small, can have little effect in determining the overall stroke path which may extend for several miles." Yet, many experienced pilots say the aircraft is a specific factor in helping set off electrical discharges.

LTRI says that all discharges which cause damage to an aircraft are lightning strikes which terminate at the ground or in another cloud. LTRI also says that static discharges are not capable of damaging even thin aluminum. Many pilots feel differently. Some airline pilots of over 20 years experience state they have never experienced a natural lightning strike. LTRI is producing valuable knowledge about the effects of lightning on aircraft, using both artificial lightning strokes in laboratory conditions and the study of natural lightning. Their research vessel *Thunderbolt* operates out of Miami, Fla.

While we have chalked up most of our electrical discharge experience as no more than incidents, it is apparent that potentially hazardous conditions exist. Furthermore, in view of past USAF experiences, it is apparent some incidents were actually sobering events which bordered on catastrophe. Consider the B–57 making an instrument penetration in a thunderstorm with the field reporting near minimums. A lightning strike punched off one tiptank shortly before touchdown. That one could have been a disaster except for professional crew performance. A flight of four F–4C's were passing between thunderstorm cells. Cloud-to-cloud lightning was observed passing through the formation. Two of the aircraft flamed out, although both made immediate restarts. The lightning strike was suspected of causing a temporary interruption of engine airflow. This incident occurred at FL 304.

To one F–105 outfit in Germany it must seem for sure that lightning can strike twice in the same place. This unit experienced five strikes in 2 consecutive days in April this year.

As a caution, do not let lightning or static discharge lead you to a false conclusion. Case in point: The left engine of a transport failed and was feathered. A few minutes later it appeared that lightning hit the aircraft and soon the right engine quit. The crew bailed out. Accident investigators found that the inboard fuel tanks were empty and that the selectors were set on these tanks (outboard tanks were full).

Although Pilot Factor was the primary cause, two of the contributing causes are of interest in this discussion: (1) Weather, in that it assisted in leading the aircraft commander to false conclusions as to the causes of engine failure; (2) Mental fixation, in that the pilot, copilot, and flight mechanic temporarily acquired one particular line of thought to the exclusion of others.

We have discussed lightning at length but we haven't said what the pilot can do to avoid it or prevent major damage. Obviously there isn't much we can do. Avoiding thunderstorms is something we all try to do, but it is difficult to avoid areas of thunderstorms. We have little control in avoiding the 0° C. area where most discharges occur. It might be wise to remember that discharges frequently occur in continuous precipitation, not necessarily in thunderstorm areas. A most probable time of occurrence is during climbout or penetration when the pilot is most occupied with flying the aircraft.

We can look for reduction of the fuel-vent explosion problem in the current research being conducted. Use of flame-arrestor screens and lightning diverter rods are being investigated as are fuel vent locations. Since wingtips are frequently struck, bonding, shielding and location of external tanks are being studied.

In the meantime, our best bet is to avoid, when possible, thunderstorms, the 0° C. level when precipitation is present, and icing areas, particularly those producing rime. Continue to report electrical discharges and lightning strikes and the atmospheric conditions existing at the time, for these reports are invaluable to scientists trying to create the protection necessary to keep lightning a nuisance rather than a hazard.

Dr. VONNEGUT. I think that there can be little question that lightning is a danger to aircraft. It is not nearly as big a danger, in my opinion, as high winds, hail, and turbulence. There are aircraft every year that are damaged, in some cases rather seriously, as a result of lightning streaks. Fortunately, only one out of one thousand lightning streaks that hits an airplane is energetic enough to really do damage, but there are a number of cases of airplanes being severely damaged. In some cases, the military airplanes, they abandon the airplane and bail out as a result of the damage by lightning.

Senator DOMINICK. As you probably know, for many years fliers felt that lightning was not really a danger as far as aircraft were concerned. This theory has been changed recently.

Have you done any analysis to determine whether the speed of modern aircraft has anything to do with this?

Dr. VONNEGUT. I think that the speed of the airplane is undoubtedly a factor. I don't think that we know enough about the problem to know whether it makes it more serious or whether it may be that the speed is a factor in the favor of the airplane.

In some cases you can see how an airplane that was going fast enough could fly away from the lightning sparks so that a spark would not follow it along. But I don't think we know enough about that. We do know that the slower flying airplane can certainly be seriously damaged.

There was a very interesting incident that took place this fall in which an airplane, taking off from Salt Lake City Airport, was struck just as he rotated, just as he left the runway. The lightning went in the vertical stabilizer and the top of that disappeared. The lightning went in from the tricycle landing gear to the runway and made three craters about 10 feet in diameter, 5 or 6 feet I guess in diameter and about 10 inches deep. Fortunately this accident did not injure anyone. The pilot kept his gear down and just made a turn and came in and landed again. But there is no question that lightning is a problem, not a serious one.

Senator DOMINICK. What kind of an aircraft was it?

Dr. VONNEGUT. Convair.

Senator DOMINICK. I asked you those questions because of personal interest. I have been flying for 30 years and I don't know how many times I have been hit and it hasn't done any damage yet, but maybe I have just been lucky.

You mentioned earlier that we needed more publications in the field of weather modification to determine whether the experiments and results were properly scientifically oriented.

We had some evidence just yesterday that the commercial operators and the universities have been publishing at the rate of about 10 to 1 on the results of their experiments as opposed to the basic scientists who have been involved in this. Do you have any comment on that?

Dr. VONNEGUT. I have not looked into this in terms of the publications, the ratio from various groups. I think that there has been an unfortunate tendency on the part of both university and private seeders to do their publications in the forms of reports. Now reports are useful but they are nowhere nearly as useful in science as publications in the scientific journals. I think that there has been, on the whole, a lack of good scientific publication concerning cloud seeding operations. I am sorry that I can't give you a breakdown as to the various groups.

Senator DOMINICK. Do you feel that the reports which have been made by commercial operators on their weather seeding operations have been helpful or not?

Dr. VONNEGUT. I think that any information is helpful, so that to the extent that it is published, it does add something to our information.

I am unhappy with the fact that, as I said, that many of the operations which are carried out are inadequately described. In other words, there is great attention given to the results, particularly in the cases of a successful operation, but these papers are very frequently deficient in that they do not tell what it was that gave the results. In other words they may say, we seeded with a certain type of generator or with a certain seeding equipment, but they do not say when, where, how much seeding was done. So the reports would be analogous to a medical report which would say, I gave the patient penicillin and he got well, but they did not tell you what the dose was, or when, where, and how much penicillin was given.

This is, I think, a serious shortcoming of many of the reports and publications on cloud seeding.

Senator DOMINICK. Doctor, you have been involved in this field for quite a long time now. How many commercial operators, would you say, are technically capable in the field?

Dr. VONNEGUT. I am afraid that I would have to duck that question. I do not know what you mean by technically capable. If by technically capable you mean that this man, the operator, understands how the atmosphere works and what the consequences are going to be of various actions that he takes on the clouds, I would say none.

Senator DOMINICK. Let me put it another way then.

Suppose either the Government or a private industry wanted to conduct a weather seeding program. How many commercial operators do you believe would be technically capable of carrying that out?

Dr. VONNEGUT. I am afraid that I do not have an adequate picture of the various groups that are presently active in this field or what their capabilities are. I am afraid I couldn't answer that.

Senator DOMINICK. Do you feel that experiments in seeding should be stopped?

Dr. VONNEGUTT. No; I do not feel that they should be stopped. I think that the experiments——

Senator DOMINICK. Do you feel that commercial contracts for seeding should be stopped?

Dr. VONNEGUT. No, sir; I do not.

Senator DOMINICK. Do you feel that the Government should say that if there is a research program going on under Government auspices that no one else should be permitted to contract for weather seeding operations in those areas?

Dr. VONNEGUT. I think that it is clear that there can be serious interference if two seeding operations are going on simultaneously, that it will be very difficult to disentangle the results. I think that in the case of certain large-scale seeding operations, that it might be desirable for the Government to set things up so that they can carry it out without interference.

The point I do raise, however, is that it is my feeling that experiments of this sort are of questionable scientific value. They are very important certainly as far as society is concerned. In other words, to determine how much you can increase cloud seeding. But the end product of these experiments is not usable scientific knowledge.

Senator DOMINICK. Doctor, it is possible, is it not, to conduct the scientific research that you are talking about at the same time that you conduct weather seeding operations?

Dr. VONNEGUT. At the same time, perhaps not in the same place.

Senator DOMINICK. But it doesn't mean that simply because we need to continue the scientific experiments that we should cut off weather modification programs under contract?

Dr. VONNEGUT. No.

Senator DOMINICK. Have you through Arthur D. Little, Inc. conducted any operating experiments yourself?

Dr. VONNEGUT. Yes, we have conducted a number of experiments in which we have been in the field and have passively observed clouds and at the same time we have also conducted experiments in which we have released electric charge into the atmosphere and attempted to see how the atmosphere moves and where the electric charge goes and on occasions we have followed this charge up in the clouds.

Senator DOMINICK. Do you attempt to protect yourselves from suit or other liability while you are doing these experiments?

Dr. VONNEGUT. I am not aware of what legal precautions we have taken in this field. The experiments that we have conducted are of a sort that one would not reasonably expect we would have large effects, so that we have not been too concerned with this end of things.

Senator DOMINICK. You don't know then whether you have tried to get liability insurance?

Dr. VONNEGUT. I think that our legal people have looked into this and it is a difficult problem. In the case of some experiments it would certainly be a vital and important problem.

Senator DOMINICK. In your prepared statement, after referring to the conduct of seeding operations as perfunctory or haphazard, you say that experiments of this sort are not good science for they contribute little or nothing to the general store of scientific knowledge.

I want to be absolutely positive you are not saying that these programs should be eliminated. You are simply saying that from a scientific point of view, you are not sure how valuable they are.

Dr. VONNEGUT. That is right. I think that one of the big dangers in the field of weather modification is that it should be generally assumed that experiments of cloud seeding that we will say are well designed statistically, experiments that are carefully analyzed, I think the public may be misled into thinking that because these experiments have certain trappings of science and because they are conducted by scientists, that this is scientific research.

I think that if this is to be the case, in other words, if these operations are to be carried out, and they are desirable from many points of view, but I think I would be disappointed if the public were to think that these are scientific experiments. I feel sure that after 10 years of these experiments, if they are the only things that are done, why we are still going to be floundering around not knowing what we are doing. I don't think that these experiments are going to further the building blocks for our foundation and I think that much of the structure of weather control is resting on a very insecure foundation.

