

Y 4
. C 73/2
94-84

1041

94-84
C 73/2
94-84

ATMOSPHERIC RESEARCH CONTROL ACT

GOVERNMENT

Storage

HEARING

BEFORE THE

SUBCOMMITTEE ON OCEANS AND ATMOSPHERE

OF THE

COMMITTEE ON COMMERCE

UNITED STATES SENATE

SEP 13 1970

NINETY-FOURTH CONGRESS

THE LIBRARY
KANSAS STATE UNIVERSITY

SECOND SESSION

ON

S. 2705

TO PROVIDE FOR A STUDY BY THE SECRETARY OF COMMERCE OF THE NEED FOR REGULATION OF WEATHER MODIFICATION ACTIVITIES, THE STATUS OF CURRENT TECHNOLOGIES, THE EXTENT OF COORDINATION AND THE APPROPRIATE RESPONSIBILITY FOR OPERATIONS IN THE FIELD OF WEATHER MODIFICATION, AND FOR OTHER PURPOSES

S. 2706

TO AUTHORIZE AND DIRECT THE SECRETARY OF COMMERCE TO PLAN AND CARRY OUT AN EXPERIMENTAL RESEARCH PROGRAM TO DETERMINE THE FEASIBILITY OF AND THE MOST EFFECTIVE METHODS FOR DROUGHT PREVENTION AND ALLEVIATION BY WEATHER MODIFICATION

S. 2707

TO AUTHORIZE THE SECRETARY OF COMMERCE TO CARRY OUT A PROGRAM OF ASSISTANCE TO STATES IN PREVENTING AND ALLEVIATING DROUGHT EMERGENCIES

FEBRUARY 17, 1976

Serial No. 94-84

Printed for the use of the Committee on Commerce

U.S. GOVERNMENT PRINTING OFFICE

WASHINGTON : 1976

71-929 O

AY
SEP 9.
48-49

COMMITTEE ON COMMERCE

WARREN G. MAGNUSON, Washington, *Chairman*

JOHN O. PASTORE, Rhode Island
VANCE HARTKE, Indiana
PHILIP A. HART, Michigan
HOWARD W. CANNON, Nevada
RUSSELL B. LONG, Louisiana
FRANK E. MOSS, Utah
ERNEST F. HOLLINGS, South Carolina
DANIEL K. INOUE, Hawaii
JOHN V. TUNNEY, California
ADLAI E. STEVENSON, Illinois
WENDELL H. FORD, Kentucky
JOHN A. DURKIN, New Hampshire

JAMES B. PEARSON, Kansas
ROBERT P. GRIFFIN, Michigan
HOWARD H. BAKER, Jr., Tennessee
TED STEVENS, Alaska
J. GLENN BEALL, Jr., Maryland
LOWELL P. WEICKER, Jr., Connecticut
JAMES L. BUCKLEY, New York

MICHAEL PERTSCHUK, *Chief Counsel*

S. LYNN SUTCLIFFE, *General Counsel*

JAMES P. WALSH, *Staff Counsel*

DR. STEVEN H. FLAJSER, *Professional Staff Member*

DEBORAH J. STIRLING, *Staff Counsel*

MALCOLM M. B. STERRETT, *Minority Counsel*

GERALD J. KOVACH, *Minority Staff Counsel*

GEOFFREY B. BAKER, *Minority Professional Staff Member*

SUBCOMMITTEE ON OCEANS AND ATMOSPHERE

ERNEST F. HOLLINGS, South Carolina, *Chairman*

JOHN O. PASTORE, Rhode Island
PHILIP A. HART, Michigan
RUSSELL B. LONG, Louisiana
DANIEL K. INOUE, Hawaii
FRANK E. MOSS, Utah
JOHN V. TUNNEY, California

TED STEVENS, Alaska
J. GLENN BEALL, Jr., Maryland
JAMES L. BUCKLEY, New York
LOWELL P. WEICKER, Jr., Connecticut

CONTENTS

	Page
Opening statement by Senator Pearson.....	1
Text of bill's:	
S. 2705.....	2
S. 2706.....	11
S. 2707.....	17
Agency comments of the Department of the Interior.....	21

LIST OF WITNESSES

FEBRUARY 17, 1976

Battan, Dr. Louis J., Institute of Atmospheric Physics, University of Arizona; Prof. Howard J. Taubenfeld, School of Law, Southern Methodist University; and Prof. Robert G. Fleagle, Department of Atmospheric Sciences, University of Washington.....	201
Prepared statement of Dr. Battan.....	204
Prepared statement of Professor Fleagle.....	211
Bellmon, Hon. Henry, U.S. Senator from Oklahoma.....	23
Booker, Dr. D. Ray, Aeromet, Inc., Norman Okla.....	217
Prepared statement.....	220
Eggers, Dr. Alfred J., Jr., Assistant Director for Research Applications, National Science Foundation; accompanied by Dr. Larry Tombaugh; and Dr. Currie Downie.....	33
Kahan, Dr. Archie M., Chief, Division of Atmospheric Water Resources Management, Bureau of Reclamation, Denver, Colo.....	183
Prepared statement.....	188
Shadid, Hoyt, district manager, Mountain Park Master Conservancy District, Altus, Okla.....	29
Sullivan, Glenn, vice president and director of water, wastewater and environmental services, Benham Blair & Affiliates, Inc.....	24
Prepared statement.....	27
White, Dr. Robert M., Administrator, National Oceanic and Atmospheric Administration.....	135

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

Atlas, David, immediate past president, American Meteorological Society, letter of January 27, 1976.....	225
Brook, Marx, chairman, New Mexico Weather Control and Cloud Modification Commission, New Mexico Institute of Mining and Technology, letter of March 31, 1976.....	291
Butler, Vern W., chairman, North American Interstate Council, letter of February 19, 1976.....	223
Christy, Donald, article.....	227
Hansen, Hon. Clifford P., U.S. Senator from Wyoming, statement.....	188
Johnson, Wendell E., chairman, National Water Policy Committee, American Society of Civil Engineers, letters of April 20, 1976.....	291, 293
Keyes, Conrad G., Jr., North American Interstate Council, letter of February 10, 1976.....	226
Kimball, Thoras L., executive vice president, National Wildlife Federation, letter of March 1, 1976.....	247
McGovern, Hon. George, U.S. Senator from South Dakota, letter of February 23, 1976.....	223
"National Atmospheric Sciences Program", article.....	41
"The Federal Role in Weather Modification", article.....	250
"Weather Modification Activity Reports, 1974", article.....	138

ATMOSPHERIC RESEARCH CONTROL ACT

TUESDAY, FEBRUARY 17, 1976

U.S. SENATE,
COMMITTEE ON COMMERCE,
SUBCOMMITTEE ON OCEANS AND ATMOSPHERE,
Washington, D.C.

The subcommittee met at 2:30 p.m. in room 5110 of the Dirksen Senate Office Building; Hon. James B. Pearson presiding.

OPENING STATEMENT BY SENATOR PEARSON

Senator PEARSON. The committee will come to order.

I am pleased to chair this afternoon's hearing of the Oceans and Atmosphere Subcommittee on three bills, S. 2705, S. 2706, and S. 2707, dealing with weather modification.

I look forward to the testimony of our distinguished witnesses on this important subject. Weather modification is a relatively new and developing science, and its advancement and application to climatic conditions affecting this country are of importance to all.

In particular, the issue of the potential of weather modification programs such as rain enhancement is of immediate relevance with respect to severe drought conditions persisting in the West and Midwest. In my own State of Kansas, the topsoil is so powder dry in some counties that a "dust bowl" disaster is feared when the April winds arrive. Throughout the Farm Belt from Nebraska to Texas, crop production, especially of winter wheat, is seriously threatened by low rainfall.

I am hopeful that the testimony today will explore not only the technical and legal questions as to the practicality of various weather modification activities, but also the problems of coordination among Federal agencies toward implementation of a strong national weather modification policy.

[The bills and agency comments follows:]

Staff members assigned to this hearing: Steven H. Flajser and Gerald J. Kovach.

IN THE SENATE OF THE UNITED STATES

NOVEMBER 20 (legislative day, NOVEMBER 18), 1975

Mr. BELLMON introduced the following bill; which was read twice and referred
to the Committee on Commerce

A BILL

To provide for a study by the Secretary of Commerce of the need for regulation of weather modification activities, the status of current technologies, the extent of coordination and the appropriate responsibility for operations in the field of weather modification, and for other purposes.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*

3 DECLARATION OF PURPOSE

4 SECTION 1. It is the policy of the United States (1)
5 to develop, encourage, and implement, through local, State,
6 Federal, and private efforts, a coordinated, comprehensive,
7 and long-range national program of weather modification for
8 the benefit of mankind through precipitation enhancement,

1 protection from severe storms, and certain other weather
2 modification activities, (2) to encourage the use of tech-
3 niques which have been proven beneficial and to encourage
4 further research to achieve orderly and beneficial uses of
5 weather modification, and (3) to encourage the safeguard-
6 ing and enhancing of agriculture, water supply, energy
7 sources, and the atmospheric environment. To promote this
8 policy, it is first necessary to assess the present technology,
9 organizational structure, funding, and problems associated
10 with the orderly implementation of the emerging science
11 of weather modification. Based on this assessment, a detailed
12 weather modification policy for the United States must be
13 established. Further legislation in this area should be guided
14 by this detailed weather modification policy.

15 SEC. 2. There is hereby established within the Depart-
16 ment of Commerce a National Weather Modification Com-
17 mission (hereinafter referred to as the "Commission").

18 SEC. 3. (a) The Commission shall be composed of nine
19 members to be appointed by the President, not more than
20 two of whom shall be representatives of each of the following
21 categories: the Federal Government, the States, colleges and
22 universities, private industry dealing with weather modifica-
23 tion, and private industry or individuals involved in the pro-
24 duction of agricultural products or energy. The President
25 shall designate one of the members of the Commission as

1 Chairman. In making such appointments, the President shall
2 appoint individuals who are known for their experience and
3 competence in the fields of weather modification research,
4 operational weather modification, agriculture, agricultural
5 economics, energy development, weather modification law,
6 and social-ecological factors. Not more than five members
7 of the Commission shall be members of the same political
8 party and not more than four members shall be from Govern-
9 ment (Federal and State).

10 (b) Any vacancy in the Commission shall not affect
11 its powers and five members of the Commission shall con-
12 stitute a quorum.

13 DUTIES OF THE COMMISSION

14 SEC. 4. (a) The Commission shall undertake a compre-
15 hensive investigation and study of the present state of de-
16 velopment of weather modification technology, the problems
17 impeding effective implementation of weather modification,
18 and other related matters. Such a study shall include, but
19 shall not be limited to—

20 (1) a review of the present and past research efforts
21 to establish the degree of development of operationally
22 useful weather modification technology, particularly as
23 it relates to precipitation enhancement and reduction of
24 damage from severe storms;

25 (2) a review of research needs in weather modifica-

1 tion to establish areas in which more research could be
2 expected to yield the greatest return in terms of oper-
3 ationally useful weather modification technology;

4 (3) a review of existing studies to establish the
5 probable economic importance to the United States and
6 to individual States in terms of agricultural production,
7 energy, and related economic factors if the present
8 weather modification technology were to be effectively
9 applied;

10 (4) a review of the legal, social, and ecological im-
11 plications of expanded and effective research and opera-
12 tional weather modification projects;

13 (5) a review of the status and any required improve-
14 ments of legislation regarding regulation of weather
15 modification activities at all levels of government;

16 (6) a review of the international importance and
17 implications of weather modification activities by the
18 United States including consideration of the potential
19 for use of weather modification for assistance to develop-
20 ing countries which are unable to produce enough food
21 for themselves;

22 (7) a review of present and past funding for
23 weather modification from all sources to determine the
24 sources and adequacy of funding in the light of the needs
25 of the Nation and the individual States;

1 (8) a review of the purpose, policy, methods, and
2 funding of the Federal departments and agencies in-
3 volved in weather modification and a review of the exist-
4 ing interagency coordination of weather modification
5 research efforts.

6 (b) The Commission shall prepare a preliminary report
7 to the President and to the Congress within one year after
8 its organization, followed within six months by a final report
9 which shall amplify the conclusions of the preliminary report.
10 The report shall contain, but shall not be limited to—

11 (1) a summary of its findings in each of the areas
12 of investigation specified in subsection (a) of this
13 section;

14 (2) other findings which the Commission feels are
15 pertinent to a consideration of a national policy on
16 weather modification;

17 (3) a recommended Statement of National Policy
18 on Weather Modification which shall consider (A) the
19 importance of weather modification to the production of
20 agricultural products and energy, to other related eco-
21 nomic factors, and the international implications in the
22 light of its findings, and (B) the roles of all levels of
23 government, the private sector, and the colleges and
24 universities in research and operational weather
25 modification;

1 (4) recommendations and justifications for any
2 changes from the present levels of Federal funding for
3 research and operational weather modification consider-
4 ing the returns to the Nation which might reasonably
5 be expected from the funding changes;

6 (5) recommendations and justifications for any
7 changes in the organization and involvement of Federal
8 departments and agencies in weather modification which
9 may be needed to effectively implement the recom-
10 mended national policy on weather modification;

11 (6) recommendations and justifications for any
12 changes in legislation which may be required to imple-
13 ment and regulate weather modification policies along
14 the lines of the national weather modification policy
15 statement.

16 POWERS OF THE COMMISSION

17 SEC. 5. (a) The Commission or, on the authorization of
18 the Commission, any subcommittee or members thereof, may,
19 for the purpose of carrying out the provisions of this Act,
20 hold such hearings, take such testimony, and sit and act at
21 such times and places as the Commission deems advisable.
22 Any member authorized by the Commission may administer
23 oaths or affirmations to witnesses appearing before the Com-
24 mission or any subcommittee or members thereof.

1 (b) Each department, agency, and instrumentality of
2 the executive branch of the Government, including independ-
3 ent agencies, is authorized and directed to furnish the Com-
4 mission such information as the Commission deems necessary
5 to carry out its functions under this Act.

6 (c) Subject to such rules and regulations as may be
7 adopted by the Commission, the Chairman shall have the
8 power to—

9 (1) appoint and fix the compensation of an execu-
10 tive director, and such additional staff personnel as he
11 deems necessary, without regard to the provisions of title
12 5, United States Code, governing appointments in the
13 competitive service, and without regard to the provisions
14 of chapter 51 and subchapter III of chapter 53 of such
15 title relating to classification and General Schedule pay
16 rates, but at rates not in excess of the maximum rate for
17 GS-18 of the General Schedule under section 5332 of
18 such title, and

19 (2) procure temporary and intermittent services to
20 the same extent as is authorized by section 3109 of title
21 5, United States Code, but at rates not to exceed \$150
22 per day for individuals.

23 (d) The Commission is authorized to enter into con-
24 tracts with Federal or State agencies, private firms, institu-

1 tions, and individuals for the conduct of research or surveys,
2 the preparation of reports, and other activities necessary to
3 the discharge of its duties.

4 (e) The General Services Administration shall provide
5 administrative services for the Commission on a reimbursable
6 basis.

7 COMPENSATION OF MEMBERS

8 SEC. 6. Members of the Commission, other than mem-
9 bers who are officers or employees of the Federal Govern-
10 ment, shall receive compensation at the rate of \$150 per
11 day for each day they are engaged in the performance of
12 their duties as members of the Commission. All members
13 shall be entitled to reimbursement for travel, subsistence, and
14 other necessary expenses incurred by them in the perform-
15 ance of their duties as members of the Commission.

16 DEFINITIONS

17 SEC. 7. As used in this Act—

18 (1) The term "weather modification" means any
19 artificially produced changes in the composition, be-
20 havior, or dynamics of the atmosphere.

21 (2) The term "atmospheric environment" includes
22 that portion of air and airborne particles surrounding the
23 Earth and bound to the Earth more or less permanently
24 by virtue of gravitational attraction, and includes any
25 resources contained therein.

1 (3) The term "weather modification activity"
2 means the use of any weather modification apparatus or
3 weather modification agent to attempt any weather
4 modification.

5 APPROPRIATIONS AUTHORIZED

6 SEC. 8. There is hereby authorized to be appropriated
7 such sums as may be necessary, not to exceed a total of
8 \$750,000 to carry out the provisions of this Act.

9 TERMINATION

10 SEC. 9. On the ninetieth day after the date of submission
11 of its final report to the President and to the Congress, the
12 Commission shall cease to exist.

S. 2706

NOVEMBER 20 (legislative day, NOVEMBER 18), 1975

Mr. BELLMON introduced the following bill; which was read twice and referred to the Committee on Commerce

To authorize and direct the Secretary of Commerce to plan and carry out an experimental research program to determine the feasibility of and the most effective methods for drought prevention and alleviation by weather modification.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*

DECLARATION OF PURPOSE

SECTION 1. The Congress hereby finds and declares that the multistate nature of climatic and related phenomena, the severe economic hardships experienced as the result of occasional drought and other adverse meteorological conditions, and the existing role and responsibilities of the Federal Government with respect to disaster relief, require appropriate

1 Federal action to assist the States in attempting to prevent
2 or alleviate such actual or potential adverse meteorological
3 conditions. It is therefore the policy of the United States—

4 (1) to determine the means by which purposeful
5 weather modification can be used to decrease the impact
6 of drought on agriculture, energy resources, water sup-
7 plies, economic growth, and the general public welfare;

8 (2) to conduct experimental research into those
9 scientific areas considered most likely to provide opera-
10 tionally useful techniques for drought prevention or
11 alleviation;

12 (3) to develop operationally useful methods and
13 devices for weather modification;

14 (4) to transfer weather modification knowledge, as
15 it is developed, to those agencies, States, private com-
16 panies, or associations who may seek to use the knowl-
17 edge for the benefit of mankind; and

18 (5) to assess the economic, social, environmental,
19 and legal impact of an operational weather modification
20 as it is developed.

21 DEFINITIONS

22 SEC. 2. As used in this Act—

23 (a) The term “Secretary” means the Secretary of
24 Commerce.

25 (b) The term “weather modification” means any ac-

1 tivity performed with the intention of producing artificial
2 changes in the composition, behavior, or dynamics of the
3 atmosphere.

4 (c) The term "State" includes the several States, the
5 District of Columbia, the Commonwealth of Puerto Rico and
6 any territory or insular possession of the United States.

7 SEC. 3. (a) The Secretary is authorized and directed to
8 carry out a ten-year experimental research effort to deter-
9 mine the feasibility and define the conditions for decreasing
10 the effects of drought through weather modification. The re-
11 search program shall cease and a final report to the Congress
12 and the President shall be due ten years after the date of
13 this Act unless an extension is specifically authorized by
14 Congress.

15 (b) To obtain the benefits of the best available scientific,
16 technical, and operational knowledge and advice in carrying
17 out and evaluating the above program, the Secretary shall
18 appoint an Advisory Board of not more than six persons who
19 possess knowledge and experience in weather modification
20 research or operations, meteorology, agriculture, and other
21 related fields and who are from States where weather mod-
22 ification research or operations are frequently conducted.
23 The Secretary shall appoint members representing the Fed-
24 eral Government, State, or local government and private
25 companies or associations dealing in weather modification

1 research or operations. Not more than two members of the
2 Board shall be employees of the United States. The Secre-
3 tary shall appoint a Chairman every two years. The Board
4 members shall serve for three-year staggered terms and may
5 not serve more than six years. The Board shall make policy
6 decisions regarding research priorities and shall recommend
7 methods for conduct and evaluation of the research effort.
8 Members of the Board who are not full-time employees of the
9 United States Government, while serving on the business of
10 the Board, may receive compensation at the rate of not more
11 than \$150 per diem plus their travel expenses, including
12 per diem in lieu of subsistence, as authorized by section 5703
13 of title 5, United States Code, for individuals in the Govern-
14 ment employed intermittently.

15 (c) The Secretary shall draw upon the capabilities and
16 expertise of other agencies where practical to avoid dupli-
17 cation of efforts.

18 (d) The Secretary shall insure that the capabilities of
19 the private sector shall be utilized, where appropriate, in the
20 conduct of the field operations and studies in the above
21 experimental program.

22 (e) The Secretary shall consult with State and local
23 officials representing those areas in which operations may
24 be conducted. The Secretary is authorized to negotiate agree-
25 ments or contracts with States or local governments to assure

1 continuity of an experimental area during the period of the
2 field operations. As part of the conditions of these agree-
3 ments, the Secretary may agree to suspend experimental
4 operations during times when the Governor of a State in
5 which research operations are conducted declares that an
6 emergency drought situation exists so that the State or local
7 agencies may conduct operational drought alleviation meas-
8 ures.

9 (f) During the course of the above program, the Secre-
10 tary shall establish a mechanism for providing consultation
11 to State and local governments who wish to mount weather
12 modification drought alleviation efforts of their own, so that
13 such efforts may be carried out using the latest scientific
14 information available.

15 (g) The above program shall include the use of adequate
16 safeguards to govern operations during potential or existing
17 hazardous weather conditions and interference with ongoing
18 Federal weather modification projects. Such safeguards shall
19 be reviewed by the Advisory Board and shall be discussed
20 with governmental officials representing the public in areas
21 where the above program will be conducted.

22 (h) The Secretary shall conduct concurrent studies of
23 the social, environmental, economic, and legal impacts of the
24 use of weather modification for drought alleviation.

25 (i) The Secretary shall choose one or more experimental

1 sites in regions of the United States in which drought is fre-
2 quently a major limiting factor for agricultural production
3 and where water supplies for municipal and other uses are
4 often curtailed by drought.

5 REPORTS

6 SEC. 4. The Secretary shall submit reports annually to
7 the Congress and the President on (1) his progress in devel-
8 oping effective means of drought alleviation or prevention
9 through weather modification, (2) summaries of other re-
10 lated developments on a worldwide scale, (3) his efforts to
11 transfer the latest scientific drought alleviation information to
12 users, (4) the problems facing effective utilization of weather
13 modification for drought alleviation, and (5) his plans to
14 overcome those problems. A final report shall be due ten
15 years after the enactment of this legislation unless an exten-
16 sion of the experimental program is specifically authorized by
17 Congress.

18 APPROPRIATIONS AUTHORIZED

19 SEC. 5. There are authorized to be appropriated to carry
20 out the purposes of this section, \$1,500,000 for the first fiscal
21 year, and such sums as are necessary, not to exceed \$10,000,-
22 000 for each successive fiscal year, to remain available until
23 expended. This authorization is not intended to limit the
24 availability of funds for other weather modification activities
25 carried out by the Secretary.

94TH CONGRESS
1ST SESSION

S. 2707

IN THE SENATE OF THE UNITED STATES

NOVEMBER 20 (legislative day, NOVEMBER 18), 1975

Mr. BELLMON introduced the following bill; which was read twice and referred to the Committee on Commerce

A BILL

To authorize the Secretary of Commerce to carry out a program of assistance to States in preventing and alleviating drought emergencies.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*
3 That the Congress hereby finds and declares—

4 (a) that the multistate nature of climatic and
5 related phenomena, the severe economic hardships ex-
6 perienced as the result of occasional drought and other
7 adverse meteorological conditions, and the existing role
8 and responsibilities of the Federal Government with re-
9 spect to disaster relief, require appropriate Federal action
10 to assist the States in attempting to prevent or alleviate

1 such actual or potential adverse meteorological condi-
2 tions; and

3 (b) that although substantial limits and uncertainties
4 still exist with respect to the state of the art of weather
5 modification, the extensive damage and adverse economic
6 impact which may result from drought and other adverse
7 meteorological conditions dictate that the Federal Gov-
8 ernment provide appropriate assistance to those States
9 that desire to use existing technology to attempt to pre-
10 vent or alleviate such damaging conditions.

11 SEC. 2. DEFINITIONS.—As used in this Act—

12 (a) The term “Secretary” means the Secretary of
13 Commerce.

14 (b) The term “approved State program” means a pro-
15 gram developed by a State, or by two or more States jointly,
16 for the prevention or alleviation of drought conditions, which
17 has been approved by the Secretary.

18 (c) The term “weather modification” means any ac-
19 tivity performed with the intention of producing artificial
20 changes in the composition, behavior, or dynamics of the
21 atmosphere.

22 (d) The term “State” includes the several States, the
23 District of Columbia, the Commonwealth of Puerto Rico
24 and any territory or insular possession of the United States.

25 SEC. 3. (a) The Secretary, upon application by a State

1 or States, is authorized to provide financial assistance in
2 implementing approved State programs in any area in which
3 it is shown, in accordance with criteria promulgated by the
4 Secretary, that there is a reasonable likelihood or actual
5 existence of drought conditions which could cause damage
6 to crops, lower water supplies, or otherwise cause substantial
7 economic hardship; criteria shall include rainfall, soil mois-
8 ture conditions, meteorological and hydrological forecasts,
9 and other related factors.

10 (b) The Secretary may hold public hearings when he
11 deems it appropriate to determine the views of local or near-
12 by interests in considering any application for assistance
13 with respect to a drought alleviation or prevention program.

14 (c) Assistance under this Act shall be made available
15 in the form of financial grants to States or political subdivi-
16 sions thereof, or organizations approved by the Secretary,
17 for the purpose of assisting and initiating weather modifica-
18 tion measures designed to prevent or alleviate drought con-
19 ditions. The total amount of such grant payments by the
20 Secretary in any fiscal year shall not exceed 50 per centum
21 of the total cost during that period of implementing such
22 drought alleviation or prevention program.

23 (d) Financial assistance under this Act shall be allo-
24 cated among the various States in accordance with guide-
25 lines established by the Secretary.

1 SEC. 4. The Secretary is authorized and directed to
2 coordinate with all appropriate Federal and State agencies,
3 and with private firms, institutions, and individuals known
4 to be authorities in the science of weather modification and
5 related fields, in monitoring and evaluating the results of any
6 assistance granted under the provisions of section 3 of this
7 Act.

8 SEC. 5. The Secretary is authorized to promulgate such
9 rules and regulations as may be necessary to carry out the
10 purposes of this Act.

11 SEC. 6. There are authorized to be appropriated such
12 sums as may be necessary to carry out the purposes of this
13 Act, not to exceed \$5,000,000 for each fiscal year, to remain
14 available until expended.

DEPARTMENT OF THE INTERIOR,
OFFICE OF THE SECRETARY,
Washington, D. C., February 18, 1976.

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

DEAR MR. CHAIRMAN: This responds to your request for this Department's views on S. 2705, a bill "To provide for a study by the Secretary of Commerce of the need for regulation of weather modification activities, the status of current technologies, the extent of coordination and the appropriation responsibility for operations in the field of weather modification, and for other purposes"; S. 2706, a bill "To authorize and direct the Secretary of Commerce to plan and carry out an experimental research program to determine the feasibility of and the most effective methods for drought prevention and alleviation by weather modification"; and S. 2707, a bill "To authorize the Secretary of Commerce to carry out a program of assistance to States in preventing and alleviating drought emergencies."

THE BILLS

S. 2705

S. 2705 would establish in the Department of Commerce a National Weather Modification Commission charged with the responsibility of reviewing activities of the various Federal agencies involved and making a report to the President and to the Congress within 1 year after its organization. Upon submission of the report to the President and to the Congress, the Commission would be disbanded. Unlike S. 2706 and 2707 which are chiefly concerned with weather modification activities for agricultural purposes, S. 2705 is broader in scope.

During the past year, the Domestic Council, through its Environmental Resources Committee's Subcommittee on Climate Change, has undertaken an extensive study of the role of the Federal Government in weather modification. Although composed of representatives from several Government agencies, the subcommittee examined all available documentation on the progress, status, and problems in weather modification, and conducted upon hearings to hear from well-informed representatives of the scientific community, commercial sector, State governments, conservation groups, agriculturalists, and the legal field. It would appear that the study proposed by S. 2705 would duplicate the work of the Domestic Council and several other reports; however, considering time lapse for passage of the bill, formation of the commission, and study time, reports would not be completed before 1978, when further assessment of a rapidly developing technology would be needed.

If the Congress should decide to establish such a commission, however, it should not be located in any mission agency, but should be completely independent. This would provide maximum flexibility and the best opportunity for an effective review and unbiased recommendations.

The Department, through the Bureau of Reclamation, the Office of Water Research and Technology, and its Power Administrations, has one of the largest research programs, has conducted emergency drought programs, is already providing scientific assistance to statewide programs, and is one of the major mission agencies concerned with future operational application of the technology for beneficial purposes.

S. 2706

S. 2706 would establish a research and development program to provide useful weather modification techniques for drought prevention or alleviation, including an assessment of the economic, social, environmental, and legal impact of these techniques operationally.

We oppose passage of this bill.

S. 2706 authorizes and directs the Secretary of Commerce to plan and carry out an experimental research program in which the Department of the Interior has a primary interest and ongoing research activity. The proposed research appears to be duplicative of the research being conducted under the Bureau of Reclamation's Atmospheric Water Resources Management Program.

The Bureau of Reclamation, as the principal water resources management and development agency in the Department of the Interior, was directed by the Congress in 1961 to develop cloud seeding techniques which could be utilized to augment water supplies, particularly in water-short areas of the Nation.