Senator DOMINICK. Would you agree with the National Academy's conclusion that at least in certain types of clouds precipitation can be increased by 10 to 15 percent?

Dr. VONNEGUT. I see no reason to doubt this. I would be very much surprised if cloud seeding did not produce significant effects in clouds.

Senator DOMINICK. What do you think are the primary areas that should be involved in further scientific research?

Dr. VONNEGUT. Well, I think that there are several very important areas. I think that one of the big barriers to understanding the action of cloud seeding and many other things that are going on in clouds, is our lack of knowledge of how the air moves in clouds and in storm systems. This, I think, you will agree is a very fundamental property. It is of importance in atmospheric electricity because the movement of the air will determine, to a large extent, where the charges will be going, and I don't think we can understand the problem that I am interested in, of atmospheric electricity, until we know how the air is moving, where the updrafts are, where the downdrafts are, and how they change with time.

These updrafts and downdrafts in circulation are vitally important to cloud seeding. They will determine where the seeding agent goes in the cloud and there obviously must be a number of different ways to seed: Under the cloud, above the cloud, on the sides of the cloud. And I don't think that we are going to be able to form an understanding of cloud seeding until we know more about where the updrafts go.

Another vitally important area that we do not understand is how rain is formed in a cloud. We know that some rain is caused by the melting of ice crystals, and in fact much of our cloud seeding is designed to this end, to make ice crystals which will then melt and form rain.

On the other hand, we are in very bad shape in understanding the so-called warm rain formation process. Clouds are made of little

drops about a thousandth of an inch in diameter and in order to form a raindrop, we must bring together on the order of 1 million to 10 million of these little droplets.

Now one way of doing this is through ice crystals. Another way is just through what we call a coalescence progress. And when we try to put in numbers to see how fast this should happen in a cloud, we come out with answers that it should take an hour to make a raindrop. We see that nature can do this in a much shorter time than this and I think if we are going to control the weather, we must know the various different things that can happen and we have an extremely important understanding of how nature makes rain by the coalescence processes.

I think that in some cases we undoubtedly run the danger in weather modification of interfering, possibly interfering, with much more efficient process that go on naturally because if you change the cloud into ice crystals, then you are stuck with a precipitation mechanism involving snow, which falls at about 2 miles an hour.

Now by rain, if you can make a raindrop, by coalescence process, that will go about five times that fast, and we are babes in the woods when it comes to understanding the natural processes. And if we do not understand these in considerable detail, I think we are going to have some unpleasant surprises in our attempts to modify weather.

Senator DOMINICK. Doctor, I have been told at one point there are at least two different scientific theories as to how weather is formed. Some time back in the early 1900's or late 19th century, the development of weather was considered by a group of scientists who came up with two different theories of how weather was formed. And that one theory is now the major one that is being used.

Do you have any knowledge of this type of discussion among scientific personnel on weather?

Dr. VONNEGUT. This is somewhat out of my field. I have been concerned with the general movement of the weather, with what is known as optic meteorology. I have been concerned with the smaller scale effects that go on in individual clouds or in individual thunderstorms. I am afraid that I could not give you a good answer to this.

My training is not in meteorology but in the field of physical chemistry. I have had very little to do with the broader aspects of the origin of storm systems.

Senator DOMINICK. Thank you, Doctor, very much. You have been very helpful and we appreciate your willingness to come down and give us the benefit of your knowledge.

Dr. VONNEGUT. Thank you.

Senator DOMINICK. Our next witness is Dr. Braham, professor of meteorology, University of Chicago.

## STATEMENT OF DR. ROSCOE R. BRAHAM, JR., PROFESSOR OF METEOROLOGY, THE UNIVERSITY OF CHICAGO

Dr. BRAHAM. Mr. Chairman, I have a prepared statement and with your consent, I would like for that statement to be placed into the record as I would prefer to pass over some parts of that statement in the interest of brevity in this oral presentation.

Senator DOMINICK. You go ahead, Doctor, whatever way you prefer. Your statement will be put in as though read in full.

My name is Roscoe R. Braham, Jr., I am a professor of meteorology at the University of Chicago and director of the University of Chicago Cloud Physics Laboratory.

Since 1946 my work has been the study of clouds, primarily in field experiments including cloud modification, as a scientist in Government and at several universities.

As a cloud physicist I wish to express our appreciation for the recognition given atmospheric science and for the concern of the Congress as evident in Senate bills S. 2916 and S. 23.

There is general agreement that the prospect of usefully and deliberately modifying weather and climate is one of the most far-reaching developments of postwar science. It is important that we pursue this subject with all possible wisdom and vigor, but we must also temper our enthusiasm with the realization that we have taken only the first feeble steps in this direction and that there is a lot of development, undoubtedly with many failures, separating us from an operational technology of weather modification. As I see it the question to which we address ourselves at this point is that of how can we best organize our quest for this goal.

It is essential to recognize that the challenge of weather and climate modification is part and parcel of the whole spectrum of opportunities presented by the atmospheric sciences. Weather and climate modification lose reality unless viewed against a broad background of atmospheric sciences. Moreover, in my view, our modest initial efforts in this area will expand only so fast as we are able to enlarge our general knowledge and understanding of the atmosphere, and the clouds and weather events therein.

The bills under consideration relate primarily to weather modification for changes of precipitation. Now in this area we recognize three factors or forces which urge an expanded effort and at the same time dictate a realistic approach.

These factors are (1) recognition that years of patient effort in basic science have already gone into the development of our mathematical-physical models of clouds and their response to artificial stimulants, and that years, perhaps decades, of basic study separates us from the full realization of our goals in weather and climate modification research.

The second of these factors is an ever expanding background of operational seeding projects, both commercial and research oriented. These continue to bring in additional endeavors.

And the third factor is the ever growing public pressures for larger, better, and more dependable supplies of water.

In my view, modern meteorology is sensitive to all three of these factors. Our diversity is largely a matter of the relative weight we give to each of them. In connection with the present proposed legislation we may also have semantic difficulties as to what is meant by basic and applied research.

It seems to me that the distinction between basic and applied research has always been a fuzzy one. In cloud physics and weather modification the problem is accentuated because of the great variabil-

ity and irreproducibility of natural cloud conditions. As a result extensive, almost routine, testing becomes an essential part of the development of basic knowledge. There are only a limited number of key physical processes operating in clouds, but several of these are competitive; the sort of weather which we experience depends upon which of the several processes gets the upper hand in a particular situation.

If I may add parenthetically, because of this interaction of processes, a single seeding technique may produce favorable results in one situation, and fail or even produce unwanted results in another situation.

Thus far there are two precipitation processes which have been identified. These also are competitive and interact in important and interesting ways. Because of the inherent variability and irreproducibility of clouds and because of the interaction and feedback loops that exist between various physical processes going on inside of clouds, field experiments and experimental testing are primarily tools of the basic research scientists in atmospheric physics.

The concept of a laboratory experiment just does not apply in the area of climate and weather modification. The capability for experiment and test verification of basic hypothesis must not be separated from the responsibility for basic research.

Much of our present knowledge of the details of precipitation has come from applied-type research testing of cloud seeding hypotheses.

Although some of the basic ideas involved in cloud research and weather modification date prior to World War II, the present state of understanding of clouds and their response to seeding has come principally in the last 15 years. A significant fraction of this advance has come from private and university groups within the last 10 years. Yes, we learned that 90 percent of all scientific literature in this field comes from these two groups.

Much of this work has been under the sponsorship of the National Science Foundation. It is my view that the NSF has done a creditable job nurturing this stepchild that no one wanted in 1958, into the viable weather modification program we have today.

I think that it is essential that the basic research responsibility of the National Science Foundation in weather modification research, thought of broadly, including the economic, social, biological, and legal aspects, be continued and expanded. However, we must also recognize that other Government agencies have, and many private and university groups have, contributions to make in weather and climate modification.

It is usually agreed that the mission oriented agencies of Government must retain the capacity for basic research wherever such is necessary for the accomplishment of their operational mission. So, also, in my view, is it important to recognize the principle that basic research groups, wherever they are located, must have available the resources and facilities for testing their hypotheses. To some individuals this activity in weather modification would be called applied research; I view it as an integral part of basic research.

I strongly endorse the principle that there are several executive departments which have unique capability to contribute to weather and climate modification research by virtue of their operational missions. These should be encouraged.

The fact that some Department of Commerce groups have great competence in many aspects of atmospheric science speaks to the value of their participation in these programs. For example, ESSA has unique capabilities to contribute to severe storm modification and world climate modification research, both of which are directly related to their mission. Similarly the Department of Interior's responsibility for national water resources gives them a clear motivation for working in precipitation modification.

I do not believe that it is in the best interests of this country, at this time, to arbitrarily restrict weather modification experimentation to any single agency.

There is such great variety and detail of research work remaining to be done in this field that it behooves us to encourage the development of such talents whenever and wherever the opportunity presents itself.

(Full text of statement follows:)

WEATHER AND CLIMATE MODIFICATION BY ROSCOE R. BRAHAM, JR., PROFESSOR OF METEOROLOGY, THE UNIVERSITY OF CHICAGO

Mr. Chairman and members of the committee, my name is Roscoe R. Braham, Jr., I am a professor of meteorology at the University of Chicago and director of the University of Chicago Cloud Physics Laboratory. It is a privilege for me to appear before you for the purpose of speaking to the point of an expanding program in climate and weather modification. What by way of background and experience can I bring to bear on this problem? Since early 1946 my work has been the study of clouds, including cloud modification, as a scientist in Government and at the University of Arizona, the New Mexico Institute of Mining & Technology, and the University of Chicago. Over the years this work has been supported by many different Government agencies (Weather Bureau, Air Force, Atomic Energy Commission, Public Health Service, National Science Foundation) private foundations and private university funds. At present I serve, or I have recently served, as a consultant on weather modification research for the U.S. Army, the Bureau of Reclamation, and the U.S. Weather Bureau.

INTRODUCTION

As a cloud physicist I wish to express our appreciation for the recognition given atmospheric science and for the concern of the Congress as evident in Senate bills S. 2916 and S. 23. It is particularly appropriate that the issues involved in expanding our effort on weather modification come up for study prior to, and independent of, appropriation legislation. This subject involves a complexity of issues, and as a consequence a diversity of opinion, all of which deserve careful consideration.