Project Skywater, as the research program is known, represents an expertise and capability in-being for weather modification activity that are currently devoted to investigation for advancing the effectiveness of this technology.

The High Plains Cooperative Experiment (HIPLEX), now underway at three sites in the drought-prone High Plains area, is aimed at developing and evaluating improved techniques for seeding more types of clouds, particularly groups of clouds, in the spring and summer months, and establishing a practical working technology capable of increasing precipitation to stabilize and augment agricultural economies and to help ameliorate the adverse effects of drought. HIPLEX also includes extensive studies of the socio-economic, ecological, legal, hydrological, and environmental aspects of precipitation management. The Bureau is also developing and testing management concepts that include the type of local-State-Federal cooperation and private industry participation needed for research-supported operational activities in precipitation management. This program will ultimately provide the increases in scientific understanding and verification of techniques that are definitely needed.

We note that considerable expertise of the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) in the field of weather modification is also a valuable asset, which should be utilized to the maximum extent possible to further progress in developing and applying this relatively new technology. In this respect, NOAA has a primary interest itself in the development and application of weather modification techniques for the purpose of abating the adverse impact of severe storms and in the area of inadvertent weather modification and its effects on weather and climate.

We believe both programs are now supportive of each other and achieve an effective, economical, and coordinated program, and is a valuable tool in helping to solve some of the Nation's water resources problems.

The proposed legislation authorizes appropriations of approximately \$91,500,000 over a period 10 years, which we believe to be excessive.

S. 2707

S. 2707 would provide matching Federal funds to support approved State programs for drought relief or prevention through the use of existing weather modification technology. It would also provide for monitoring and evaluation of results by the Department of Commerce in coordination with other groups known to be authorities in the science of weather modification.

We do not support this bill.

There are still many scientific uncertainties in the science of cloud seeding, especially in seeding warm cumulus clouds and during drought conditions. There are also many questions to be resolved in this form of aid, including: (a) balancing of risks and benefits, (b) downwind impacts and emotional factors which become much more critical during drought, (c) whether the overall public interest and welfare are adequately safeguarded, (d) the effects of such aid on critical ongoing and future research efforts, and (e) whether funds should also be made available for similar assistance to States or local governments with whether modification programs in water resources development for purposes other than drought relief. Coordination, both technical and operational, of State programs becomes a central question and the impact of Federal aid may also bring Federal regulation. We believe it is necessary to provide a planning and study phase to address some of these questions before approving and funding such a full-scale operational program. We also believe that the efforts initiated in this bill should be better coordinated with existing programs and studies being conducted in various agencies, so that we may more efficiently address the problems involved.

For the reasons stated above, we oppose S. 2705 at the present time, and we strongly oppose S. 2706 and S. 2707.

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

Sincerely yours,

NATHANIEL P. REED,
Assistant Secretary of the Interior.

Senator PEARSON. As our first witness, then, I call my distinguished colleague from Oklahoma, Senator Bellmon.

STATEMENT OF HON. HENRY BELLMON, U.S. SENATOR
FROM OKLAHOMA

Senator BELLMON. Thank you. I want to express my appreciation to you for providing me the opportunity of participating here.

It is a pleasure to testify before the Commerce Committee on an issue so vital to American agriculture. I commend the distinguished senior Senator from Kansas for holding hearings on these three weather modification bills.

Once again, Western States are suffering from a severe drought that may substantially decrease U.S. food production if rains do not soon fall.

Not only will the grain available for export be decreased, but many farmers and ranchers will face financial ruin. Problems with production may be further compounded by the severe erosion of the land due to a lack of vegetative cover, which often permanently diminishes the soil's productivity.

The effects of drought are not confined to the agriculture sector. The U.S. Treasury is also adversely effected. The Agricultural Stabilization and Conservation Service paid more than \$500 million to farmers under the disaster clause of the 1973 Agriculture and Consumer Protection Act for drought relief on 1974 wheat, cotton, and feed grain production.

In 1973, the Farmers Home Administration made \$557 million in disaster loans to the agricultural sector due to unfavorable weather conditions. Approximately 70 percent of these were forgiveness loans, with the remainder of the loans being made at 1 percent. An expenditure of up to \$5 million for operational weather modification annually would save the treasury many millions of dollars as well as preventing widespread hardships.

Clearly, Mr. Chairman, there is a need to increase rainfall in most agricultural States. This year western Kansas is a prime example of an area where grain production will be severely diminished because of drought.

An extra inch of rain at the right time can often make the difference between an average crop and failure in a dry year. A successful weather modification program may not totally prevent drought, but can lessen the severity of the droughts and significantly increase crop production.

Weather modification has been a reality for 25 years. The great potential benefits to be derived from weather modification have not occurred because the Federal Government, which has financed most of the work, has failed to organize itself to give its resources maximum impact.

S. 2705 would create a weather modification Commission to study the need for coordination of weather modification activities, the status of current technologies, the extent or coordination and appropriate responsibilities for operations in the field of weather modification. Basically, the Commission would determine what is being done in weather modification and what more needs to be done.

S. 2707 would authorize the Secretary of Commerce to carry out a program of assistance to States in preventing and alleviating drought emergencies. Our present programs are always too little and too late. What is needed is a program authorizing weather modification when a drought threatens and before crops are ruined.

The Oklahoma Water Resources Board has testified before the Senate Committee on Agriculture and Forestry that a \$250,000 expenditure for cloud seeding in five southwestern Oklahoma counties in 1972 produced a 20 to 1 benefit to cost ratio in terms of increased crop production alone.

Dr. Merlin Williams, who was then State director of the South Dakota State weather modification program testified that a program in that State produced a 30 to 1 benefit to cost ratio in increased crop production.

In a time when agriculture crop production is becoming increasingly important, the United States must effectively use the technology we have to maintain our upward trend in production.

S. 2706 would authorize and direct the Secretary of Commerce to plan and carry out an experimental research program to determine the feasibility of and the most effective methods for drought prevention and alleviation by weather modification.

Mr. Chairman, again I commend you for your promptness in calling these hearings. It is unfortunate that an operational weather modification program is not now in operation in this crop year in the Western States. Hopefully, by passage of these bills, the severity of this kind of drought may be prevented in the future.

Senator PEARSON. Thank you, Senator Bellmon.

We have several witnesses here from the State of Oklahoma. I wonder if you would be good enough to introduce them at this time, and ask them to all come forward and to present their testimony in a panel form.

Senator BELLMON. Thank you.

Our first witness is Mr. Glenn Sullivan who represents the Benham Blair & Affiliates in Oklahoma City. Also, Mr. Hoyt Shadid, formerly the mayor of Altus, and Dr. Ray Booker from Norman, who operates a weather modification company.

Is Dr. Booker here?

Mr. SULLIVAN. I think he got lost.

Senator PEARSON. Well, we'll hear him when he gets here.

We appreciate your being willing to participate, and make a contribution to this record today, and as I indicated, we started late in the afternoon for hearings. We have a large number of witnesses.

If you could accommodate those that are to follow you with short statements, it would be appreciated.

STATEMENT OF GLENN SULLIVAN, VICE-PRESIDENT AND DIRECTOR OF WATER, WASTEWATER, AND ENVIRONMENTAL SERVICES FOR BENHAM BLAIR & AFFILIATES, INC.

Mr. SULLIVAN. Thank you, Mr. Chairman. I will be brief.

I am Glenn Sullivan, vice-president, and director of water, wastewater, and environmental services for Benham Blair & Affiliates,

Inc., an international architectural engineering firm with corporate offices in Oklahoma City.

Prior to joining Benham Blair & Affiliates, I was assistant director of the Oklahoma Water Resources Board, and director of the Department of Pollution Control for the State of Oklahoma.

During the late 1950's, I had the honor of working for the late Senator Robert S. Kerr and the Senate Select Committee on Water Resources.

The surface water within our State has been appropriated in the western half of the State. There is no future development possible in our streams in western Oklahoma.

There is sufficient quantities of good quality water, however, in eastern Oklahoma.

The people in western Oklahoma, however, do have some relief in the form of ground water. This is also true in the Texas high plains area, Colorado, and Kansas, as you are well aware.

However, therein lies some of the problems.

The red flags are starting to fly—90 percent of the municipalities in Oklahoma being supplied water from ground water and 72 percent of the irrigation is provided from ground water.

This has created quite a problem. In the panhandle of Oklahoma, the water table has dropped 66 feet since 1938. The alarming thing is that it has dropped 44 feet since 1966.

The reason for this is the fact that irrigation has developed since 1950, from 200 wells to over 2,000 wells.

At the present time, the water resources board in Oklahoma has concluded their phase 1 report for the feasibility of a water supply program for the State of Oklahoma.

In that phase 1 report, it has been identified that water can be transferred from eastern Oklahoma to western Oklahoma in an effort to satisfy the present, as well as future water needs of our State.

The cost of such a program has been estimated to be \$87 per acre-foot of water transferred to southwestern Oklahoma.

Let's compare, if you will, that \$87 to the estimated cost of a weather modification program, which provides water for something in the neighborhood of \$2.50 per acre-foot.

It can readily be seen that the economics for weather modification is certainly there, if we can identify all the problems and establish a program in which everyone can cooperate.

We don't feel that weather modification is the only answer for providing the water to the area whose ground water will be depleted in 20 to 30 years' time. We think the economic advantage where this cost of \$2.50, as compared to \$87 per acre-foot certainly warrants full consideration.

It is recommended that the Federal Government become more involved in the operation of weather modification projects, and programs such as envisioned in S. 2705, S. 2706, and S. 2707.

We thank you for the opportunity to share with you some of the problems which we constantly face, and how weather modification can help to alleviate the extreme drought conditions, and subsequent Federal expenditures for disaster relief.

I will be happy to answer any questions at the appropriate time.
 Senator PEARSON. Thank you very much.

It's my understanding that generally speaking, the States haven't been very active in weather modification, that the efforts they have been making have been those that you have described, the underground water levels, et cetera.

Senator Bellmon, do you have any questions?

Senator BELLMON. Yes, Mr. Chairman. Can you describe what's going on in the State of Oklahoma as far as weather modification is concerned?

Mr. SULLIVAN. Senator, about 4 years ago—August 1971—the first real program was initiated at the time of an extreme drought. At that particular time, as we reported in hearings back in 1972, or 1973, something like a 20 to 1 benefit-cost ratio was realized in those emergency operations in the southwestern five counties.

Since that time, State laws have been passed authorizing the organization of weather modification districts. There has been an attempt from time to time to seek appropriations at the State level to assist communities in weather modification.

However, as you are well aware, considerable remarks come out in the news media about who knows what, about weather modification.

In North Dakota and South Dakota, their programs have been very active and all indications are that their results are commendable.

Senator BELLMON. When a program is undertaken, are you aware of any efforts to monitor the results and to try to determine what the effects are, and what this produces?

Mr. SULLIVAN. That's difficult to answer. I know Dr. Booker has that. He has worked directly in this particular area. I haven't seen Dr. Booker come in. But, I would rather refer that to him.

Senator BELLMON. You made the point that the water table is dropping in Oklahoma. This is also true in Texas and Kansas. You mentioned also that it will cost some \$87 per acre-foot to transfer water into that area.

Is it your thought that we should go ahead now and attempt weather modification to see if it does alleviate drought problems and then perhaps make water transfer unnecessary?

Mr. SULLIVAN. I don't believe that it will make water transfer unnecessary. But we have contended in the preparation of Oklahoma's comprehensive water plan that if 10 percent of the needs can be met through weather modification programs, where the cost is, say, \$2.50 an acre foot, just from the monetary standpoint alone, you can see the benefits, let alone the energy that could be saved if you had to take the water all the way across.

So, we think that weather modification is a part of the long-range comprehensive water supply system, not only for Oklahoma, but for the 17 Western States where water shortages exist.

Senator BELLMON. You have talked a lot about the rainfall. Are there other benefits from weather modification?

Mr. SULLIVAN. First of all, the needs in meeting the needs of the agricultural people, and the agricultural benefits alone.

For instance, the city of Altus has been active in weather modification. The city of Lawton has launched considerable programs in

this area. Certainly, the mayor would be able to attest to the benefits of water supply from municipalities alone.

Senator BELLMON. What about such things as hail suppression?

Mr. SULLIVAN. That has been a commendable program, and I think the desired results have been shown there; yes, sir.

Senator PEARSON. You said that the State passed a law providing for weather modification districts. I think I heard you indicate that you had had trouble getting appropriations to implement the program.

One of Senator Bellmon's pieces of legislation provides for matching funds. What sort of an influence would that have upon the State legislature?

Mr. SULLIVAN. I think it would have a dynamic influence. Most of those districts have had ongoing programs where they were financing weather modification at the rate of 4 to 5 cents per acre. And that's strictly voluntary.

The reason that this problem exists today in western Oklahoma is that, of course it's sort of like that hydroillogical cycle you have seen when you are in a rainy season, it's hard to understand why you need another continuing program of weather modification, plus the attitude of the people if you will, about what is the best procedure, that has lent itself to the problems of them continuing this program.

I know there has been three areas that had failed to continue support of the local program. I feel as though with a 50-50 cost share program in, it would be an incenive for those people to get back on the bandwagon, and I feel that the State would be in a position to finance the other 50 percent with a program of this nature.

[The statement follows:]

STATEMENT BY GLENN SULLIVAN, VICE PRESIDENT,
BENHAM BLAIR & AFFILIATES, INC.

Mr. Chairman, distinguished members of the committees, ladies and gentlemen, it is a real pleasure for me to appear before you today and relate to you the status of water resources in Oklahoma.

I am Glenn Sullivan, vice president and Director of Water Wastewater, and Environmental Services for Benham Blair & Affiliates, Inc., an international Architectural Engineers Firm with Corporate offices in Oklahoma City. Prior to joining Benham Blair & Affiliates, I was assistant director of the Oklahoma Water Resources Board and director of the Department of Pollution Control for the State of Oklahoma.

During the late 1950's I had the honor of working for the late Senator Robert S. Kerr and the Senate Select Committee on Water Resources.

Since I was born and raised in Western Oklahoma where there is continuing concern about drought conditions, and Water resource problems, my interest in management and planning came natural.

Undoubtedly, everyone understands that we will have to be operating under a comprehensive water supply system in the years to come if we are in fact able to supply the needs for tomorrow.

"All the rivers run into the sea; yet the sea is not full; into the place from whence the rivers, thither they return again." Ecclesiastes, Chapter 1, Verse 7.

This biblical quotation by Solomon is a description of what we call the water cycle. This unending cycle has been going on since time began. No puny efforts of man have changed it in the least. The amount of our water supply has not increased since the beginning of time. Mother Eve might have taken shelter under an apple tree from a rainstorm containing some of the same water which you used in your shower this morning.