There is general agreement that the prospect of usefully and deliberately modifying weather and climate is one of the most far-reaching developments of postwar science. It is important that we pursue this subject with all possible wisdom and vigor, but we must also temper our enthusiasm with the realization that we have taken only the first feeble steps in this direction and that there is a lot of development, undoubtedly with many failures, separating us from an operational technology of weather modification. As I see it the question to which we address ourselves at this point is that of how can we best organize our quest for this goal.

ATMOSPHERIC SCIENCE—HEART AND SOUL OF WEATHER MODIFICATION

It is essential to recognize that the challenge of weather and climate modification is part and parcel of the whole spectrum of opportunities presented by the atmospheric sciences. Weather and climate modification lose reality unless viewed against a broad background of atmospheric science. Moreover, in my view, our modest initial efforts in this area will expand only so fast as we are able to enlarge our general knowledge and understanding of the atmosphere, and the clouds and weather events therein. In addition, it is important to

develop apace the full range of alternatives (social, economic, biological) involved in a complete and effective use of our atmospheric resources. It is reasonable to think that we can achieve most of these goals, albeit they are not within our grasp at present.

In the area of weather modification for changes in precipitation we recognize three factors which urge an expanded effort, and at the same time dictate a realistic approach. These are (1) recognition that years of patient effort in basic science have already gone into the development of our mathematical-physical models of clouds and their response to artificial stimulants, and that years, perhaps decades, of basic study separates us from the full realization of our goals in weather and climate modification research, (2) an ever-expanding background of operational seeding projects. Both commercial and research oriented, and (3) the ever-growing public pressures for larger, better, and more dependable supplies of water.

In my view, modern meteorology is sensitive to all three of these factors. Our diversity is largely a matter of the relative weight we give to each of them. In connection with the present proposed legislation we may also have semantic difficulties as to what is meant by basic and applied research.

### BASIC VERSUS APPLIED RESEARCH IN WEATHER MODIFICATION

The distinction between basic and applied research has always been a fuzzy one. In cloud physics and weather modification the problem is accentuated because of the greater variability and irreproducibility of natural cloud conditions. As a result, extensive, almost routine, testing becomes an essential part of the development of basic understanding. There are only a limited number of key physical processes operating in clouds, but several of these are competitive; the sort of weather which we experience depends upon which of the several processes gets the upper hand in a particular situation. Thus far, two precipitation processes have been identified. These also are competitive and interact in interesting and important ways. Because of the inherent variability and irreproducibility of clouds and because of the interaction and feedback loops that exist between various physical processes going on inside of them, field experiments and experimental testing are primary tools of the basic research scientist in atmospheric physics. The concept of a laboratory experiment which can be prescribed and repeated for as many times as desired just does not apply to the area of climate and weather modification. The capability for experiment and test verification of basic hypotheses must not be separated from the responsibility for basic research. Much of our present knowledge of the details of precipitation development has come from applied-type research testing of cloud seeding hypotheses.

Although some of the basic ideas behind cloud research and weather modification date prior to World War II, even into the previous century, the present state of understanding of clouds and their response to seeding has come principally in the last 15 years. A significant fraction of this advance has come from private and university laboratories within the last 10 years. Much of this work has been under the sponsorship of the National Science Foundation. It is my view that NSF has done a creditable job nurturing this stepchild that no one wanted in 1958, into the viable weather modification program we have today.

I think that it is essential that the basic research responsibility of the National Science Foundation in weather modification research, including economic, social, biological, and legal aspects, be continued and expanded. However, we must also recognize that other Government agencies have a contribution to make in weather and climate modification research.

It is usually agreed that the mission oriented agencies of Government must retain the capacity for basic research wherever such is necessary for the accomplishment of their operational mission. So, also, in my view, it is important to recognize the principle that basic research groups, wherever they are located, must have available the resources and facilities for testing their hypotheses. To some individuals this activity in weather modification would be called applied research; I view it as an integral part of basic research.

I strongly endorse the principle that there are several executive departments which have unique capability to contribute to weather the climate modification research by virtue of their operational missions. These should be encouraged to develop these unique abilities.

The fact that some Department of Commerce groups have great competence in many aspects of atmospheric science speaks to the value of their participation in these programs, e.g., Environmental Science Service Administration and the Weather Bureau have unique abilities to contribute to severe storm modification and world climate modification research, both of which are directly related to their mission. Similarly the Department of Interior's responsibility for national water resources gives them a clear motivation for working in precipitation modification. However, I do not believe that it is in the best interests of this country, at this time, to arbitrarily restrict weather modification experimentation to any single agency.

There is such great variety and detail of research work remaining to be done in this field that it behooves us to encourage the development of such talents whenever and wherever the opportunity presents itself.

Thank you, Mr. Chairman. I will be glad to answer your questions.

Senator DOMINICK. Thank you.

Dr. Braham, you are professor of meteorology and you have served as a consultant on weather modification research for the Army, the Bureau of Reclamation, and the Weather Bureau. What particular type of activities were involved?

Dr. BRAHAM. I served on the advisory panel to project Stormfury in the U.S. Weather Bureau. I have consulted with the Bureau of Reclamation, Denver office, with regard to their present program, which they have had going the last couple of years.

For the U.S. Army, the work centers out of Crell, N.H., and pertains primarily to white-out modification. White-out is a low visibility condition encountered in the Arctic regions.

Senator DOMINICK. You have had pretty broad experience then in proposed weather modification, not only in trying to do something about massive storm situations under "Stormfury," but also increased precipitation for the Bureau of Reclamation, and dissipation of low visibility conditions; is this correct?

Dr. BRAHAM. I have been involved in all three of those. I hope I contributed usefully to them.

Senator DOMINICK. I am just trying to highlight your qualifications here as much as I can and I know that they are very, very good.

You say in your statement:

It is my view that NSF has done a creditable job nurturing this stepchild that no one wanted in 1958, into the viable weather modification program we have today.

When you refer to weather modification in that context, what weather modification are you talking about?

Dr. BRAHAM. Well, sir, in the midfifties we had active groups involved in basic experimentation, in changing weather events. This work is going on in the Weather Bureau, in the Air Force, in the Navy, and perhaps other agencies. All of these were terminated in the latter part of the 1950's when it became rather obvious that we were not to receive the spectacular effects that we had hoped for initially and when it was realized that basic research stood between us and the realization of our goals.

Senator DOMINICK. Doctor, in 1957, the Weather Advisory Commission, which had been appointed by the President, reported that we were able to increase precipitation by 10 to 15 percent. It is my recollection that at that time the meteorologists said that this had

no scientific basis and that no further work on a scientific basis should be continued. Is that accurate or is that an exaggeration?

Dr. BRAHAM. If I correctly recall, the report stated that the evidence indicated that in certain types of weather situations, namely, orographic winter storms, the evidence indicated we might be able to obtain precipitation increases of the order of 15 percent, but that studies of seeding operations in other regions, and particularly the flatland weather situation, indicated very little evidence that we had been able to achieve modification successes.

Senator DOMINICK. Am I correct in saying that at that point a number of people suggested that these experiments should not be continued because they might have an adverse effect on weather and therefore should be cut off?

Dr. BRAHAM. Yes, substantially so. The position in the scientific community at that time was that the evidence, on which these conclusions had been based, was rather unsatisfactory. And although the conclusions might be correct, it was very necessary in order to back up the evidence and put it on a firm scientific basis.

Senator DOMINICK. Now 9 years later we are back to the same position, aren't we?

Dr. BRAHAM. Well, not quite, sir. A good deal of work has been done in the past decade. We know considerably more about the basic physics of clouds than we did then.

Much of the major emphasis we have coming in the last two or three, say in the last year, in fact has dealt not with orographic or winter cloud. The main thrust of the National Academy really had to do, it seems to me, at least, had to do with the nonorographic situation, and it was largely because of this ever-increasing amount of evidence, both from commercial and from university and research-oriented projects, that those conclusions were possible.

Senator DOMINICK. My recollection of the report is that it said we are able to increase precipitation by 10 or 15 percent in certain types of clouds, which is exactly what was said in 1957, almost word for word. Isn't that true?

Dr. BRAHAM. I don't have that command of the report. Certainly that statement by itself could hold in either of the situations. However, if I recall the Advisory Committee report, the emphasis certainly was on the winter orographic cloud condition.

Senator DOMINICK. Doctor, the point I am making here is that between 1957 and apparently up to this year, there has been a group, at least in the scientific community—and I have no idea where you stand on this—which has been opposed to commercial seeding operations and as a result, a good deal of this has gone down the road to destruction as far as economics are concerned.

Now we are right back where we were before, where apparently the commercial operators have provided a fair amount of evidence that their operations can be successful under certain conditions. Is that accurate?

Dr. BRAHAM. I would say the evidence that their operations have provided useful results is continually increasing. I think there are many members of the scientific community that would say even today, the evidence is not satisfactory. And as our previous speaker testi-

fied, and I would agree with him at this point, that regardless of the amount of that evidence, it is of a rather unsatisfactory kind, that a truly useful weather modification technology will come only when we know why the results are as they seem to be.

Senator DOMINICK. Do you feel that commercial operations should be sharply curtailed or regulated or restricted?

Dr. BRAHAM. As a matter of principle I think that the commercial operations should be continued. We have certainly gained considerably from them. The only place where I might question whether they be carried out is when such an operation impinges directly upon a bona fide Government-sponsored research project which a panel of impartial experts might feel in the long run would contribute more.

Senator DOMINICK. Doctor, let me put the same question to you that I put to some other people in the previous hearings.

Let's take the State of Oklahoma. I take Oklahoma since a lot of work has been done there. The Government decides to conduct a research program there and they determine that they are going to seed in a certain area and to be able to do this properly they set aside control areas, so that they can determine the impact of their research. Those control areas happen to hit an area where farmers are suffering a drought or the city municipal water supply is having problems. Those areas want to have commercial seeding operations done for their own situation but they are prohibited from so doing by governmental programs that are going on.

Now what are the equities there?

Dr. BRAHAM. This, of course, is a tough question. In general, I would think that if this hypothetical Government research-sponsored project is a sound one, one that represents a considerable effort and one that has promise of yielding some of the knowledge that we really need as basic to the broad development of weather modification research, then I would think that the broad interest of the public should prevail. And that the individuals then should not be permitted the privilege of hiring the rainmaker in particular conditions.

Senator DOMINICK. Even though the municipality has run out of water?

Dr. BRAHAM. I think this is one of the questions that has to be weighed by the group that makes the decision as to whether that is the proper time and place for that particular experiment.