The amount is the same as the Romans had when they built the aqueducts: however the quantity of water we need and use as individuals has increased tremendously. That wouldn't be so frightening, but the number of individuals has increased astoundingly.

Some people have even referred to the water we had this morning as being bathed in by Cleopatra some 2,000 years ago, and if you happen to live in some areas of Oklahoma, you might even say it tastes like it.

The collection of rainfall and runoff data provides a means of predicting the reoccurrence of the water cycle. Oklahoma's records show that the average annual rainfall varies from 15 inches in the northwest to 60 inches in the southeast corner of the state. Generally the people in Northwest Oklahoma can tell you the day that the 15 inches came. Data such as this has been compiled and is available for the entire United States.

The annual runoff averages from a quarter of an inch in the Panhandle to over 100 tons or 20 inches in eastern Oklahoma. This information has been obtained by maintaining some 165 stream gauging stations located throughout the state.

The quality of water existing throughout Oklahoma is generally poor to fair in the western half of the state and varies from extremely good to fair in the eastern part of the state.

All of this information has been published in twelve publications entitled, "Regional Appraisals of the Water and Related Land Resources of Oklahoma". Upon the completion of the appraisals of water and related land resources, and evaluation of the water rights situation can readily be made. If there were an imaginary line up and down the center dividing the state in half, the western part of Oklahoma would be in extremely poor condition, since virtually all of the streams in that area are either fully appropriated and no water available, or there is water available, but it is unusable because of natural pollution. The ground water situation in Oklahoma is much better for those in the western part of the state, however, the red flags are starting to fly. For instance, there have been twelve communities in southwestern Oklahoma that have had well failures within the last three years time, and it became essential for those communities to haul water. In the Panhandle Northwest Oklahoma, there are two locations where the water table has dropped over 66 feet since 1938. The alarming thing is that the water table has dropped over 44 feet since 1966. The reason? In 1950 there were less than 200 wells in the three Panhandle counties of Oklahoma, and today there are over 2,000 wells.

As a result of the basic data collection programs, and the public cry of concern, the Oklahoma Legislature directed the completion of the Feasibility Level Study for the 33 counties in southern Oklahoma. The 44 counties in northern Oklahoma were to retain a reconnaissance level survey. The total projected water requirements for Oklahoma will increase from 2 million acre feet in 1976 to 6 million acre feet in 2020, and roughly 10 million acre feet by the year 2070.

As director of Oklahoma's planning program for the development of a long range comprehensive water supply system for the entire state, I had the opportunity of coordinating the state Water Resources activities with the U.S. Army Corps of Engineers, the U.S. Department of Interior's Bureau of Reclamation and Geological Survey, and the U.S. Department of Agriculture Soil Conservation Service.

Completed in September 1975, the Phase I report of the Oklahoma Comprehensive water plan calls for the construction of an Interconnected system of reservoirs which will supply surplus water from Southeast Oklahoma to Central and Southwest Oklahoma. The Interconnected system will transport 1.3 million acre-feet of water annually. Irrigation water for Southwestern Oklahoma, when computed interest free under Reclamation Law, will cost \$87 per acre-foot delivered to the farms. It is estimated that annual direct and indirect benefits will be about \$521 per acre. Additional economic studies conducted both in Oklahoma and Texas indicate that for each \$1 in agriculture products generated, \$2 is generated locally and \$7 to \$11 is generated nationally.

In view of the worlds demand for food and fiber, we cannot and must not limit ourselves to traditional approaches and solutions because the problem we face is not a traditional one. Augumentation of water supplies through such

means as weather modification, as well as interbasin transfer of water must be considered and has been a part of Oklahoma's Comprehensive Water Supply Systems since the early planning phases.

In 1972 cloud seeding activities in five Southwestern counties in Oklahoma produced an estimated 20 to -1 benefit cost ratio in terms of increased crop production alone. North Texas, the Panhandle of Oklahoma and Kansas are experiencing the driest fall and winter since 1922. Tom Ford, Oklahoma Commission of Agriculture and Don Dudley Executive Director of the Oklahoma Wheat Commission have estimated that the present drought has caused a reduction in business volume and tax collections amounting to \$377 million for the 1976 wheat crop even though a record 7½ million acres was planted. The tragedy is even greater because activation of a large scale weather modification program costing \$1.5 to \$2.0 million dollars could have alleviated the severeness of the drought, saving many acres of wheat that are now being plowed under.

We in Oklahoma don't feel that weather modification is the only answer for providing water to an area whose ground water will be depleted in 20 to 30 years time. We do think that the economic advantages of weather modification where the cost is \$2.50 per acre foot as compared to \$87 per acre foot for interbasin transfer warrants full consideration.

Gentlemen, who can really measure the price of water when there isn't enough.

It is recommended that the Federal Government become more actively involved in the operation of weather modification projects and programs such as envisioned in S. 2705, S. 2706 and S. 2707.

It is further noted that local Control with Federal assistance has been included in the proposed program.

We thank you for the opportunity to share with you some of the problems which we constantly face and how weather modification can help to alleviate extreme drought conditions and subsequent Federal expenditures for disaster relief.

Senator PEARSON. All right. Now we will hear from Mr. Shadid.

STATEMENT OF HOYT SHADID, DISTRICT MANAGER, MOUNTAIN PARK MASTER CONSERVANCY DISTRICT, ALTUS, OKLA.

Mr. SHADID. Thank you, Mr. Chairman. My name is Hoyt Shadid. I reside in Altus, Okla., and am now serving as district manager for the Mountain Park Master Conservatory District, which, upon completion, hopefully will serve municipal and industrial water to the cities of Altus, Frederick, and Snyder, Okla.

Immediately prior to my assuming the duties of district manager, I served for six terms as mayor of the city of Altus. I am a former president of the State of Oklahoma Municipal League and served as chairman of the Oklahoma Community Affairs and Planning Commission.

I do not appear here this afternoon as a particular expert in any field, but as a person who had had a number of opportunities to observe the tears, the heartaches, and the shambles which a drought can produce, and the productivity and security that only rain can make possible.

In the middle 1930's when I was attending high school, we were taught that civilization would last only as long as the top 6 inches of soil, that the roots of civilization were no deeper than the topsoil. This really got my attention, for back there in the 1930's I thought a number of times that civilization had blown clear out of Oklahoma.

All of us now know that because of new technology, herbicides, and fertilizers, man has succeeded in making the barren deserts be-

come most fruitful. Today, man's future is fused to the availability of water.

During my tenure as mayor of the city of Altus, it was necessary a number of times to ration our municipal water. Our main source of supply comes from Lake Altus, some 18 miles to the north of us. When full, it holds 145,000 acre-feet, and in recent years we have seen it with less than 10,000 acre-feet of water.

Under construction at this time is the Tom Steel Reservoir which will help our immediate area provided we are able to receive the rainfall. Also under construction in Altus, Okla., is a water treatment facility designed so that with an additional small outlay of capital expense it will have the capability of treating water which could supply the cities of Duke, Eldorado, Olustee, and Martha. All have an acute water problem because of drought.

Gentlemen, out of 20 billion tons of water that flows daily over the continental United States, borne by prevailing west to east winds, only 10 percent is deposited as snow or rain on land areas, Altus experienced its worst drought in history. We had a total rain-and that which falls is unevenly distributed. In 1970, the city of fall of 14.10 inches for the year. Having practically burned up, we were fortunate a few months later to have the Bureau of Reclamation come in 1971. I personally witnessed them seeding clouds, and I personally witnessed the rains that came.

We received 10 inches of rain in September of 1971. It took care of our immediate problem. Today, weather modification is a reality. I have personally witnessed the seeding of clouds and the desired results which were obtained.

America's greatness lies in the fact that we place value on every human individual. It is a matter of historic record that our Government endeavors to respond to the needs of the people. As we experience droughts, floods, storms, and tornadoes, our Government spends vast sums of money to assist the victims of such tragic happenings.

Gentlemen, a weather modification program correctly implemented, can alleviate many of the hardships and effects created by offensive weather, not to mention the savings of untold billions of dollars. Without any mental reservation, it is my firm opinion that we have in our grasp this afternoon the very tool which can embark this Nation on the most productive project ever in the history of our country. Cost ratio, when compared with benefits, would be practically nil, not to mention the impact upon the rest of the world in the form of added food and fiber.

I have studied S. 2705, S. 2706 and S. 2707 as presented by Senator Bellmon, and I am thrilled at the fresh approach he has taken. As you know, S. 2705 relates to the need, the responsibility of operation, the status of current technology, and for other purposes.

S. 2706 relates to the implementation of a 10-year program. Although I am in full agreement with the three bills, I am especially impressed with paragraph E in section 3 of S. 2706, wherein it states that the Secretary may agree to suspend experimental operations during times when the Governor of a State in which research operations are conducted declares that an emergency drought situation exists, so the State or local agencies may conduct operational drought alleviation measures.

Those who appreciate good government, herein recognize the valued principle of government doing that for the State and its citizens which the State and the citizens cannot do for themselves, and the Federal Government ready to stand aside when the State is ready to stand in.

This is the type of legislation which lends stature and dignity to our great Nation. This is the type of legislation which the masses will quickly approve and wholeheartedly welcome.

S. 2707 is most invigorating. In essence it says, "Let us do now with what we have." Let us apply our proven technology, let us begin.

Gentlemen, today you are standing on the threshold of what could be the greatest boon to mankind. I shall always be appreciative for the genuine honor and privilege accorded me by the invitation to appear before this august body.

I am available for whatever questions you may wish to ask.

Thank you.

Senator PEARSON. Senator Bellmon?

Senator BELLMON. Thank you.

You referred to your experience with the weather modification program in 1971. Could you tell the committee, from the time the drought started how long it was before that program began?

Mr. SHADID. Yes, sir. The drought started early in 1970, and we, as I stated, had 10 inches of rain for the entire year of 1970. We received help from the Bureau. They came in in August of 1971. And the following month, in September, the rains came for the next several days.

They were to work for a month, but the operation, we were fortunate to get it extended another month. But, you know, generally, and as I say, I am no expert, but this I have learned, that when you are in the throes of a drought, this is the period of time that the clouds that produce water, there just aren't very many of them at the time.

From what I have read, the time to cure a drought is before the drought actually exists. When you wait for the drought then the clouds that can be seeded are very few and far between.

We were fortunate that there were those types of clouds that had some moisture in them, and they were able to seed these clouds and bring us water.

Senator BELLMON. All during the year 1970, you only got 10 inches of rain?

Mr. SHADID. That's right.

Senator BELLMON. There was no program available to help with this problem?

Mr. SHADID. No, sir.

Senator BELLMON. Then 1971 came and it was also dry. It was not until the month of August that the program actually began?

Mr. SHADID. That's right.

Senator BELLMON. And again the crops were ruined because it was so late in the year?

Mr. SHADID. Right.

Senator BELLMON. Are you a believer in weather modification?

Mr. SHADID. Oh, there is absolutely no doubt. I believe just as sure as there is a God in heaven that weather modification can be one of the greatest things that mankind can experience on this Earth.

Senator BELLMON. If there had been a program available of 50-50 sharing between Federal funds and local funds, do you suppose the city of Altus would have undertaken a weather modification program at an earlier date?

Mr. SHADID. Absolutely. There is no doubt.

Senator BELLMON. At the present time, if a community wishes to undertake a weather modification program, is there any coordinating body? Does each community do its own thing, so to speak?

Mr. SHADID. Yes, sir. Mostly county by county. I think you worded it correctly when you said that each community or county does its own thing.

The city of Lawton was carrying on a program and here we were, some 56 miles to the west, carrying on our program.

In spite of all our mistakes we could see the greatest blessings that lie in it. It can be the answer, I know, for Oklahoma's water problems.

Senator BELLMON. Jackson County is fairly close to the Texas line. Suppose a cloud that looks promising arises over the Texas State border; are you free to go over there and seed it if you wish to do so?

Mr. SHADID. We had some form of agreement to do some seeding in Texas. Here again, this comes under proper management and coordination. But to be more specific and try to answer your question, we had no problems at the time that we experienced weather modification. But I do think that it would be an area that would need to be resolved.

Senator BELLMON. You are thinking that perhaps some Federal authority may be necessary in areas that are close to the State lines to avoid a conflict between the two jurisdictions?

Mr. SHADID. I can't see weather modification coming into full bloom without the Federal Government serving in a very good capacity in the program.

Senator BELLMON. Thank you.

Senator PEARSON. This is not an uncontroversial issue, is it?

Mr. SHADID. No.

Senator PEARSON. Tell me about some of the controversies you ran into in 1967 and 1971.

Mr. SHADID. The controversy was the type; some people say those airplanes can't do it. Some said stick around and you will see them do it. That was the only controversy. It wasn't whether you could modify the weather. But some said you need generators and some said you need airplanes. Both will work, and I know both have been used. This was our problem.

Senator PEARSON. What about the town 50 miles away that had one modification program going and you had another one going in your area?

Mr. SHADID. We really didn't have that particular problem because our town, the city of Altus and the city of Lawton, were experiencing the same drought and same problem.

Although we had some counties that were more or less involved with us, we were the daddies, you might say, and we didn't infringe upon the other one in any way that I recall. There was no problem that arose between the two.

Some of us may have claimed that we made it rain, and some claim that they didn't make it rain I know that the Bureau of Reclamation made it rain. It saved us. But the reason they didn't want to admit it, some lady in Granite, Okla. wrote the State metropolitan newspaper saying that she wished she could meet the mayor of Altus and shoot him because one of her trees drowned out in the water.

Senator BELLMON. Are there farmers or hay raisers who feel you made a run on their hay?

Mr. SHADID. In our area it was so dry everywhere that people were glad to read about rain if they couldn't get it. It just didn't get that far out. It stayed within the confines of Oklahoma.

Senator PEARSON. Thank you. You have been very helpful.

Mr. SHADID. Thank you very much.

Senator PEARSON. Dr. White is not here yet. Because of that, let's go on to Dr. Eggers.

Would you identify the gentlemen here with you for the record?

**STATEMENT OF DR. ALFRED J. EGGERS, JR., ASSISTANT DIRECTOR
FOR RESEARCH APPLICATIONS, NATIONAL SCIENCE FOUNDATION;
ACCOMPANIED BY DR. LARRY TOMBAUGH, AND DR. CURRIE DOWNE**

Dr. EGGERS. Yes. On my right is Dr. Larry Tombaugh, who is director of our environmental research division of the NSF, and on my left is Dr. Currie Downie, who is the lead program manager of our weather modification research program. I thought it would be good if they could join me so we could go into any depth you choose with regard to the issue before you.

Senator PEARSON. Go ahead.