Senator DOMINICK. As you can see, this is a difficult problem to wrestle with, because if we take the advice of certain people who have testified, we will insert an absolute prohibition in the legislation banning outside seeding operations in any of the areas which might affect a Government research program.

The question then is, is our knowledge far enough advanced so that we are able to tell whether the areas that are under a research program are in such trouble that they actually need commercial operations for additional precipitation or suppression of hail?

Dr. BRAHAM. Perhaps I can speak to this from a slightly oblique point of view with reference to an operational seeding project which we have only recently concluded, a project operated at the University of Chicago, and this project was based in southern Missouri. At the time the project was located in southern Missouri. We felt that our

major problem, scientific problem, was to determine the conditions under which the modest increases in precipitation might occur. It didn't occur to us that there might be situations in which we would have an unfavorable result.

Yet, as a consequence of that long series of studies, we now come to realize that indeed there may be periods in the weather, certain weather situations in southern Missouri, in which our seeding, using standard seeding techniques, resulted in decreases in the precipitation in that region.

Now it is perhaps only an accident that you have chosen Oklahoma for your example rather than Nebraska, because it so happens that in the weather conditions which in Missouri appeared to be favorable for these decreases; in fact, they are more common in Oklahoma than they are in Missouri. And I think it illustrates the necessity for simultaneously providing for a research capability that will ferret out the scientific bases on the operation of clouds and the degree to which we can modify them, while at the same time being as equitable as one can to the needs of individuals.

Certainly for the municipality that is running out of water, this is a first-rate public problem that has to be recognized, too.

Senator DOMINICK. I have been a member of the Interior Committee on the House side, and the Senate side, since I have been in Congress. I was instrumental in getting further authorization and appropriations for weather research for what I had hoped would be applied research for producing more precipitation.

As you probably know, there is a considerable problem now in the Colorado River Basin among all of the States served by the Colorado River as to who is going to get what share of the water.

Dr. BRAHAM. That isn't just a "now" problem, is it?

Senator DOMINICK. I said we have had a long-time problem with California and California says they have had a long-time problem with Colorado. We now have a proposal that there be a study on the importation of water from the Northwest in order to supply additional water. It seems to me that it would be of vast value to the people of this country if we could solve this problem and perhaps we could solve it by inducing more precipitation in the Colorado River Basin instead of importing water from the Northwest. And with one noticeable exception that you referred to in the very small project that is being conducted by the Bollays in Boulder, we are not having any applied research in that area under governmental funding.

Now this is a real problem, not only to Colorado, but to all of the States and the people who live in those areas. And it occurs to me that we have a situation where if a Government research program was to be done in one small area with control areas on the outside, the opportunity of the States to use weather programs, or private industries to hire commercial operators for weather programs might be substantially curtailed to the detriment of the whole area. I wonder how you put these things together?

Dr. BRAHAM. Certainly curtailed. Now whether it is to the detriment of the whole area, of course, is the fundamental question that has to be resolved and presumably that has already been resolved if the Government undertakes an operation in that area, which requires the curtailment of seeding in other areas.

Senator DOMINICK. Well, perhaps I don't follow your reasoning on that. The people of California might have a totally different idea than does the particular program operator who is conducting one in a small section of the Colorado mountains.

Dr. BRAHAM. We are searching for a mechanism by which we can make an equitable decision and I think that the suggestion of one of the earlier speakers at this hearing is useful at this point. It was suggested that there be instituted a Board similar to the CAB, a Board that has the power of regulation and licensing, before which hearings of all parties interested in this problem might be heard.

Senator DOMINICK. This is exactly what I hoped you would say. I gather you think that this Board is a worthwhile idea.

Dr. BRAHAM. I think that it is obvious that ultimately such a board will be required. Now there may be a question as to whether there is need today for such a board, but ultimately as weather modification becomes more and more highly developed, such a board will have to be formed.

Senator DOMINICK. Do I understand that you think this Board should be separate and apart from any of the existing departments or agencies of government?

Dr. BRAHAM. I think it should be separate and apart from any agency that has an interest in the problem. Now there indeed may be appropriate agencies that have no applied mission in weather modification to which this Board could be attached.

Senator DOMINICK. Do you feel that the National Science Foundation might be such an agency, which would be capable of doing the regulation and have regional coordinating offices, such as the National Center for Atmospheric Research in Boulder?

Dr. BRAHAM. I think it would be rather unfortunate if the National Science Foundation was placed in this position. They have an operational program in basic research and weather modification.

Senator DOMINICK. If such a Board is established I would presume it would consist of representatives of the different operating agencies, is that accurate?

Dr. BRAHAM. I would assume so, but also representation from the private sectors of our economy. I think that it is necessary to recognize these.

Senator DOMINICK. Have you made any study or given any extended thought to the size of any such agency?

Dr. BRAHAM. No; I have not.

Senator DOMINICK. The present bill, as you know, contemplates that the Commerce Department would take over centralization of authority in this area. Do you have any comment on that?

Dr. BRAHAM. My comment would be that the Commerce Department has a great contribution to make in the area of weather modification by virtue of their competence in atmospheric sciences, particularly in ESSA and for this very reason the Commerce Department should be disqualified as an agency with whom to lodge this Board.

Senator DOMINICK. You don't want someone incompetent on this Board?

Dr. BRAHAM. We are not saying that the people on the Board should be incompetent. What we are saying is that the Board

should be autonomous insofar as not being attached to any of the agencies that have vested interests in the subject. I think it would be difficult enough to make the decisions of the types you raise, about the community in western Oklahoma, without handicapping this Board by placing them in an environment where their actions are always suspect, even though the individuals may indeed have the best interests of their job at heart.

Senator DOMINICK. All I can say is, I don't envy the job of anybody who is on that Board. I don't know how it is in the East, but I do know that in the West you start tampering with someone's water, and you are liable to get shot.

Dr. BRAHAM. Isn't it true that other boards do have difficulties such as allocating radio channels?

Senator DOMINICK. That doesn't involve someone's life.

In your statement, you refer to the viable weather modification program we have today. What are you taking into account in that phraseology? What do you refer to as the viable weather modification program that we have today?

Dr. BRAHAM. Weather modification will advance only as fast as our understanding of the basic atmospheric sciences will advance. This is the framework which I have to answer your inquiry.

Now the weather modification program we have today involves work sponsored by the Department of Interior, involves that of the Weather Bureau, Navy, that sponsored by the National Science Foundation, and private university sectors. It is a rather broad one. But certainly it is making progress in many areas. For that reason I feel it is viable.

Senator DOMINICK. There have been suggestions that we ought to sharply increase the amount of funding. What is your position on that?

Dr. BRAHAM. I think the scientific engineering community involved here certainly is in a position to usefully and intelligently handle an enlarged program.

Senator DOMINICK. We have also had some questions as to whether we have enough scientific personnel trained in fields which would apply directly to the weather modification questions, atmospheric questions, that we have still facing us. What is your view on that?

Dr. BRAHAM. This is one of the problems, and I would not favor abuse of great magnitude, lest indeed we would run into this very problem. But I do believe that the growth potential of this community, of science and engineering that is involved, and their present potential, their present capability is adequate for handling an enlarged program. Part of this program, indeed, should be the continued development of that community itself.

The universities have a role to play here in increasing our manpower in this area.

Senator DOMINICK. Would anything of value be obtained from research in basic science if the Government should fund and contract a major weather modification program for increased precipitation in the upper Colorado River Basin?

Dr. BRAHAM. If that operation is properly organized to carry it out, very definitely, it would. It would be basic science. There

would be basic science advantages. Perhaps I might read a short portion of a paragraph.

Senator DOMINICK. Just before you do, let me just ask a couple more questions.

You say basically oriented and carried out. Now, would part of this involve the participation of commercial operators in actually providing the technique for seeding?

Dr. BRAHAM. Well, I would assume so. I wouldn't think that it would have to, but it would seem to me that it is a logical way of proceeding.

Senator DOMINICK. How large an area do you think should be covered in order to make this realistic, both from terms of results and terms of scientific knowledge that might come from it?

Dr. BRAHAM. I think that is a matter that would have to be decided by considerable study. Right offhand I couldn't say. I am fairly sure that we do know enough about clouds to be able to predict that if you want the answer for the upper Colorado, the research will have to be carried out in Colorado. Similarly if you want the answer for Montana, it will have to be carried out in Montana, because of the great variability and the rates at which cloud processes proceed. I would be very hesitant, for example, to try and extend the results of our work in Missouri beyond a limited geographical region. So the actual size depends upon a number of things: the logistic capability, the terrain, and other things. It would require considerable study, but I am quite sure to put it in a framework that we are talking about an operation that comes in six figures, seven figures maybe, if this gives us a feel for what we mean by size.

Senator DOMINICK. In other words we have the conditions from the point of view of orographic conditions and cold weather which might be very fruitful in trying to conduct a fairly large scale program?

Dr. BRAHAM. I would say so, yes. It seems to me that there are basically two approaches one can take. One can follow on the oft-quoted criticism of the scientific community, that we learn all about everything before we proceed.

Now indeed, if we knew in great detail the physics of the clouds and their response to various things, one then might be able to predict the results that would come from seeding in a particular location.

The other alternative however is to carry out meaningful scientific programs in various areas——

Senator DOMINICK. To see if they work.

Dr. BRAHAM (continuing). To see if they work.

Senator DOMINICK. I am with you.

Dr. BRAHAM. By meaningful at this point I do mean that we have to organize them in such a way that we are able to tell whether they work.

Senator DOMINICK. I understand.

Dr. BRAHAM. And for this purpose we have to admit the possibility of a negative answer as well as a positive one, although in organizing the thing, I should think it would be rather foolish to organize a project which we were pretty sure was going to fail. We will organize those where we think the results are likely to be useful. But we have to be prepared to accept whatever the answer turns out to be.

Senator DOMINICK. Doctor, one of our witnesses yesterday referred to the fact that other governments were ahead of us in this field: France, Italy, Japan, Russia, and Brazil. Do you have knowledge of how they approach this problem of coordination of efforts, working with commercial operators and what they are particularly emphasizing?

Dr. BRAHAM. My specific and detailed knowledge is limited primarily to the Australian problem. I have served as a consultant to the Australian Government in their cloud seeding efforts. In Australia the weather research, weather modification research, is under a branch of the Government. It is operated, managed, handled entirely within that Government basis, no commercial operators involved.

Senator DOMINICK. What are they attempting to do? All the things we are trying to do?

Dr. BRAHAM. Generally speaking, yes, although the full scale of their operation is considerably below that of the United States. They have basic research going on, they have laboratory research, basic cloud studies; they were pioneers in studies to understand the basic physics of clouds. They have cloud seeding operations going on in orographic situations.

Senator DOMINICK. Do you feel they are ahead of our knowledge or do you think that they are ahead of our technique in organization of experiments?

Dr. BRAHAM. No, I don't think so. I think that there is complete communication between the Australian groups and our groups, and I think that they are certainly not ahead in knowledge.

In organization I think the Government of Australia recognized the fact that they have a country the size of ours and 10 million people in it, and that if anything was to be done by way of increasing the precipitation, it would be done by Government agencies.

Senator DOMINICK. In general then, as far as this legislation is concerned, you agree with some of the other witnesses that we should in the long run, at least, have a regulatory body and that the various departments which are now conducting research on operating techniques, should continue in their present framework with perhaps a gradual increase in the funding for these operations?

Dr. BRAHAM. That is the substance, yes.

Senator DOMINICK. Thank you very much, Doctor. You have been very helpful.

These hearings will be recessed now until they are taken up in the field in Denver on the 31st of March and the 1st of April.

(Whereupon, at 11:35 a.m., the committee adjourned, to reconvene in Denver, Colo., on March 31 and April 1, 1966.)

AMERICAN SOCIETY OF CIVIL ENGINEERS,
*New York, N.Y., March 14, 1966.*

Re S. 2916.

U.S. Senator WARREN G. MAGNUSON,
*Senate Office Building,*
*Washington, D.C.*

DEAR SENATOR MAGNUSON: The following information is presented in reply to your letter of February 28, suggesting that the American Society of Civil Engineers submit a statement with regard to your pending legislation S. 2916. We appreciate your reply and the opportunity to comment.

Research and practice in the field of weather modification are important to national water resources and control of damage, significant to air transportation,

and directly related to air pollution problems. As set forth in the recent reports of the National Academy of Sciences and the National Science Foundation, considerable experience has been gained in augmentation of water supply, control of lightning and fog, and some worthwhile steps have been taken in the field of damage from hail. The advice of the persons and organizations who have been active in this field should be utilized, in framing legislation and the future development of weather modification technology and practice.

There is obvious reason for separating such regulatory agencies as the Federal Power Commission and FAA from research and practice in these fields. Similarly, responsibility for regulation of weather modification activity should be separated from the agencies which conduct these activities.

With these points in mind, it is suggested that the following persons may bring worthwhile experience and understanding to your committee. We believe that each one would respond favorably to an invitation to your committee hearings in Denver, Colo.

Richard A. Schleusener, director, Institute of Atmospheric Sciences, School of Mines, Rapid City, S. Dak.

Wendell A. Mordy, director, Desert Research Institute, University of Nevada, Reno, Nev.

Eugene Bollay, E. Bollay Associates, Boulder, Colo.

Boynton Beckwith, meteorology department, United Air Lines, Chicago, Ill.

Donald M. Fuquay, U.S. Forest Fire Research Laboratory, Missoula, Mont.

William Parsons, meteorologist, Pacific Gas & Electric Co., San Francisco, Calif.

R. N. Coe, vice president, Southern California Edison Co., Los Angeles, Calif.

Several principles are important if maximum benefit is to be realized from legislation in the field of weather modification:

1. Regulation of weather modification activities should retain and support the experience and achievements of private industry, local and national governmental agencies, and encourage continuing contributions.
2. Weather modification research and operations should utilize fully the capabilities of universities and industries.
3. Weather modification activities in Government should be assigned to agencies which have demonstrated vigor and competence in this area.
4. Weather modification activities should develop the consideration of the atmosphere as a natural resource.

Sincerely,

WILLIAM H. WISELY, *Executive Secretary.*

---

WEATHER MODIFICATION BY LOUIS J. BATTAN, PROFESSOR OF METEOROLOGY AND ASSOCIATE DIRECTOR, INSTITUTE OF ATMOSPHERIC PHYSICS, THE UNIVERSITY OF ARIZONA, TUCSON, ARIZ., AND PRESIDENT, AMERICAN METEOROLOGICAL SOCIETY, BOSTON, MASS.

Thank you for the invitation to submit a statement relevant to S. 2916 and S. 23, two bills dealing with weather modification. The American Meteorological Society has a vital interest in these matters and as president I would like the record to show our desires that research efforts in weather modification and the atmospheric sciences in general be substantially enlarged. Secondly, as a scientist who has been actively engaged in research in cloud physics and weather modification since the early fifties, I would like to express my personal views on these subjects.

AMERICAN METEOROLOGICAL SOCIETY

Since its founding in 1919, the American Meteorological Society has played an important role in the advancement of meteorology in the United States and, indeed, has exerted a constructive influence on meteorology around the world. The objectives of the society as stated in its constitution are, "The development and dissemination of knowledge of meteorology in all its phases and applications and the advancement of its professional ideals."

The society has a membership of about 8,000, roughly half of whom are professional members. Among this group are scientists engaged in research on the atmospheric sciences as well as professional meteorologists engaged in weather forecasting or the providing of other meteorological services. For the most part, the members are associated with government agencies, universities, profit and nonprofit corporations or as private weather consultants. All of the Federal agencies involved in geophysical activities are represented on the society's membership roles.

The society as an organization, has been concerned primarily with what needs to be done in the atmospheric sciences, rather than who should do the job. Within this framework it has focused attention on particular scientific and technical problems requiring attention. Among the most pressing problems are the following: improved weather observations over oceans and sparsely populated areas; improved weather forecasting; increased activity in air pollution research; enlarged efforts in the study of the upper atmosphere; a better understanding of radiation processes in the atmosphere; greater efforts in the study of severe weather events such as violent thunderstorms, hail, tornadoes and hurricanes; and the development of means for detecting and forecasting clear-air turbulence.

The subject of weather modification has had the special attention of the society. Its executive director, Mr. Kenneth C. Spengler, was a member of the President's Advisory Committee on Weather Control during its existence from 1953 to 1957. In May 1957 the society, after a survey of the state of knowledge in weather modification, issued a statement giving the society's opinions on the subject. A new committee is now engaged in the preparation of a new society position.

Over the past 15 years the society has been a major force in dissemination of information concerned with research and other activities in weather modification. It has done this through the medium of conferences on regional, national, and international scales. A significant number of these conferences have been cosponsored with such organizations as the American Geophysical Union, American Society of Civil Engineers, and the American Association for the Advancement of Science.

Probably the major function performed by the American Meteorological Society in fulfilling the objectives of its charter is the publication of periodicals containing the results of basic and applied research in the atmospheric sciences. The society issues the following journals: Bulletin of the American Meteorological Society, Journal of Applied Meteorology, Journal of Atmospheric Sciences, Meteorological Monographs, Weatherwise, and Meteorological and Geoastrophysical Abstracts.

All of these outstanding publications, contain articles or information directly or indirectly bearing on the subject of weather modification. The Journal of Applied Meteorology started in 1962 has become a favored vehicle for the publication of articles on this subject. The last periodical listed, briefly called the Abstracts, represents an invaluable source of information for researchers, particularly for students and others newly interested in weather modification and related subjects.

In its publication activities, the aims of the society are to stimulate more and better research and services by all its members—government, university, and private. It has become increasingly clear in recent years that the national effort in the field of weather and climate modification falls far short of the level the problems deserve. The American Meteorological Society stands ready to take its rightful place in an enlarged effort.

### INDIVIDUAL VIEWS

For the last 15 years, the author of this document has been directly involved with cloud physics and weather modification research. As a consequence, I have certain opinions on the subject and would like to express them. It is emphasized that these views are strictly my own and are not to be construed as representing those of the American Meteorological Society.

In certain respects the report by the Panel on Weather and Climate Modification of the National Academy of Sciences is in agreement with the final report issued in 1957 by the President's Advisory Committee on Weather Control. The Academy report notes that the evidence on hand supports the conclusions that in certain circumstances precipitation may be increased by 10 to 20 percent. How-

ever, the careful wording of the conclusions should not be overlooked. They do not say it has been proved that precipitation can be increased. They suggest optimism and hold out the hope for precipitation increases, but do not promise them.

Both the Academy report and the one issued by the Special Commission on Weather Modification of the National Science Foundation caution that, in certain instances, cloud seeding might lead to precipitation decreases.

In my view, the evidence points to three possible effects on rainfall by cloud seeding with ice nuclei: (1) increase, (2) decrease, or (3) no effect. On the basis of number of project studies, the first category is dominant, but it is not clear that one can confidently predict beforehand which result is likely to occur and give an adequate explanation therefore.

For these reasons, rainfall augmentation cannot be regarded as entirely in the category of an engineering project. To be sure once a cloud-seeding project has been adequately designed, its conduct is largely one of engineering. The design and selection of precipitation measuring gages, their installation and maintenance, the design, testing, and operation of the seeding generators are all engineering problems. Also, if the project has been properly designed, even the analysis of the data can be largely routine, insofar as answering the question, "Did the cloud seeding increase precipitation?" However, the interpretation of the data collected in terms of the physical mechanisms involved is by no means routine. It requires meteorological knowledge and insight.

In the design phase of a cloud-seeding project, it is essential that combined talents of meteorologist, statistician, and in some cases engineer be employed. It is essential that every program be planned and carried out in such a fashion that at the conclusion, valid statistical and physical evaluations can be made to determine if the seeding had any effect. A large measure of the uncertainties existing today in the evaluation of weather modification exist because relatively few of the many projects conducted during the past 15 years have involved the type of controls needed to draw convincing inferences about the results.

It is reasonable to ask why this is regarded as an appropriate time for an enlarged research effort. In my opinion, there are several reasons: (1) Although conclusive proof of the efficacy of cloud seeding for rainfall augmentation is still not in hand, the evidence strongly suggests that in certain circumstances, increases of 10 to 20 percent can be produced. (2) The growing need for new supplies of fresh water makes it imperative that all possible sources be investigated. (3) We now have a better understanding of the properties of cloud systems and their microphysics than we had 10 to 15 years ago. (4) New instruments are now available for cloud and precipitation observations (doppler radar, aircraft instrumentation, and satellites). (5) New Theoretical models of atmospheric phenomena coupled with high speed computers allow investigations which would have been virtually impossible a decade ago. (6) The number of scientists with an interest in weather modification research has increased and continues to increase. (7) There is an increasing desire within the Federal Government to tackle the difficult job of weather modification and a greater determination within the Congress that progress be accelerated.