Dr. EGGERS. Mr. Chairman and Senator Bellmon, it is a pleasure for me to be able to describe for you the NSF's weather modification research activities and how what we have learned from them may bear on your consideration of S. 2705, S. 2706, and S. 2707.

The weather modification program of the NSF is rooted in Public Law 85-510, which gave us the initial go-ahead to establish the Nation's first weather modification activity. The program was initiated in 1958 as a program in basic and applied research and evaluation. At the same time, the NSF increased its support of basic research on cloud physics and other aspects of atmospheric sciences, and this research has strengthened our weather modification efforts. In 1969, the Interdepartmental Committee on Atmospheric Sciences (ICAS) requested the NSF to plan and conduct a national hail suppression research program.

ICAS has representatives from 12 agencies, including NOAA, Interior, and many others and has probably been one of leading if not the leading major committee under the Federal Council on Science and Technology in coordinating major research efforts in the United States, and in this case weather modification research.

When transferred to the Research Applied to National Needs (RANN) program in fiscal year 1972, the entire program was focused on actual problems of environmental hazard mitigation.

It is currently the largest weather modification research program in the Federal Government. Funding levels over the past 5 years for the three agencies with the largest programs are shown in the attachment.

[The attachment follows:]

FUNDING OF DELIBERATE WEATHER MODIFICATION RESEARCH¹

[In millions of dollars]

	Commerce	Interior	NSF
1972.....	3.9	6.7	5.5
1973.....	3.8	6.4	6.2
1974.....	3.3	3.9	4.7
1975.....	2.7	3.5	4.7
1976.....	3.3	4.6	5.6
	17.0	25.1	26.7

¹ Source: "The Federal Role in Weather Modification," Domestic Council, Environmental Resources Committee, Subcommittee on Climate Change, December 1975.

Senator PEARSON. I see the military phased out in this chart and the Navy stays at about par. Are you picking up some of the work that they have been doing?

Mr. EGGER.. Yes, as it relates to basic research and in certain of the applied research activities in the area of either precipitation suppression or precipitation augmentation. Both problems can be important as you well know.

However, it would be a mistake to suggest that we are picking up in direct proportion to the rate which they are phasing down.

I believe that our program is a balanced one, in that it is concerned both with intentional weather modification and with the unintentional or inadvertent modification of weather caused by large cities, large energy facilities, or other land uses. It is balanced also in that it fully recognizes the societal implications of the technology. Consequently, we do support research to fully understand the legal, economic, and social implications of weather changes.

The largest weather modification study we have funded is the National Hail Research Experiment (NHRE), a project managed and coordinated by the National Center for Atmospheric Research, with 13 subcontracts to universities and three to small business, plus involvement by NOAA and other Government agencies. The overall goal of the experiment is to determine whether hail suppression is feasible and cost-effective, and whether it can be accomplished without affecting overall precipitation.

You may know, Mr. Chairman, that hail damage to crops was estimated in 1973 to be \$685 million, with \$130 million in other property damage, so there is a high level of interest in developing hail suppression techniques to the point where they can be effectively utilized. The ICAS recognized the dollar losses due to hail when it requested the Foundation to plan and support a major hail suppression experiment.

In the initial stages of the experiment—which incidentally is the largest statistically controlled weather modification experiment in the world—the most knowledgeable scientists in the Nation provided guidance on the appropriate experimental design. The early en-

thusiasm for the experiment on the part of ICAS and the scientific community stemmed largely from the reported successes in hail suppression in the Soviet Union. The Russian concept of hail suppression was widely believed to be the appropriate concept for guiding our experiment.

Over the 3 years of field operations of the NHRE, several important findings have been made which call into question the applicability of the Russian concept to hailstorms in the United States. The entire technical basis for the experiment is now being reassessed in light of these findings.

The first and foremost findings was that hailstorms are more complex than first was anticipated. In the most simplistic model of these storms, one has to identify at least two types, the so-called supercell storm and the multicell storm.

The supercell storms are very damaging. The multicell storms are more complex—as you would imagine by the title—and the challenge there is probably greater in terms of identifying the most effective areas in which to seed. The conclusions from the experiments carried out to date are that for effective seeding, contrary to the findings which apparently came out of early Russian experiments, the seeding must take place much earlier in the development of nuclei and prior to the formation of small hailstones. That implies the seeding probably should take place closer to the fringes of the cloud in the early development of the storm itself.

In terms of the statistical significance of the evidence in the early phases of development of the activity, early statistical results indicated to us that we were perhaps achieving as much as 30 percent suppression of the development of damaging hailstorms. Indeed as you know, the intent is to have fewer large hailstones and more small ones, which won't be damaging. That is the purpose of the seeding.

There were also indications that, as a result of the seeding activity, there would be increased water precipitation. One year ago approximately, we went into a holding pattern on the field experiments, which have been extensive in the Colorado, Wyoming area, and spent the year in an evaluation of the data that had been obtained.

The conclusion that even though the early evidence over a period of from 1 to 2 years of seeding was favorable in terms of suppressing the formation of hailstones, it is now clear that in fact there was not profitable suppression. To the extent the data indicate anything, it's in the opposite direction and there was no profitable evidence with regard to the augmentation of rainfall. This is a very important finding for us to keep in mind, because it points up the complex nature and unpredictable nature of at least weather modification in terms of hail suppression in the light of all complex phenomena that take place and the development of further bases for understanding these cloud formations, the nuclei development rate and where best on a predictable basis to seed and cause the suppression of hail.

In fiscal year 1977, we plan to undertake additional research on the formation and structure of convective clouds as these bear on weather modification. It is our view that this research is an essential ingredient in assuring that operations are achieving their objectives without creating unexpected adverse consequences.

Senator PEARSON. Tell me about the Russian experiments.

Dr. EGGERS. They have now begun to phase down. Their seeding was somewhat different from ours. They used the artillery approach. Ours have been primarily in the hail suppression experiments I described, either from seeding directly through ejection from flying aircraft or launch of rockets from aircraft.

Their feeling was that the reduction in crop damage was sufficiently great to justify so-called continued operational programs.

And that, as I indicated, sir, that feeling had a good deal to do with the points of view that developed in this country with regard to carrying forward a major experiment patterned to some significant degree after the Russian undertaking.

The information we have now is that the Russians are beginning to place doubt on whether or not—

Senator PEARSON. You have a free exchange of information with the Soviets?

Dr. EGGERS. It is relatively free. Maybe Dr. Downie can elaborate on that.

Dr. DOWNIE. Yes. I would say the flow of information is quite good. We had a delegation of Russians over here not too long ago and there are some plans for a visit to their sites over there, their hail sites and other weather modification sites. So I think the exchange of information is relatively good.

I might mention that one of the problems here is that our people have seen books of data and they have no real way of convincing themselves whether this really proves the issue or not. And so we have a good bit of doubt. They don't have a randomized experiment. They use a comparative technique of seeding this area and don't seed the area beside it some distance away and compare the results. Our statisticians just can't come up with any positive proof.

Senator PEARSON. What other areas or nations are moving forward in weather modification? Is there a substantial program, for instance, in Western Europe?

Dr. EGGERS. I believe there is some interest there. There is a program going on in South Africa.

Senator PEARSON. The No. 1 goal for the Chinese is to grow enough food for their population. Are they getting into any sort of weather modification?

Dr. DOWNIE. They are interested in this area. yes. I think perhaps this question might be better addressed to the NOAA people. They stay closer to the international situation.

Senator PEARSON. All right. I will wait for that. You may go ahead with your testimony.

Dr. EGGERS. Another program of major scientific complexity supported by RANN is Project Metromex (Metropolitan Meteorological Experiment), which is being conducted at St. Louis by several universities and the Illinois State Water Survey. The purpose of Metromex is to learn about the relationship between urbanization and precipitation and related weather conditions. Important findings to date include an observed 30-percent increase in rainfall downwind of St. Louis, a 25-percent increase in thunderstorms, a 50-percent increase in "heavy" rainstorms, and a 200-percent increase in hail in some areas.

Future research will concentrate on practical uses of this knowledge for urban planning, engineering practices for handling waste matter, and power park siting. These studies will be extended to other regions of the country.

We are also expanding our emphasis on weather modification in support of agriculture. The National Academy of Sciences is assessing for us the present and potential role of weather modification in increasing national and world agricultural production. We are also supporting an evaluation of drought alleviation in the Midwest.

As I mentioned earlier, our program is dealing with the economic, environmental and social impacts of weather modification. People are concerned about the impact of this technology on their lives, and the costs and benefits of its application can sometimes be difficult to make crystal clear. For instance, in South Dakota, public concern over weather modification programs has placed State support for the entire State hail suppression and precipitation augmentation program in doubt.

I might add that probably the best proven weather modification activity at the present time, the so-called snowpack activity to increase snowfall and thereby increase the water runoff, poses very major issues in terms of effects on people—among them the impact on the populations on which the snowfall is increased.

Not all the consequences there are viewed to be beneficial. That's one of a whole host of issues that has to be faced.

One of our major current activities is support for the Study Group on the Societal Consequences of Weather Modification. The study group, formed at the request of the ICAS is completing the final year of a 3-year study supported by RANN. We have much to learn concerning the societal effects of weather modification experiments and programs, and, in some cases, the very success or viability of these programs may depend on how much we have learned about the societal effects.

I will now turn briefly to the specific bills concerning weather modification that are now being considered by this committee.

S. 2705 provides for a National Weather Modification Commission to be established within the Department of Commerce. The Commission would conduct a study of the status of current weather modification capability, the extent of coordination among agencies and the appropriate responsibility for operation in the field of weather modification.

We question whether such a study could usefully enlarge upon the assessment of Federal weather modification activities that was recently completed by the Domestic Council's Subcommittee on Climate Change.

If such a study were to be undertaken, we recommend that the Commission be established in such a way as to require the full participation of the Department of Commerce, the Department of the Interior, and the National Science Foundation, but that it be chartered independently of any single agency. It is essential that all approaches to weather modification arising from activities of the Federal agencies as well as universities and others be thoroughly

assessed and that this assessment serve as the basis of the recommendation concerning future programs.

S. 2706 would authorize the Secretary of Commerce to carry out a 10-year research program to determine the feasibility for decreasing the effects of drought through weather modification.

Weather modification, including precipitation enhancement, is not a well-developed technology. Considerable research will be required on both the scientific and technological aspects as well as the societal implications before the technology can be applied with confidence. In this embryonic stage, it is the administration's view that a policy which would provide for a multiplicity of approaches and which would tap the best of the Nation's scientific talent, whether in Federal laboratories, universities, or private businesses, is likely to be more productive than a policy which would concentrate the bulk of weather modification resources in a single mission agency.

S. 2707 would provide for a program of assistance to States in preventing and alleviating drought emergencies through weather modification. We believe at this time that the emphasis on drought alleviation should be on research and development of the technology. Operational programs should be considered only where the technology is adequately developed to provide a reasonable level of confidence that operational programs will be successful.

If this bill is pursued further, we recommend that it contain the stipulation that all data generated by the State experiences be collected in a systematic manner so that results can be evaluated at a later date. This could greatly enhance the information base upon which future weather modification research efforts and operations could be built.

Before I close my remarks, let me say I personally have been impressed with the thrust of your bill to take steps to see that our own activities which are particularly focused on working with the State and local governments to use the technology more effectively, that there be special emphasis placed on the coordination of activities and a greater emphasis with State and with local governments as well as a communication of information and gained from these activities both from the Federal level to the State and local level and back to our level.

This completes my statement, Mr. Chairman, and I will be pleased to answer any questions you may have.

Senator PEARSON. Do you believe we have had some startling advances in this technology?

Dr. EGGERS. My background comes from many years involved in aerodynamic phenomena and I see a similarity between the progress being made in weather modification and that area over many years.

Where you have boundary conditions, if you will, physical phenomena that have a tendency to isolate the situation as in a single cumulus cloud or tend to force the flow of mountains like the Rockies will tend to be a controlling feature over the clouds as they rise up and cool down, so that physical processes are predictable, then the ability to alter those processes in a predictable fashion, in this instance seeding, is one that you can make real progress in, in terms of bringing the capability to reality.

Where you get into phenomena that become highly turbulent, and our storms tend to have that feature to them, or dispersed, then you have many of the same features as turbulent flow in gas dynamic phenomena. Hundreds of thousands of dollars have been spent on understanding the flow because of its importance to problems of flight and minimal progress has been made to date in that area, including the prediction of the onset of turbulence.

Senator PEARSON. Let me ask my question another way. Let me ask all the questions at the same time.

What I am trying to understand and put into the record is how much progress we have been making in this field, and how that relates to a rather constant funding level we have had for the last 3 or 4 years; and whether or not that funding is adequate; whether or not your advancement in technology is adequate to the current Federal organization. Are we making progress so that it is commensurate with the funding levels?

Dr. EGGERS. I believe that increased funding, carefully applied, can accelerate progress.

Senator PEARSON. There is no use spending money there if it will not help.

Dr. EGGERS. We have been driven back at this time to the drawing board, and this is an experience none of us should forget because a lot of Federal money went into this and it was an experiment which was good, in my opinion. I gave that reference to turbulent boundary layer phenomena.

When you have to study something statistically, it automatically is going to cost you more to do it. Be that as it may, we're back to the drawing board with the largest single weather modification experiment we have ever undertaken in this country, and I don't think at this time doubling or tripling the amount of money we put into it is going to get us off the hook, if you will.

We have to figure out where in the development of those clouds it really makes sense to initiate seeding, so that you do have this cause-and-effect relationship; namely, you cause, as a result of more nuclei, the formation of smaller hailstones, so that you have less damaging hail. It's no simple trick to find out where that is in these clouds.

Senator BELLMON. Dr. Eggers, on the first page of your statement you cite the ICAS. What have they done in the weather modification field; could you elaborate on that?

Dr. EGGERS. The committee was formed back in the same time period as FCST was formed. It has been among the most effective committees proceeding in authoritative fashion, because its views are respected by the Federal agencies involved in it.

It has been extremely effective in providing guidance to the development of the component programs of the various Federal agencies involved. They put out a report annually, the national atmospheric science program. Here is the publication for fiscal year 1976, and the components of that program are moved forward by the various Federal agencies.

[The publication referred to follows:]

ICAS 19-FY 76

May 1975

National Atmospheric Sciences Program

Fiscal Year 1976

*Interdepartmental Committee
for
Atmospheric Sciences*

FEDERAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Science and Technology Policy Office • National Science Foundation

Interdepartmental Committee for Atmospheric Sciences

EDWARD P. TODD, *Chairman*

Member

Edward P. Todd
National Science Foundation

Talcott Edminister
Department of Agriculture

Edward S. Epstein
Department of Commerce

Herbert Wiser
Environmental Protection Agency

Kenneth W. Ruggles
Department of Defense

James Kerr
Department of the Interior

Rudolf Engelmann
Energy Research
and Development Administration

W. E. Stoney
Department of Transportation

John E. Naugle
National Aeronautics and Space
Administration

Herman Pollack
Department of State

Staff Assistant

Fred D. White
National Science Foundation

Charles F. Roberts
Department of Agriculture

Walter Telesetsky
Department of Commerce

David H. Slade
Energy Research
and Development Administration

Samuel C. Coroniti
Department of Transportation

Morris Tepper
National Aeronautics and Space
Administration

Robert G. Morris
Department of State

Alan R. Siegel
Department of Housing and Urban
Development

(Continued on Cover 3)

PREFACE

The Federal Council for Science and Technology was established by Executive Order of the President in March 1959. Its members consist of officials from those Federal Departments and Agencies that conduct extensive scientific research and development. The FCST considers problems in science and technology that affect more than one Federal agency or concern the overall advancement of the Nation's science and technology; it also considers and recommends measures for effective implementation of Federal policies relating both to the administration and to the conduct of programs in science and technology. The deliberations and actions of the Council are based, in part, on studies and recommendations generated by its subcommittees and panels. One of these bodies is the Interdepartmental Committee for Atmospheric Sciences (ICAS), which has been continuously active in support of Council affairs since 1959.

The functions of the ICAS are: (1) to survey and evaluate the national research effort in the atmospheric sciences, (2) to examine the role and activities of the Federal agencies therein, and (3) to make recommendations for appropriate allocation of responsibilities among the Federal agencies. To perform these functions the ICAS usually meets monthly, except in August, normally in Washington, D.C.; occasionally a meeting is scheduled at a field research site. At its regular meetings, the ICAS conducts reviews of the major atmospheric research programs being carried on by its member agencies and makes recommendations concerning them.

In addition to reviewing major Federal programs, the ICAS reviews major fields of atmospheric sciences research. During FY 1975, for example, the field of cloud physics was examined in some depth. If such a review indicates the advisability of so doing, the ICAS takes action to achieve modifications; this action could, for example, take the form of requesting one or more member agencies to change the level of effort in some facet of the field. If the actions required are beyond the scope of the ICAS members, the matter alternatively might be referred to the FCST, with appropriate recommendations for action at that policy level.

The ICAS acts for the FCST in yet another way by sponsoring investigations and studies by organizations outside of the Government. Such efforts are normally identified and requested by the FCST. On some occasions, however, requirements have been originated within the ICAS itself.

The ICAS coordinates its work with the efforts of the other FCST subcommittees whose concerns impinge upon the atmospheric sciences, such as the Interdepartmental Committee for Marine Science and Engineering (ICMSE) and the Interagency Arctic Research Coordinating Committee (IARCC). This activity is accomplished primarily through exchanges of documents and correspondence, with intercommittee meeting attendance when appropriate. The ICAS further maintains close liaison with the Federal Committee for Meteorological Services and Supporting Research, whose mission is to coordinate meteorological services and supporting research. *The Federal Plan for Meteorological Services and Supporting Research*, prepared under the auspices of the Federal Committee, includes the budgets of the Federal agencies for meteorological services and supporting research. The supporting research figures in the Federal Plan are extracted from the total research figures for meteorology in the ICAS report and cover some 42 percent (\$87

million) of the meteorological research reported herein. The total amounts budgeted for meteorology by the Federal agencies can be derived by adding the meteorological operations figures in the Federal Plan to the research figures in the ICAS report. The ICAS interacts in a similar manner with the subcommittees of the Federal Committee for Meteorological Services and Supporting Research, such as the Interagency Committee for the World Weather Program (ICWWP) and the Interdepartmental Committee for Applied Meteorological Research (ICAMR). The ICAS further maintains close contact with other atmospheric sciences deliberative bodies such as the National Academy of Sciences Committee on Atmospheric Sciences (NAS/CAS) and the National Advisory Committee on Oceans and Atmosphere (NACOA).

Of the many activities that involved the ICAS during the past year, two specific efforts, one national and one international, deserve brief mention. The Climatic Impact Assessment Program (CIAP), directed by the Department of Transportation with participation by many of the ICAS agencies, was successfully completed. In addition to achieving its designed purpose, the CIAP research made a substantial addition to the body of knowledge about the stratosphere. The GARP Atlantic Tropical Experiment (GATE) field observational phase was also conducted this past year. GATE was the largest experiment ever carried out in the international arena. The data gathering phase was a huge success. The ICAS member agencies that participated in the experiment are proud to have had a part in it. Both the CIAP and GATE are the subject of further attention in this report.

In its annual report for 1973, NACOA expressed concern that expenditures for capital support items for oceanic and atmospheric sciences might not, in the future, keep pace with the needs for such equipment. The Secretary of Commerce relayed this concern to the Chairman, FCST, with the request that the FCST look into the problem. In turn, the Chairman, FCST, commissioned the ICMSE and the ICAS to investigate the situation in oceanic and atmospheric sciences respectively. The two subcommittees sponsored studies, performed by the Center for Naval Analyses, to survey the capital structure supporting oceanic and atmospheric sciences to determine if it in fact is to be adequate in the future. That work has been completed and the results are in the publication process; the report is expected to be released to NACOA shortly.

Beginning in June 1974, there have been reports published in scientific journals about the possible adverse effects of certain of the fluorocarbons on the atmospheric ozone layer. These compounds can diffuse upward into the middle stratosphere, where they can become dissociated by the intense ultraviolet radiation that is present there. Following dissociation, free chlorine atoms produced in this process can act to catalytically destroy ozone. Mathematical computer model calculations indicate a reduction in total ozone with which there would be a concomitant increase in the intensity of ultraviolet light reaching the Earth's surface. This increased level of radiation could be dangerous to life forms and could as well cause significant changes in the world climate. In consideration of the possibilities raised by these articles, a Joint Task Force on Inadvertent Modification of the Stratosphere (IMOS) was created by the Council on Environmental Quality and the FCST. The section of the IMOS Report that deals with the subject of Stratospheric Effects was prepared by a select group of ICAS affiliates.

There is little reflection of the research program associated with the fluorocarbon-ozone issue in this ICAS annual report. This lack of prominence concerning

such a vital issue does not reflect a lack of interest on the part of the ICAS member agencies. The lack of visibility is the result of the surfacing of the fluorocarbon matter well into the budget cycles for FY 1975 and 1976. The ICAS member agencies are responding to the problem with reprogramming actions where possible to accommodate the most urgent needs for research associated with the problem. Additional budget actions are being considered for further research work deemed necessary. Readers desiring the details of the Federal atmospheric science program regarding the fluorocarbon-ozone issue are urged to review the IMOS Report, "Fluorocarbons and the Environment" (1975), which was released to the public on July 2, 1975.

In addition to its regular annual report, the ICAS published during the past year a special document, "Report of the Ad Hoc Panel on the Present Interglacial," ICAS Report 18b. A second document, "The Possible Impact of Fluorocarbons and Halocarbons on Ozone," ICAS Report 18a, is in final draft awaiting publication.

Research efforts in the atmospheric sciences will continue on a broad front in FY 1976. Within the Department of Commerce (NOAA) and the National Center for Atmospheric Research (NCAR), an extensive GATE data processing effort is now in progress and will continue over the next two years. This work, which complements similar undertakings in other nations, is intended to organize the massive amount of data that was collected and make it available to the international scientific community. In particular, the GATE Convection Subprogram Data Center, which is located at NOAA, will reach its full operating stage; the university community and the National Center for Atmospheric Research will play major roles in this effort along with NOAA. As a follow on to the CIAP, the Department of Transportation is beginning its High Altitude Pollution Program, aimed at monitoring the stratosphere to determine the effects of aircraft operations there.

Within the Energy Research and Development Administration, a major new program is beginning, the Multistate Atmospheric Power Production Pollution Study, MAP3S. The program is designed to provide information needed to assess the impact of current power production practices and to develop techniques to assess the fate and effects of pollution that may result from new methods of fuel use. At the National Aeronautics and Space Administration, mission studies on the STORMSAT vehicle are underway. This new satellite system is being designed to provide additional information, obtained from geostationary platforms, for use in the observation and forecasting of severe weather phenomena such as tornadoes and hurricanes. Another advanced system, SEASAT, that will seek to demonstrate the feasibility of acquiring data applicable to ocean monitoring and predicting physical ocean phenomena, has been defined and procurement of long lead-time items for it is in progress.

The program mentioned above are but a few of the many that are to be carried out in the next few years by the Federal atmospheric sciences research community. On balance, the Federal Atmospheric Sciences Program continues to expand, though at a somewhat slower rate (about 4%) than has been observed in recent years. The dollar values reported in this document for FY 1974 are actual expenditures, those for FY 1975 are estimated expenditures, and those for FY 1976 are planned expenditures.

In accordance with a decision taken during the past year by the ICAS, this report does not contain an appendix devoted to the Federal Weather Modification Program. Descriptions of the weather modification plans and programs of those member agencies that conduct this work are included in the regular agency program descriptions.

Contents

Preface.....	iii
National Atmospheric Science Program Summary.....	1
Department of Agriculture.....	3
Department of Commerce.....	5
Department of Defense.....	27
Department of the Interior.....	39
Department of Transportation.....	41
Energy Research and Development Administration.....	45
Environmental Protection Agency.....	47
National Aeronautics and Space Administration.....	49
National Science Foundation.....	61
Appendix I.....	75
Appendix II.....	81

The first of these is the fact that the
total number of cases of smallpox in
the United States in 1881 was 1,000.
This is a very small number compared
with the number of cases in previous
years. The second fact is that the
mortality rate was very low. Only
one person died of smallpox in 1881.
This is a very low mortality rate
compared with previous years. The
third fact is that the disease was
very mild in its course. Most of the
cases were cured without any serious
complications. This is a very good
result for a disease which has been
so common in the past.

Program Summaries

Table 1. National Atmospheric Sciences Program Summary
(In thousands of dollars)

	Agriculture			NBS			NOAA			OT		
	FY 1974	FY 1975	FY 1976	FY 1974	FY 1975	FY 1976	FY 1974	FY 1975	FY 1976	FY 1974	FY 1975	FY 1976
Meteorology												
Physical Meteorology	508	495	491	190	0	0	1,626	1,568	1,539	77	115	85
Dynamic Meteorology	91	225	244	125	55	50	9,612	16,723	17,308			
Observation	394	545	327	370	437	450	10,643	11,314	8,501			
Description	407	570	596	20	0	0	3,300	3,774	4,374			
Prediction	307	496	513				2,913	3,016	3,133			
Modification	270	86	83				4,695	4,505	5,055			
Dissemination							63	72	82			
Systems							5,452	5,023	5,664			
Support							14,363	12,588	7,403			
Total	1,977	2,417	2,254	705	492	500	52,697	58,583	53,069	77	115	85
Aeronomy												
Aurora and Airglow				0	105	65	214	217	219	45	0	30
Ionospheric Physics				700	256	250	1,100	891	909			
Atmospheric Chemistry				350	465	325	316	609	535			
Atmospheric Structure							235	221	219			
Energetic Particles							302	433	592			
Atmospheric Geomagnetism							49	86	117			
Solar Terrestrial Studies				350	114	100	397	215	262			
Dynamic Aeronomy							0	44	44			
Instrumentation, General							227	165	192			
Instrumentation, Rockets							124	85	85			
Instrumentation, Satellites												
Support				450	400	500	147	350	417			
Total				1,850	1,340	1,240	3,111	3,316	3,591	45	0	30
Planetary Atmospheres				85	179	200						
PROGRAM TOTAL	1,977	2,417	2,254	2,640	2,011	1,940	55,808	61,899	56,660	122	115	115
In-house (incl. Gov't Labs)	1,472	1,967	1,804	2,600	1,976	1,910	42,322	49,236	45,512	122	115	115
Industry (Profit)	25	50	50				10,634	9,691	8,089			
University	480	400	400	40	35	30	2,232	2,260	2,414			
Other (Non-profit Labs)							620	712	645			
ARMY												
NAVY												
AIR FORCE												
ARPA												
Meteorology												
Physical Meteorology	360	1,015	775	685	737	788	103	90	51			
Dynamic Meteorology	340	230	400	75	85	85	217	321	350			
Observation	2,415	3,946	3,743	940	1,060	1,368	1,027	1,317	1,371			
Description	1,344	930	1,065				750	972	925	3,462	2,700	1,472
Prediction	820	1,032	945	973	983	1,148	241	241	239			
Modification	172	0	0	180	180	180	568	273	295			
Dissemination	1,040	1,261	1,179				3135	4,364	4,883			
Systems	200	0	0									
Support	3,050	4,232	4,800									
TOTAL	9,641	12,646	12,907	2,853	3,045	3,569	6,041	7,578	8,114	3,462	2,700	1,475
Aeronomy												
Aurora and Airglow							676	743	800	25	0	0
Ionospheric Physics	100	0	0	171	164	180	2,742	2,918	2,756	375	185	200
Atmospheric Chemistry	140	270	270				2,840	2,940	2,984	15	15	0
Atmospheric Structure	739	830	1,077				7,085	8,907	9,611	210	415	400
Energetic Particles							817	962	825			
Atmospheric Geomagnetism							972	654	770			
Solar Terrestrial Studies				431	802	880	3,062	2,843	2,798			
Dynamic Aeronomy							952	1,006	998			
Instrumentation, General							1,248	1,123	1,153	10	10	0
Instrumentation, Rockets												
Instrumentation, Satellites												
Support	979	1,100	1,347	602	966	1,060	20,394	22,096	22,695	635	625	600
Planetary Atmospheres												
PROGRAM TOTAL	10,620	13,746	14,254	3,455	4,011	4,629	26,435	29,674	30,809	4,097	3,325	2,075
In-house (incl. Gov't Labs)	9,460	10,712	10,886	3,157	3,714	4,341	17,800	18,134	19,075	3,712	2,885	1,625
Industry (Profit)	820	1,804	2,693	117	116	107	3,215	4,616	4,644	110	365	300
University	240	855	440	181	181	181	5,170	6,500	6,640	275	75	150
Other (Non-profit Labs)	100	375	235				250	424	450			