Most of the emphasis in weather modification research has been centered on rainfall stimulation. Other areas of study also need to be given increased attention. The accumulation of engineering data for use in dissipating supercooled clouds and fogs over airports has been unnecessarily slow. Progress in developing techniques for opening holes through "warm" fogs has been disappointing.

Research in the physics of hail and hail suppression has been grossly inadequate. Efforts abroad particularly from Russia, Switzerland, and Argentina are conflicting. The Russians report amazing success in hail suppression by means of ice nuclei seeding, other groups suggest that seeding in particular instances might cause more damaging hail. In light of the tremendous destruction of agricultural products in the United States, it is essential that we learn more about hailstorms and how to influence them.

The research programs on such problems as lightning suppression, hurricane modification, tornado modification, range from very modest to virtually negligible in size.

The need for investigation of the causes for climatic change and the feasibility of exerting influences on the climate are of great importance. In this regard, the requirement for further international cooperation becomes increas-

ingly obvious. The climate on one part of the globe cannot be changed without causing a change on other areas. The problem is, of course, quite complicated. At the present it is impossible to predict satisfactorily what the consequences would be if any large part of the earth were to be artificially warmed or cooled. As has been noted by others, it is essential that a better understanding of climate be obtained before attempting any experiments of this nature.

How much larger should the program of weather modification be than it is today? How fast should it grow? How many qualified people are working in this area today and how many can be attracted as more funds become available? How crucial are weather modification problems when compared with other Government programs?

These questions are not easy to answer. Clearly the present funding is inadequate when measured against the number of people eager to work on the problems and the importance of weather modification in relation to other Government programs. The Academy Committee and the NSF Commission project requirements of $20 to $50 million by 1970. Considering that the fiscal 1966 budget for Federal programs is $7.2 million, these projections do not strike me as exorbitant.

In my view, decisions on which agencies should play a major role in carrying out weather modification research should certainly take into account performances in the past as well as the existing scientific and professional staff with meteorological competence. At this stage the major problems are still meteorological ones.

On this basis, the National Science Foundation's program in weather modification research should not only be continued but should be enlarged. With limited resources at its command, the Foundation has supported an active and productive program at universities, private companies, and has assisted various Government research efforts through transfer of funds. In supporting university research on the basis of merit, the Foundation has made it possible to carry out meaningful research. Some of this research has built the foundations for work now being financed by other agencies. A very important consideration which must be taken into account is that university support from NSF has provided for the training of graduate students and increased the number of available scientists.

The Environmental Science Services Administration (ESSA) has the greatest concentration of atmospheric scientists of all the Government agencies. Over the year it has shown that it can efficiently manage large observational programs involving up-to-date equipment. In the past the Weather Bureau, for various reasons, one of them being a shortage of funds, has not had an ambitious weather modification effort. Senate bill S. 2916 proposes that the Department of Commerce, presumably through ESSA, be authorized to carry out an enlarged program of weather modification. Since progress in this field will depend largely on the scientific talent employed, it makes sense to me that a greatly enlarged effort in ESSA be supported. It also seems reasonable to me that ESSA be charged with the responsibility of monitoring weather modification activities to prevent undesirable interference between projects, to protect federally supported programs from liability, and to indemnify the public for damages which might arise as a result of Government-supported work. ESSA also is a logical agency to assume the responsibility for collecting and evaluating data produced by weather modification projects and for publishing the results at reasonable intervals.

Other Federal agencies having specific mission requirements should also be supported in larger measure. The work of the Bureau of Reclamation has brought about the initiation of precipitation augmentation projects in the West. These new programs promise to yield answers to important questions relating to increased precipitation in a number of river basins.

Agencies such as the Federal Aviation Agency, Forest Service, Air Force, Army, and Navy have specific programs concerned with their assigned missions. In the past some of these agencies have had to seek funds from the National Science Foundation to conduct research. Their programs should be supported directly at the levels which can be reasonably justified.

At the present time, Federal efforts in weather modification research is partitioned among the Departments of Defense, Commerce, Interior, Agriculture, and the National Science Foundation. Certainly close coordination is needed and a mission-oriented agency needs to be assigned certain regulatory responsibili-

ties. But at the present time there does not appear to be sufficient information on hand to justify the centralization of all authority in one agency. In my opinion, the absence of such centralized authority has not been the major reason for the inadequacy of our research efforts in weather modification. The low level of support and the shortage of qualified scientists must be regarded as important reasons for slow progress. Note that although Federal expenditures in weather modification research in fiscal 1965 and 1966 are listed as about $5 and $7.2 million, for the preceding 6 years they averaged just slightly over $3 million per year for the entire national effort.

The realization is that a much greater research effort is overdue and the trend of increased funding over the last 2 years has injected new life into weather modification research. Continued increases in funding are in order if the problems are to be solved in reasonable times. At the same time, greater coordination is needed within the Government to assure that the available funds are being used wisely.

I thank you for the opportunity to express these views.

---

UNIVERSITY OF WASHINGTON,
*Seattle, Wash., March 4, 1966.*

Hon. Senator WARREN MAGNUSON,
*Senate Office Building, Washington, D.C.*

DEAR SENATOR MAGNUSON: Because of the present stage of development of weather modification and the lack of scientists trained in this phase of atmospheric sciences, I feel it would be unwise to place the sole responsibility of weather modification and climate control, including research and training of a future generation of scientists, under a single Government agency.

Therefore, I wish to point out that since 1958 the National Science Foundation has had the responsibility of initiating and supporting programs of study and research in the field of weather modification. The Foundation has pursued this goal by providing financial support on a wide basis to Government, university, and private research teams engaged in theoretical and applied research activities in weather modification. As a result of these programs many significant scientific advances have been made in the subject.

The bill now before you proposes that the responsibility for weather modification research and applied work be removed from the National Science Foundation and placed with the Secretary of Commerce. Numerous arguments for and against such a move will be put to you, but we do not wish to add to these here. We would, however, like to draw your attention to the important role which university research and teaching has to play in any national program of weather modification.

Firstly, it is clear that university research teams, by virtue of their emphasis on fundamental research into the physical processes which lead to the formation of clouds and to the development of snow and rain, will continue to provide the scientific basis for weather and climate modification experiments. It is only through a continuation and expansion of such basic research that further progress is likely to be made in the field. Secondly, no matter which Government agency is assigned the responsibility of directing the national program, it must ultimately rely on university departments to provide sufficient numbers of properly trained scientists in this field. It is a sobering thought that at the present time this country produces fewer than five Ph. D. students per year who have specialized in the physics of clouds and weather modification.

I would therefore urge that steps be taken to insure that if and when increased funds are appropriated for new programs in weather modification, commensurate funds be made available for university research, teaching and complete funding of buildings for this subject and the related atmospheric sciences. By virtue of its responsibility to support basic research and education in the sciences, the National Science Foundation would seem the appropriate agency to administer the funds for the all-important university research and training of men who will be capable of directing weather modification experiments.

Sincerely,

P. E. CHURCH,
*Professor of Atmospheric Sciences.*

UNIVERSITY OF CALIFORNIA, BERKELEY,
*Berkeley, Calif., March 11, 1966.*

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

DEAR SENATOR MAGNUSON: With reference to your invitation of public debate on bills S. 2875 and S. 2916, as quoted in Science (vol. 151, 1966, p. 806), the purpose of the present is to submit to you the desirability of creating a facility, perhaps to be called "statistical weather modification facility" (SWMF, for short). This facility would have two related purposes: (1) to preserve in usable form the data on completed weather modification experiments, data obtained at the cost of millions of dollars through many years of experimentation, and (2) to conduct statistical research, partly theoretical, concerned with the methodology of weather modification experiments, and partly empirical, using the data on completed experiments.

Enclosure A outlines the functioning of the proposed SWMF. Enclosure B indicates some of the reasons for my making the present suggestion. Naturally, I should be delighted to answer any questions you may wish to ask.

Yours respectfully,

J. NEYMAN,
*Professor, and Director of the Statistical Laboratory.*

[Enclosure A]

OUTLINE OF FUNCTIONS OF THE PROPOSED STATISTICAL WEATHER MODIFICATION FACILITY (SWMF)

(1) *Data collections and storage.*—The SWMF would collect, sort, organize, and store, on punchcards, magnetic tapes, or on microfilms, relevant data relating to all publicly funded weather modification experiments conducted in the United States and also relating to such other weather modification experiments in the United States and abroad that may be judged sufficiently significant and that the collection of data on them will be found feasible.

The data in question would be not only those that the experimenters concerned would collect on their own initiative, data intended to answer questions formulated by these experimenters, but also collateral data, the relevance of which may be only suspected, but which later on may become invaluable as a source of information on questions that may be asked in the future. The success in this respect will depend very much on the scientific initiative, alertness, and foresight of the directing body of the SWMF.

(2) *Legal basis.*—The basis for the activity of SWMF must be a law requiring (a) that the facility be informed of each incipient publicly funded weather modification experiment, including the design of the experiment, its purpose and the data collection program; (b) that photocopies of the original data on every such experiment be routinely made available to the facility as they are collected, perhaps within 3 months of each completed experimental season.

(3) *Collateral data.*—The SWMF would be authorized to seek cooperation of the appropriate Federal and State agencies in collection of the relevant collateral data, such as photocopies of radiosonde data, precipitation records in areas adjoining the weather modification experiments, etc.

(4) *Use of data.*—The purpose of data collected and organized by the SWMF would be to create the possibility of using the weather modification experiments already completed in order to answer questions which were not formulated at the time when these experiments were planned and executed. For this purpose, and subject to the restriction explained in (5) the data collected by the SWMF would be available, at cost, to all agencies of the United States and to all authorized individuals and research institutions.

(5) *Priority rights of the experimenters.*—The availability of data on completed experiments would be subject to the restriction designed to protect the priority rights of the experimenters: the latter must be allowed a reasonable time, perhaps a year, to analyze and to evaluate their experiments themselves. Thereafter, the results of the experiments would become public property.

(6) *Own research of the SWMF.*—In addition to collecting, organizing, and preserving data on completed weather modification experiments, the SWMF would conduct its own research in the following domains:

(*a*) Theoretical research aiming at the development of particularly efficient statistical techniques for the evaluation of weather modification experiments.