Table 1—Continued

	DNA			EPA			Interior			ERDA		
	FY 1974	FY 1975	FY 1976	FY 1974	FY 1975	FY 1976	FY 1974	FY 1975	FY 1976	FY 1974	FY 1975	FY 1976
Meteorology												
Physical Meteorology				350	350	350				1,799	2,703	3,892
Dynamic Meteorology										3,089	4,936	5,596
Observation				6,180	6,480	6,480				1,200	918	1,199
Description				2,800	6,200	7,400				253	483	507
Prediction				50	50	50						
Modification							3,900	4,000	4,649			
Dissemination												
Systems										325	462	479
Support												
Total				9,380	13,080	14,280	3,900	4,000	4,649	6,666	9,374	11,673
Aeronomy												
Aurora and Airglow	5,075	2,714	2,765							310	175	400
Ionospheric Physics										210	444	500
Atmospheric Chemistry	1,060	930	913							30	5	10
Atmospheric Structure	375	267	247							2	6	6
Energetic Particles	55	60	65							75	76	80
Atmospheric Geomagnetism										388	455	625
Solar Terrestrial Studies												
Dynamic Aeronomy												
Instrumentation, General		4,223	2,875							4	4	8
Instrumentation, Rockets	3,245	60	95									
Instrumentation, Satellites	425											
Support												
Total	10,235	8,274	6,960							1,019	1,167	1,629
Planetary Atmospheres												
PROGRAM TOTAL	10,235	8,274	6,960	9,380	13,080	14,280	3,900	4,000	4,649	7,685	10,541	13,302
In-house (incl. Gov't Labs)	5,075	3,310	2,784	3,222	3,422	3,422	800	1,000	1,249	2,379	3,109	3,825
Industry (Profit)	4,883	4,534	3,936	5,373	7,823	8,523	1,300	1,400	1,500	222	65	30
University	277	430	240	785	1,835	2,335	1,000	700	800	809	1,560	1,961
Other (Non-profit Labs)							800	900	1,100	4,275	5,807	7,686

	Transportation			NASA			NSF			Totals		
	FY 1974	FY 1975	FY 1976	FY 1974	FY 1975	FY 1976	FY 1974	FY 1975	FY 1976	FY 1974	FY 1975	FY 1976
Meteorology												
Physical Meteorology				3,832	5,345	5,649	6,697	7,031	8,091	16,227	19,449	21,711
Dynamic Meteorology	1,826	1,581	650	1,796	1,316	1,985	9,127	11,406	15,949	26,298	36,750	42,617
Observation	5,402	3,548	3,096	23,100	31,869	30,053	6,836	6,524	6,467	58,507	68,098	63,055
Description							3,067	3,330	3,817	15,303	16,259	18,784
Prediction	313	321	285				305	260	560	5,922	6,399	6,973
Modification	1,397	1,615	555				5,081	4,860	6,470	16,263	15,539	17,287
Dissemination	2,617	2,988	4,685							3,720	4,321	5,956
Systems	2,828	3,302	2,428	1,366	750	725	430	300	200	13,281	13,739	13,900
Support	848	0	50				3,500	3,550	4,220	22,116	20,832	16,952
Total	15,231	13,455	11,749	30,094	39,280	38,412	35,013	37,281	45,874	177,737	204,046	206,610
Aeronomy												
Aurora and Airglow							1,485	1,640	1,810	7,830	5,594	6,089
Ionospheric Physics				1,965	2,579	6,830	2,345	2,570	2,815	9,708	10,007	14,440
Atmospheric Chemistry				545	803	1,878	285	600	910	5,581	6,637	7,825
Atmospheric Structure				402	307	439	1,175	1,300	1,500	10,223	12,273	13,499
Energetic Particles				80	80	180	825	800	850	2,154	2,513	2,582
Atmospheric Geomagnetism							690	800	940	2,099	1,995	2,452
Solar Terrestrial Studies				111	111	318	3,230	3,310	3,840	7,581	7,595	8,298
Dynamic Aeronomy				70	70	180	425	530	640	1,427	1,850	1,862
Instrumentation, General							1,160	1,123	1,403	1,391	1,292	1,603
Instrumentation, Rockets				2,520	2,515	2,858	310	310	170	7,147	7,956	6,971
Instrumentation, Satellites				6,580	4,706	335	1,170	1,170	1,200	7,315	5,078	600
Support										1,787	1,920	2,117
Total				12,273	11,173	13,018	13,080	14,453	16,178	64,223	64,510	68,348
Planetary Atmospheres				14,104	17,238	11,538	1,135	1,245	1,370	15,324	18,662	13,108
PROGRAM TOTAL	15,231	13,455	11,749	56,471	67,691	62,968	49,228	52,979	63,422	257,284	287,218	290,126
In-house (incl. Gov't Labs)	3,697	3,454	3,491	9,210	11,052	10,137				105,028	114,086	109,976
Industry (Profit)	6,536	6,196	6,338	37,476	46,391	42,748	3,210	480	920	73,921	83,541	79,876
University				9,785	10,248	10,085	19,435	25,195	28,462	40,709	50,774	54,136
Other (Non-profit Labs)	4,998	3,805	1,920				26,563	27,294	34,040	37,626	39,317	46,076

AGENCY PROGRAMS

DEPARTMENT OF AGRICULTURE

The Department of Agriculture carries out a broad research program in the Atmospheric Sciences that is designed to cover major agricultural weather problems and atmospheric processes involved in the management and protection of forests and rangelands.

The Agricultural Research Service of the Department of Agriculture is conducting studies in its atmospheric sciences research program on those climatic factors affecting plants, insects, and disease. Studies are also being conducted to determine the relationship between climate and crop hardiness, quality, and productivity. Drought resistance is an item of major concern. The Department is directing a national research program on plant dis-

ease epidemiology and forecasting in which extensive use is made of micrometeorological data observed at the plant level. Studies concerned with developing techniques, including models that are capable of predicting the consequences of various storms and other weather conditions on the quantity and quality of our Nation's soil, water, and air resources, are part of the program. Atmospheric studies are being performed to determine the action of air pollutants on plants and methods of controlling the damage.

The Cooperative State Research Service conducts a research program in cooperation with the States that provides detailed descriptions of the climate of regional and State agricultural areas.



A backscatter transmission meter is used to monitor time changes in the density of a smoke plume from a prescribed burn in a Southern Pine forest. (U. S. Forest Service photo.)

The atmospheric research program of the Forest Service is concerned with problems related to fire-weather phenomena, the transport and dispersion of smoke from silvicultural burning, and the outbreak and spread of insects and disease. The Forest Service also carries out a small effort in weather modification research.

Physical Meteorology

The FY 1976 program proposes research work by the Forest Service on lightning characteristics.

The Agricultural Research Service will continue work in atmospheric radiation, evapotranspiration, heat and mass exchange processes and boundary layer turbulence as it relates to the dispersion of aerosols and particulates.

Dynamic Meteorology

Research in dynamic meteorology within the Department of Agriculture is concentrated in the Forest Service and is concerned with the development of laws governing the windflow in the friction layer of the atmosphere and the energy exchange and transformation processes that are involved in these motions. The work is aimed at obtaining methods for specifying and predicting the interactions of the large-scale force fields of the atmosphere and the topographic and aerodynamic characteristics of the earth's surface.

Observation

The research work in weather measurements continues to involve experimentation with several types of remote automatic weather stations capable of telemetering data to a central location. An analysis of the time and space variability of fire weather and other agricultural weather elements is underway to define the required spatial distribution of weather measurement sites and the cycling rate of observing the different elements.

Description

The efficient production of agricultural crops continues to be the aim of the work carried out in the Cooperative State Research Service. Studies are underway to define the variations in the climate of the various regions of the country, particularly in respect to those elements that have a considerable importance to agriculture. These studies recognize the impact on and the tolerance of biological species to weather events such as frost, maximum temperature, and peak winds. Work in this area is also considering how remote sensing and satellite observations can be applied to crop-weather problems. Descriptions of fire climate and local fire weather events are also studied as aids to fire planning and fire control operations by the Forest Service.

Allocation of Funding (In thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Physical Meteorology	508	495	491
Dynamic Meteorology	91	225	244
Observation	394	545	327
Description	407	570	596
Prediction	307	496	513
Modification	270	86	83
TOTAL	1,977	2,417	2,254
Distribution of Funding			
In-house	1,472	1,967	1,804
Industry	25	50	50
University	480	400	400

DEPARTMENT OF COMMERCE

The Department of Commerce (DOC) program in atmospheric science responds to important aspects of the Department's broad mission to foster, serve, and promote the Nation's economic development and technological advancement. Specific DOC responsibilities served by this program are those of improving man's comprehension and uses of the physical environment and of assuring effective use and growth of the Nation's scientific and technical resources. To advance comprehension and beneficial use of the physical environment, the National Oceanic and Atmospheric Administration (NOAA) conducts a comprehensive program of meteorology and a program of aeronomy. Through atmospheric science programs in meteorology, aeronomy, and planetary atmospheres, the National Bureau of Standards (NBS) provides physical data, basic measurement methods, and calibration needed in the advancement of science and technology. To advance telecommunications technology, the Office of Telecommunications' Institute for Telecommunications Science (ITS) conducts atmospheric science programs in meteorology and aeronomy.

NATIONAL BUREAU OF STANDARDS

As the Nation's central physical measurement laboratory, the National Bureau of Standards provides the basic measurement methods and calibrations and much of the physical data needed for monitoring and understanding physical processes occurring in the atmosphere.

METEOROLOGY

NBS develops many of the basic measurement methods and instruments essential to the investigation of meteorological phenomena. Work on accurate air pressure measurement, humidity measurement, flow measurement, and the study of turbulence all support the development of quantitative meteorology.

The ease and reliability of meteorological pressure measurements will be substantially increased by two types of work. New primary pressure gauges are being designed and built at NBS. They employ a laser interferometer for increased accuracy and ease of automation. The transfer of this new technology to users will then be assured by attention to secondary standards and the numerical analysis of corresponding measurements in various laboratories in order to identify sources of error. Training courses for personnel of secondary laboratories are also part of this effort.

In humidity measurement, attention will be focused in several areas. The operating range of NBS reference standards will be extended. Vapor measurements over ice will be initiated. Finally, the response time of humidity sensors will begin to receive attention.

Several new air flow measurement services will also be developed. One will permit calibration of air velocity as low as ten feet per minute. A second will measure the response of wind speed instruments in gusty wind. The errors associated with the Pitot measurement are being evaluated quantitatively. A program of error analysis among cooperating measurement laboratories will be initiated in order to improve the consistency of these measurements.

Finally, an NBS program in the statistical properties of turbulence has bearing on meteorological dynamics.

NBS continues to study actively and to correlate the physical properties of those atomic and molecular species comprising the atmosphere, its pollutants, and their behavior and mutual interactions including thermodynamic and kinetic properties, gas phase chemical reaction rates, collisional ionization processes, infrared and microwave spectroscopy, absorption phenomena, gaseous dissociation, molecular bonding, and multimeter growth (such as water multimeters in clouds). There is a continuing program to provide information on the electronic structure and energy surfaces of the molecular species, water, ozone, and carbon dioxide, in order to understand their roles in atmospheric chemical processes. Measurements of

photochemical processes involving the oxides of nitrogen, their reactivity with oxygen and water, together with determination of the near ultraviolet radiation extinction coefficients in nitric oxide will be useful in assessing the impact of high altitude aircraft on the stratosphere. NBS is performing studies to predict the damage from the release of radioactive sources and fission products such as tritium and xenon-133 by nuclear plants into the atmosphere.

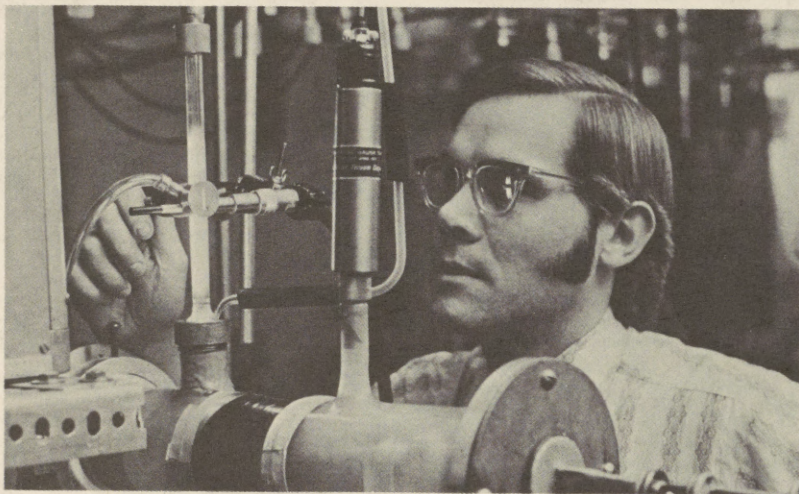
AERONOMY

The understanding of reactions taking place in the upper atmosphere is being increased by several NBS projects in atomic and molecular physics and chemistry. These include plasma physics, radiation transfer, the behavior of ionized species, and the

statistical mechanics of dilute gases. Experiments and theoretical studies involve spectroscopy, photochemistry, measurements of cross sections for photoionization, collisional ionization, energy exchange and collisional dissociation, chemical reaction kinetics, electron scattering energy loss mechanisms, the development of plasma diagnostic techniques, and electronic infrared and microwave sensing of the molecular constituents of the atmosphere.

Aurora and Airglow—Transition probabilities for aeronomically relevant transition in O_2 and NO will be calculated. The direct and predissociation probabilities for the Rydberg states of Na will be calculated. These results will be used in modeling the odd nitrogen in auroras.

Atmospheric Chemistry—Chemical reactions of the type occurring in the upper atmosphere are receiving attention at NBS. The reaction rate of NO



D.R. Johnson adjusts the flow of gas to the discharge tube of the NBS microwave spectrometer. The products of the microwave discharge in the gas will be reacted with another gas downstream to form unstable molecules. Laboratory detection of these highly transient molecules aids their identification in the upper atmosphere and in space. (National Bureau of Standards photo.)

and O_3 will be determined as a function of temperature, and the effect of SO_2 and O_2 on O_3 -olefin reactions will be investigated. The extinction coefficients of NO_2 in 190-400 nm wavelength range will be measured over the temperature range that prevails in the stratosphere (220-260K). The fluorescence technique for measuring SO_2 in smokestack plumes will be refined to take into account the effect of NO and O_2 . The ultraviolet photochemistry of CCl_2F_2 (F-12) will be determined in order to help assess the impact of the present atmospheric fluorocarbon burden on the ozone layer.

Support—Through its National Standard Reference Data System, NBS provides evaluated technical data on the thermodynamic and transport properties of gases, infrared, microwave, and ultraviolet spectroscopic information, cross sections for molecular collision and ionization processes, and gas phase reaction kinetics used in the modeling of atmospheric processes. A principal effort involves chemical rate constant quantum yields and optical absorption coefficients* of atmospheric species.

PLANETARY ATMOSPHERES

The microwave spectral tables being computed at NBS are serving as the basis for work in many laboratories and observatories on the chemical composition of planets and other astronomical objects.