(*b*) Development of experimental designs with which significant results on weather modification might be obtained through a shorter period of experimentation, and therefore, at a savings expected to be substantial.

(*c*) Evaluation and reevaluation of selected experiments already performed.

(7) *Consulting service.*—The SWMF would provide statistical consulting service to all research workers and institutions who may request it, particularly with reference to evaluation techniques and to planning of new experiments.

(8) *Governing Body.*—The SWMF would function under policy decisions of a governing body composed of representatives of research institutions concerned with weather modification problems, to be determined by a separate regulation.

(9) *Autonomy.*—The SWMF must have a degree of autonomy and be free to collect and, when the occasion arises, to publish data and evaluations at its own discretion. In particular, SWMF should be financially independent of the institutions engaged in actual experimentation with weather control. This would insure impartiality in the analysis performed by a group which would have no vested interests in the results.

Perhaps the best way to achieve this autonomy is to locate the SWMF within the academic community rather than to have it attached to a governmental agency.

Respectfully submitted.

J. NEYMAN,
*Professor and Director of the Statistical Laboratory.*

---

[Enclosure B]

MOTIVATION FOR THE PROPOSAL TO CREATE THE STATISTICAL WEATHER MODIFICATION FACILITY

(1) *Usefulness of "collateral data" on weather modification experiments.*—The usefulness of collateral data on weather modification experiments may be dramatically illustrated by the following fact: As revealed at the recent meeting "Weather Modification of the Fifth Berkeley Symposium" (see attached program), the first and, thus far, the only unambiguous evidence that cloud seeding with silver iodide can increase precipitation came from the hail prevention experiment, so-called "Grossversuch III," performed in Switzerland from 1957 to 1963. Here, then, precipitation amounts were "collateral" to the purpose of the experiment and it is pure luck that they were published in the annual reports. The significance of the precipitation data was largely overlooked. Thus, for example, the 1964 preliminary report of the NAS Panel dismisses the Swiss experiment in one sentence to the effect that no significant effect of seeding on hail incidence was found. (In actual fact, a more detailed analysis revealed that seeding increased the incidence of hail.)

(2) *A special agency to assemble and to preserve data on completed experiments is needed.*—Here again Grossversuch III may serve as an illustration. In order to gain insight into the mechanism of the noted increase in precipitation certain meteorological data not published in the annual reports are necessary. The data are available partly in the archives of the Osservatorio Ticinese at Locarno-Monti and partly in Italy. The retrieval of the data may seem trivial. In actual fact, the process is troublesome and not inexpensive. Above all, it is time consuming.

One might perhaps think that the difficulties mentioned are due principally to the fact that the experiment in question was performed in Switzerland, where there is no problem with precipitation, while the data are needed in the United States. However, this point of view is mistaken. As a general rule, once an experiment is performed and evaluated, the individuals concerned tend to lose interest in it. They move to other jobs and to new projects and the retrieval of the original data, while theoretically possible, becomes practically as difficult as if the experiment were performed in a foreign country. This is particularly true when, for one reason or another, the results of the experiment fall short of the original hopes of the experimenters.

The situation is aggravated by the following circumstances of a psychological character. It is human nature that any attempt by an interested research worker to have a closer look at the raw data of an experiment performed by someone else is bound to be considered as an intrusion and be resented. A special agency, established on the principle that the results of an experiment performed from public funds are public property, an agency established for the specific purpose of preserving this property, would be treated differently.

(3) *Need for theoretical research in statistical methodology and the design of experiments.*—Experiments in physics and chemistry are as old as these sciences. They were going on without special theory and with great success, because in the laboratories it was possible to isolate the factors studied and to eliminate extraneous sources of variation. This was not and is not the case in the domains where great variability is an inherent feature of the subjects of study. Cases in point are agricultural, medical, and, more generally, biological studies. Here the variability from one plot of land to the next, from one patient or from one rat to another is so large as to hide the effects of treatments studied. In these domains, scientific experimentation was born in the 1920's and 1930's with the foundation, by R. A. Fisher, of special discipline: theory of experimentation. Through the work of Fisher and of his numerous followers, the theory of experimentation spread over many domains of science. However, thus far very little has been done with reference to weather modification experiments where there are special specific difficulties. In parallel with the extension of the theory of experimental design there are other statistical theoretical problems to be solved. Such work as has been done already indicates that merely by a change of statistical technique and/or by a modification of the experimental design, the time of experimentation necessary for detecting a significant effect of cloud seeding may be shortened by a factor of two or more.

Research of this kind requires special qualifications, those of a mathematical statistician. However, it cannot be conducted in the abstract, but requires contacts with live experimental and observational data. The creation of the proposed Statistical Weather Modification Facility would provide an appropriate ground for such contacts.

Respectfully submitted.

J. NEYMAN,
*Professor and Director*
*of the Statistical Laboratory.*

---

STATE UNIVERSITY OF NEW YORK,
ATMOSPHERIC SCIENCES RESEARCH CENTER,
*Schenectady, N.Y., February 28, 1966.*

Re: your February 21, 1966, letter.

Hon. WARREN G. MAGNUSON,
*Chairman, Senate Committee on Commerce,*
*Washington, D.C.*

DEAR SENATOR MAGNUSON: I deeply appreciate your thoughtfulness in inviting me to testify during the hearings on S. 2916 and S. 23.

Prior commitments prevent me from taking advantage of your kind offer to personally appear before your committee, although I will be in Washington March 2, 1966.

My general views about the importance of this subject have been stated in portions of the enclosed reprints. Anything I may say before your committee would merely emphasize my conviction that there is a big job to be done in this field, and it is of the greatest importance that all available interests should be invited to help do the job. In my view, it would be a grave mistake at this time to place the responsibility for this undertaking on any one Government organization. The widest spectrum possible of disciplines, and enthusiastic and capable individuals, is needed to cope with the present needs in this field.

The following extract from my paper, "Some Problems Concerning Weather Control," published in the Journal of Applied Mathematics and Physics (JAMP) 14, 523–528 (1963), represents my current views on this matter:

"Encouragement should be extended to the university community throughout the United States so that they might bring their specialized knowledge to bear on the multidisciplinary problems involved.

"It seems to me that the logical partners in such an activity are the National Science Foundation (to provide support for basic studies), the Bureau

of Reclamation (to provide the engineering design and supervision), and the Weather Bureau to provide the weather forecasts and observations. Cooperation from the scientific and engineering community will support a comprehensive plan if it is carefully developed and conducted with enthusiasm and imagination. The best individuals in each area of activity must be utilized in making the plans. We should continually search for high-ability young people to become actively involved in these activities if we are to achieve the long-range potential of such efforts.

"I sincerely hope the time has come when we can go forward without further delay with a comprehensive plan for the development of our water resources in the sky, on and under the ground, enjoying the fullest cooperation of public and private organizations, scientists, engineers, technicians and our representatives at the State and Federal level. All are essential since we deal with one of the most complex and challenging problems in science.

"Water and air are among our most valuable natural resources. Until we adequately understand them and their interrelationship, we will not be able to properly develop, conserve, and utilize them to the betterment of mankind * * *."

I plan to personally deliver 75 mimeographed copies of my more extended paper, to your office by May 2, 1966. I hope this may be helpful.

Sincerely,

VINCENT J. SCHAEFER,
*Director of Research.*

## SOME PROBLEMS CONCERNING WEATHER CONTROL

(By Vincent J. Schaefer, research consultant)

In the nearly 20 years which have passed since the writer dropped 6 pounds of dry ice into a supercooled altocumulus cloud over Greylock Mountain in Massachusetts, (1) the field of experimental meteorology has developed into a major scientific activity engaging atmospheric scientists throughout the world.

The rash of entrepreneurs and "rainmakers," which developed shortly after these experiments were announced, and the expansive claims and brash attitudes, played on the relative ignorance and desperate situation of groups of farmers and ranchers, mulcting them of hundreds of thousands of dollars; at the same time putting the entire field of experimental meteorology in disrepute. This unfortunate development has gradually been supplanted by individual scientists and research groups anxious to establish the scientific facts and thus delineate the possibilities and limitations existing in this new area of science.

The task of establishing a sound scientific understanding of the effects of seeding and other triggerlike effects which interfere with the "natural" course of events in atmospheric processes, is fraught with intricate problems, not the least of which is our limited knowledge of many of the fundamental dynamic properties of the atmosphere. Such seemingly simple things as the formation of snow and rain, the cause of the electrical charge buildup in thunderstorms, and the structural features of cumulus clouds, are inadequately understood at the present time despite several decades of intensive studies.

In view of the current discrepancies in our knowledge, it is not surprising that occasional disagreements take place during meteorological meetings dealing with the effects of cloud seeding operations. Because of its vast complexity, there is probably no scientific subject more difficult to understand than the behavior of the atmosphere.

As Langmuir has pointed out, (2) the many atmospheric processes which combine to cause weather developments include phenomena of a divergent nature. Such phenomena defy prediction, since they result from minor disturbances which trigger off major results. Only convergent-type phenomena lend themselves to prediction. In one of his later public lectures, Langmuir said, "It may be easier to make the weather than to predict its behavior."

The activities of Project Cirrus (3) between 1947 and 1952 established a number of the potentialities and limitations of the use of dry ice and silver iodide as seeding materials. In the 10-year period following the termination of the Cirrus operation, a number of more elaborate research programs were conducted, the results of which are only now being published.

As might have been expected, the results of these efforts are not without disagreement. They range from the reports of research groups in Arizona (4) and

California (5) covering 4 years of aerial and ground seeding effects with the use of silver iodide generators, reporting no statistical evidence supporting increased precipitation; to the findings of the Australian group, (6) showing precipitation increases of 9 to 21 percent with some statistical significance, to the highly positive but not yet statistically significant of the Japanese, (7) reporting increases of 150-percent precipitation downwind of the Sea of Japan. Other studies, not yet ready for publication but conducted by capable researchers known to the writer, imply that the Japanese result may be quite real due to ideal conditions and well designed and operated fieldwork. In areas of the world adjacent to rich moisture sources where supercooled clouds develop in abundance and naturally occurring ice nuclei are rare, seeding effects may be quite spectacular if intelligent activities are conducted. On the other hand, there will be geographical areas where little if any effects can be expected no matter how intensive or intelligent the effort.

At the present time there are few countries in the world that do not have field programs underway in experimental meteorology. (8) At the International Conference on Cloud Physics (9) held September 1961 in Australia, more than 70 scientists representing 17 countries described the progress being made in their respective areas. These efforts ranged from token activities to very elaborate and intensive studies on a wide front. Research is now being directed toward a wide variety of problems related to experimental meteorology ranging from cloud modification to some which closely approach "weather control." These include such efforts as the studies of simple systems involving supercooled fogs and stratus clouds, hailstorms, orographic snowstorms, "lake effect" snowstorms, thunderstorms, tornadoes, orographic cumulus, manmade cumulus, "blowdown" storms, hurricanes, frontal cyclones, and large-scale circulation. Some of these studies are well underway; others in only the initial exploratory phase. In a number of instances multiple studies of these storm types are underway in different parts of the world. Some results will be similar, but others are bound to show differences since there are few places where all of the significant variables are the same or even have any but the most superficial features in common.

Dry ice and silver iodide are still the most promising materials for producing "trigger" effects in atmospheric clouds, although they are strictly limited to supercooled clouds. While the majority of the activities in various parts of the world utilize silver iodide invisible smokes from ground and airborne generators, (10) (11) a number of new materials and effects are the subject of investigations. The introduction of positive or negative ion clouds in substantial quantities has been achieved by Vonnegut (12) in Texas, Illinois, and New Mexico. Claims have recently been advanced by the Russians that substances such as phloroglucinol are as effective as silver iodide and become active as nuclei for ice crystal formation at a temperature of $-2°$ C. Procedures for generating high concentrations of these materials are not currently as easy to carry out as with silver iodide.

The placing of finely divided carbon black into clouds to modify them was given enthusiastic support for a short period. Further studies, however, failed to confirm the results claimed, and the present status appears to be that effects, if any, are of dubious economic value for affecting clouds.

Sodium and calcium chloride, ammonium sulfate, and similar substances, some having a hygroscopic nature, have been tried as materials which hopefully would initiate warm rain precipitation. It was hoped that the results might be as effective in warm clouds as silver iodide and dry ice is in supercooled clouds. These materials thus far have failed to produce effects to a degree of economic value. This is because the warm cloud lacks the instability that makes the supercooled cloud so easy to modify. The other feature so important in economic evaluation is that silver iodide is effective when about 0.01 micron in diameter. Dry ice and similar materials colder than $-40°$ C. are as efficient as silver iodide, weight for weight, when used properly. Materials thus far used in warm clouds must be 1 to 10 microns to have any effect. Thus the volume or weight of materials necessary to produce triggering reactions (if they can) must be at least a million times greater. If delivery is by plane or even by some sort of ground generator, the logistical problems make such procedures of doubtful economic value.

While it has been demonstrated (13) (14) that relatively small amounts of water can initiate precipitation in warm clouds by a "chain reaction," the economic value of such operations is also doubtful except under very special conditions.

An example of such a condition exists in the Hawaiian Islands. On the island of Maui, Hawaii, water from a mountain stream, which ordinarily flows into the sea, has been diverted and sprayed continuously into the oncoming streams of trade wind clouds at the point where they contact a steep cliff and are forced rapidly upward. The droplets sprayed into the cloud grow about 100-fold in volume while in the upward moving clouds. They then fall earthward from the clouds as a drizzle at a point where the resulting precipitation can be caught in a flume and usefully deployed.

Similar conditions probably occur on many forested mountains swept by storm clouds.

While there remain uncertainties concerning the economic value of cloud seeding activities and we are still waiting for results acceptable to the statistician, a number of us who have been active in the field are convinced that the time has arrived when we must encourage the development of what might be termed the "engineering phase" of weather modification. (15) This activity would deal with the procedures, logistics, and routine operational problems which are the steps necessary to implement a reliable large-scale utilization of scientific knowledge. It would be, in my opinion, a mistake to delay the inauguration of this step until everything is understood to the ultimate degree. A certain degree of gambling is necessary in any applied science development.

If plans are laid carefully, with thoroughness and intelligence, many worthwhile results will accrue from such activity. The greatest care must be exercised to insure that such projects are designed to take advantage of the most up-to-date scientific knowledge available and that active field research programs are superimposed on the field activities.

The trend of nearly every long-range precipitation increase operation I am aware of in America and in other countries (8) shows evidence that positive effects occur when seeding activities are carefully executed and realistically applied in relation to the local weather systems. Some of these effects cannot be interpreted as having important economic value, although the majority indicate the results have value in excess of the cost of the seeding activities. In fact the relative cost of seeding compared to the economic advantages possible in most areas is so great that the utmost effort must be directed to understanding the possibilities and limitations of such activities.

The economics of cloud precipitation in each area must be better evaluated in order to establish these relationships. Even trace amounts of rain or snow at critical periods of the year may have value or cause losses entirely out of proportion to much larger amounts at other periods. The secondary effects and byproducts of the type of studies which need to be made might in special cases actually turn out to be of greater value than the seeding effects. (15)

The definite buildup of interest in the atmospheric sciences now underway as part of the concerted effort (16) (17) of Government, educational institutions, private industry, and the scientific community, is bound to provide useful information, manpower, and ideas that will need testing and operational activities by weather engineering groups.

The increase of supply of irrigation water in semiarid regions by augmentation of the snowpack in the high mountains nearby is a logical development which might be anticipated. In addition to increasing the snowfall by more effective cloud-water extraction by intelligent seeding activities, increased supplies in the lowlands might also be achieved by improved forest management, evaporation reduction, melting control, and other manipulations of the mountain precipitation.

If methods are discovered which will lead to a control of the general circulation, potential troubles to the economy might occur to a dryland adaptation such as has been achieved by Reno, Palm Springs, Phoenix, and Albuquerque, to mention a few American cities which have grown because of the predominance of sunny skies and mild dry climate. Much of the economy of such places is based on an adjustment to the salubrious climate, an inherent feature of a dry environment.

The augmentation of rainfall in the local area to any considerable degree would cause many painful economic readjustments because of the change in sunshine, humidity, and the general ecology that would follow a radical change in the precipitation regimen. It is unlikely this problem will confront us immediately, but we should be actively evaluating all such possibilities as part of a broad plan dealing with the proper use of our natural resources.

While it may be desirable to concentrate efforts in certain watersheds, especially those already in critical supply such as the Colorado, it may be desirable to direct attention to other areas, too, such as the Sacramento, the Columbia, the Platte, the Missouri, and the Hudson. Some of these latter might provide more useful procedural information in the early stages of weather engineering development than areas where economic pressure demands immediate attention.

Encouragement should be extended to the university community throughout the United States so that they might bring their specialized knowledge to bear on the multidisciplinary problems involved.

It seems to me that the logical partners in such an activity are the National Science Foundation (to provide support for basic studies), the Bureau of Reclamation (to provide the engineering design and supervision), and the Weather Bureau to provide the weather forecasts and observations. Cooperation from the scientific and engineering community will support a comprehensive plan if it is carefully developed and conducted with enthusiasm and imagination. The best individuals in each area of activity must be utilized in making the plans. We should continually search for high-ability young people to become actively involved in these activities if we are to achieve the long-range potential of such efforts.

I sincerely hope the time has come when we can go forward without further delay with a comprehensive plan for the development of our water resources in the sky, on and under the ground, enjoying the fullest cooperation of public and private organizations, scientists, engineers, technicians, and our representatives at the State and Federal level. All are essential since we deal with one of the most complex and challenging problems in science.

Water and air are among our most valuable natural resources. Until we adequately understand them and their interrelationship, we will not be able to properly develop, conserve, and utilize them to the betterment of mankind.

## References


1. Schaefer, V. J. "The Formation of Ice Crystals in the Laboratory and the Atmosphere." Chemical Review 44, 2 (1949).
2. Langmuir, I. "Science, Commonsense, and Decency." Science 97, 1 (1943).
3. Schaefer, V. J. Final report, Project Cirrus, part I. Laboratory, field and flight experiments, contract No. DA–36–039–SC–15345, report No. RL 785, General Electric Research Laboratory, Schenectady, N.Y. (March 1953).
4. Battan, L. J. and Kassander, Jr., A. R. "Cloud Seeding Experiments in Arizona." Monograph No. 16, International Union of Geodesy and Geophysics, Paris, January 1962, p. 73.
5. Neyman, J., Scott, E. L., and Vasilevskis, M. "Statistical Evaluation of the Santa Barbara Randomized Cloud Seeding Experiment." Bulletin American Meteorological Society, 41, 531 (1960).
6. Adderly, E. E. "Analysis of Cloud Seeding Trials in Australia." Monograph No. 16 International Union of Geodesy and Geophysics, Parts, January 1962, p. 77.
7. Isono, Kenji. "Some Results of Cloud Seeding Experiments With Use of Silver Iodide Ground Generators." Monograph No. 16, International Union of Geodesy and Geophysics, Paris, January 1962, p. 75.
8. Third Annual Report on Weather Modification (1961), National Science Foundation, 78 pp., Superintendent of Documents, Washington, D.C.
9. International Conference on Cloud Physics, Monograph No. 16, Paris, January 1962, p. 89. International Union of Geodesy and Geophysics. International Association of Meteorology and Atmospheric Physics.
10. Schaefer, V. J. and Dieterich, J. H. "The Seeding of Cumulus Clouds by Ground Based Silver Iodide Generators." Journal of Applied Mathematics and Physics, 10, 174 (1959).
11. Fuquay, D. M. "Generator Technology for Cloud Seeding." Journal Irrigation and Drainage Division Proceedings American Society Civil Engineers 86, No. IRI, 79 (1960).
12. Vonnegut, B. "Recent Studies of Cloud Electrification." Monograph No. 16, International Union of Geodesy and Geophysics, Paris, January 1962, p. 29.
13. Langmuir, I. "The Production of Rain by a Chain Reaction in Cumulus Clouds at Temperatures Above Freezing." Journal of Meteorology 5, 175 (1948).

14. Braham, Roscoe R., et al. "Artificial Nucleation of Cumulus Clouds." Meteorological Monographs 2, 47 (1957), American Meteorological Society, Boston.
15. Schaefer, V. J. "Serendipity and the Development of Experimental Meteorology." Journal of the Irrigation and Drainage Division. Proceedings of the American Society of Civil Engineers 86, 1 (1960).
16. The Atmospheric Sciences, 1961–71, vol. I and II, Public No. 946. National Academy of Sciences-National Research Council, Washington, D.C. 1962.
17. Schaefer, V. J. "Atmospheric Sciences Program for High-Ability Students." Weatherwise 14. 183 (1961).

○