NBS microwave spectroscopists, using the National Radio Astronomy Observatory's facilities, detected the large molecule dimethyl ether in the direction of the Orion Nebula molecular cloud, as well as interstellar ethanol molecules in the direction of Sagittarius B2.

As part of the NBS response to a Department of Transportation program on Climatic Impact Assessment, NBS Astrophysics Laboratory compiles extensive data on photoabsorption cross section data of stratospheric molecules. These will be included in a series of documents entitled, "The National Atmosphere," to appear under DoT sponsorship.

The fluorescence properties and photochemistry of C_2H_2 and C_2H_4 will be studied in order to assess their importance in the atmosphere of Jupiter.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NOAA's mission includes major responsibilities for describing, developing understanding of, and predicting the condition of man's physical environment. To carry out this mission, NOAA conducts a program of research in the environmental sciences which includes nearly all aspects of the ICAS-defined areas of meteorology and aeronomy.

This program concentrates on the interactions and interrelations of the atmosphere, the oceans, the earth, the sun, and of man's activities and well-being. The program includes the improvement of warning and prediction systems to reduce the economic and social disruption produced by natural disasters of diverse scopes such as hurricanes, tornadoes, torrential rain, electrical storms, severe drought, storm surges, winter storms, and magnetic storms. It includes support to the economic operation of energy distribution systems. It includes efforts to help resolve the dilemma between economic development and environmental conservation. It includes the assessment and projection of inadvertent effects, e.g., atmospheric pollution and climate change, which may occur in atmospheric properties and processes as a result of man's activities. It includes developing the potential for intentional modification of weather by man's technology in order to add the ameliorating influences of modification to those of warning and prediction in mitigating the adverse effects to which man is subjected by disastrous atmospheric phenomena. Conversely, the development of weather modification technology is also pursued in order to enhance the benefits which may accrue thereby.

The technical facilities by means of which NOAA conducts this program are concentrated mainly in its operational line components: the Environmental Data Service (EDS), the Environmental Research Laboratories (ERL), the National Weather Service (NWS), the National Environmental Satellite Service (NESS), and the National Ocean Survey (NOS).

Allocation of Funding
(in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Physical Meteorology	190	—	—
Dynamic Meteorology	125	55	50
Observation	370	437	450
Description	20	—	—
TOTAL	705	492	500
Aeronomy			
Aurora and Airglow	—	105	65
Ionospheric Physics	700	256	250
Atmospheric Chemistry	350	465	325
Solar Terrestrial Studies	350	114	100
Support	450	400	500
TOTAL	1,850	1,340	1,240
Planetary Atmospheres	85	179	200
PROGRAM TOTAL	2,640	2,011	1,940
Distribution of Funding			
In-house	2,600	1,976	1,910
University	40	35	30

METEOROLOGY

Different elements of NOAA's meteorological science R&D program investigate weather systems varying in spatial extent over a comprehensive range. On one end are severe local convective storms, which are characteristically limited to areas as small as several miles in cross section and can have devastating effects on local populations. On the other end is the entire fluid thermodynamic engine that constitutes the global weather system. Here many interactions apparently need to be established in order to achieve deterministic long or intermediate range prediction of regional weather. This scale of weather helps to determine the quality of life of extensive populations. NOAA's investigations on the global or para-global scale are coordinated with those of other nations through the World Weather Program.

World Weather Program

The World Weather Program is under the cog-

nizance of the United Nations' World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU). The Department of Commerce was designated by the President, following Senate Concurrent Resolution 67, to be the lead agency in coordinating the United States' participation in the World Weather Program.

NOAA's research and development activities planned for FY 1976 specifically in support of the World Weather Program (WWP) are concentrated exclusively in the Global Atmospheric Research Program (GARP), which is one of WWP's three components. The other two components are the World Weather Watch (WWW) and the Systems Design and Technological Development Program (SD&TDP). Additional NOAA activities in atmospheric modeling and simulation also provide contributory support to GARP, but are planned primarily in support of other immediate mission needs. NOAA also provides further contributory support to the Systems Design and Technological Development component of the WWP, which facilitates the establishment of observational systems

that are essential to the full operation of the WWW and to GARP observational experiments.

NOAA's participation in WWP is described as such in the World Weather Program Plan for Fiscal Year 1976. It includes all or parts of the efforts described in the present report under the following sections: Global Atmospheric Research Program, Computer Modeling, the inadvertent aspects of Weather Modification, Remote Sensing, NOAA Data Buoy Program, and Environmental Satellite Research.

Global Atmospheric Research Program (GARP)

GARP is an international program aimed at improving the time, range, and accuracy of weather forecasts for periods of one day to several weeks, and obtaining a better understanding of the physical basis of climate and climate fluctuations.

The first international experiment of GARP is the GARP Atlantic Tropical Experiment (GATE), which investigates the structure and evolution of weather systems in the tropical eastern Atlantic, and assesses the extent to which tropical disturbances affect the behavior of the global atmosphere. GATE recently concluded a highly successful field observational phase. It was based on specially instrumented ships and aircraft supplemented by buoys, operational sun-synchronous and geostationary satellites, and the augmented World Weather Watch network of continental and island-based weather stations. The broad area of the experiment included the entire tropical Atlantic and the adjacent continental regions. A selected smaller area, a hexagon with 90 nautical mile sides was the subject of intensive observations with ships and aircraft. The principal base of operations was Dakar, Senegal.

Thirteen nations: Brazil, Canada, Finland, France, Federal Republic of Germany, German Democratic Republic, Mexico, Netherlands, Portugal, Senegal, United Kingdom, U.S.S.R., and the United States committed substantial dedicated resources to the experiment; about 60 additional nations in the region made special efforts to obtain needed observations in their territory. The United States provided nine ships equipped with meteorological and oceanographic instrumentation,

eight instrumented aircraft, and polar-orbiting and geostationary satellites. NOAA had the ships RESEARCHER and OCEANOGRAPHER and its DC-6 and C-130 aircraft in the experiment. \$3,864,000 of the GARP base funds will be used in FY 1976 to process and analyze the massive amounts of data that were collected in GATE. During the next three years the primary effort will be to process complete GATE data sets and make them available to the international scientific community, and to conduct the meteorological analysis of these data.

The first GARP Global Experiment (FGGE) has four basic objectives: (1) to obtain a better understanding of atmospheric motions for the development of realistic models for extended range forecasting, general circulation and climate; (2) to assess the ultimate limit of predictability of weather systems of various sizes and time scales; (3) to develop new methods for assimilation of meteorological data in numerical weather forecast models, in particular, for more effectively using satellite data in the models; and (4) to design an optimum composite global observing system for routine numerical weather prediction on a global basis.

International planning for FGGE, whose field phase is scheduled to begin in 1977, is in advanced stages. Several international conferences have occurred and significant international cooperation in carrying out the experiment appears assured. A FGGE Intergovernmental Panel reporting to the WMO's Executive Committee has been formed to include representatives from Argentina, Australia, Brazil, Canada, France, the Federal Republic of Germany, Iran, Japan, Nigeria, the United Kingdom, U.S.S.R., and the United States, as well as participants from a half dozen international environmental and scientific organizations.

The major portion of United States participation in FGGE will be jointly sponsored by NASA, NOAA, and NSF. The United States activities in FGGE are expected to include scientific planning, computer modeling and processing, data analyses, archiving, and development and procurement of sophisticated technological observing systems. \$2,325,000 of the GARP base funds will be used in FY 1976 to prepare detailed scientific plans, con-

tinue development of computer models, and initiate procurement of long lead time observation systems for FGGE.

Computer Modeling

The Geophysical Fluid Dynamics Laboratory conducts fundamental investigations of the dynamics of geophysical fluids, the atmosphere, the hydrosphere and the cryosphere, over a wide range of time and space scales. The studies are comprised of basic and exploratory applications research on the structure and circulations of planetary fluid systems in general, and the terrestrial troposphere, upper atmosphere and oceans in particular. Phenomenologically the studies include the dynamics of synoptic scale evolutions, convection and internal geochemical-dynamical interactions. An understanding of these processes, mechanisms and phenomena bears on a wide variety of potential applications in geophysical prediction. Examples of these are deterministic medium range atmospheric forecasting (several days to several weeks), long-range atmospheric forecasting (several weeks to several months), the evolution and stability of climate, the dispersion in the atmosphere and oceans of inert and interactive substances either natural or manmade, mesoscale variability in the atmosphere and oceans, urban scale atmospheric variability and micro-climate, the life cycle of hurricanes, and clear air turbulence.

The research program is pursued primarily through theoretical analysis and numerical simulation. The latter requires extremely powerful high speed digital computers which, beginning in FY 1975, involves the use of the new Texas Instrument Advanced Scientific Computer. The new computer provides the basis for employing a host of new models of enhanced physical fidelity and improved computational resolution. One experiment will include the use of estimates of the sea surface temperature during the last major ice age 18,000 years ago from the program Climate: Long-range investigations, Mapping and Prediction (CLIMAP) to study, by comparison with contemporary climate, mechanisms which can maintain an ice age. Sub-models accounting for the active ozone photochemistry will be devised for inclusion in more sophisticated atmospheric general circulation

models, and will also account for the minor constituents which influence the formation and destruction of ozone. As part of this work, a 40-level general circulation model extending to 80 km will be used to study the dynamics and energetics of the stratosphere and mesosphere. A new global coupled ocean-atmosphere model will be employed in studying the seasonal variation of the joint ocean-atmosphere system. Global data sets being created for the GATE period from a 9-level, four-dimensional assimilation model with 2-degree latitude resolution will be used for several-week prediction experiments.

An experiment will simulate the stratospheric circulation of Venus to assess the role of diurnal solar heating effects and the pole-to-equator insolation gradient in producing cloud structure and motions in the upper atmosphere as observed by the Mariner 10 satellite. To investigate a three-dimensional hurricane vortex imbedded in a larger scale atmospheric environment, methods will be developed for dealing with a vortex in a moving nested grid system with open boundaries and for initializing a calculation from observed data. A three-dimensional mesoscale model capable of accounting for the dynamical interaction of penetrative convection, gravity waves, and unsteady processes in a planetary boundary layer driven by diurnal heating at the ground will be constructed with open boundary conditions in preparation for the study of a number of mesoscale problems including the urban heat island effect. A three dimension moist model of buoyant convection, including the rain-water phase, refined cloud physics and dynamics appropriate to deep convection will be used for studies of interaction with larger-scale flow. Studies with simple models will be conducted to investigate the sensitivity and stability of model climate to such "external" variables as the solar constant and atmospheric carbon dioxide. A prime objective of this work is to determine the model dependence of such simulations for assessing the value of simple models in climate studies.

The National Meteorological Center (NMC) conducts research to improve numerical models of the atmosphere in order to increase the accuracy of the daily public forecasts. This research concentrates

on assimilation of incoming atmospheric observations, fidelity of the models, forecasts over periods of 12 hours to one week, 30-day outlooks and stratospheric and mesospheric phenomena.

Incoming atmospheric observations from conventional and satellite sources on wind, temperature, pressure, and moisture distributed unevenly in space and time are received via the Global Telecommunications System. Research is conducted to improve the techniques by which this data is assimilated to form coherent reference descriptions of the atmosphere which can serve as bases for operational computer forecasts.

Increased fidelity of the prediction models to actual atmospheric processes is sought by research on improved mathematical simulations of the effects of such parameters as underlying topography, latent heat in the precipitation process, frictional dissipation of energy, and sensible heat exchange at the earth surface.

Research on extended forecasts concentrates on models for treating the details of global weather changes. Short-range forecast research concentrates on models capable of resolving smaller scale motions over limited spatial domains. This research includes a coordinated plan by the National Weather Service and the Environmental Research Laboratories for the development of a hurricane model suitable for producing improved trajectory forecasts.

NMC research on the stratosphere and mesosphere focuses on specific studies with particular emphasis on the development of dynamic prediction methods, application of the new satellite data, and a better understanding of the mid-winter "sudden warming" phenomenon.

Weather Modification

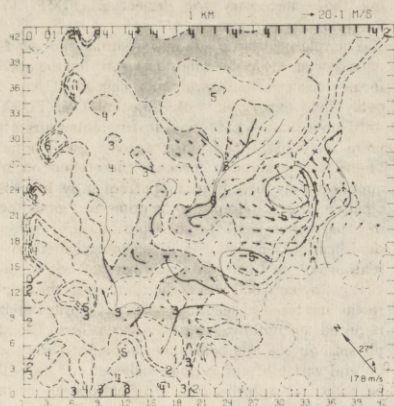
NOAA's Weather Modification Program in FY 1976 will concentrate on the following problems: Modification of convective clouds in a subtropical environment (Florida); development of the theoretical basis for modifying hurricanes, other severe storms and extratropical cyclones; increasing the understanding of the physics and chemistry of cloud and precipitation processes; and modernization of the Research Facilities Center's research aircraft to meet NOAA and other Federal agencies needs for airborne research measurements includ-

ing those necessary for Project STORMFURY Pacific in the summer of 1977.

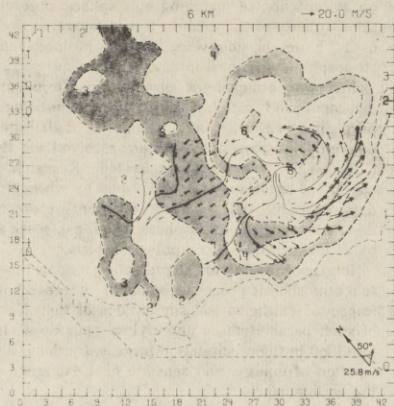
The relative scarcity of storms suitable for seeding experiments in the Atlantic Ocean, and the need for newer aircraft and equipment caused NOAA to delay field experiments of Project STORMFURY until such time as safe, well instrumented aircraft were available for operations over the Pacific. There storms suitable for experimentation occur approximately three times more frequently. In anticipation, efforts to improve the numerical modeling of hurricanes will be intensified, and other modification techniques will be investigated. Attention will be focused on seeding methods by investigating convective cell distribution in the hurricane and types of seeding agents and pyrotechnics required to optimize the seeding effect. Cloud physics, air-sea interaction measurements, and the natural variability of various scales of motion will be investigated during FY 1976 field operations in the Atlantic. Attention will also be placed upon determining aircraft operational capabilities in selected portions of the hurricane during these operations.

The National Hurricane and Experimental Meteorology Laboratory will continue research to determine the potential of dynamic seeding for area-wide rain enhancement. Analysis of the Florida Area Cumulus Experiment (FACE) of 1973 is nearing completion. Although the sample of experimental days (only 37 to date) is too small to determine the effects of dynamic seeding, many important results have been obtained. These include: detailed documentation of convective events from the ground and the air, definition of an improved method of convective rain measurement from combined use of gages and radar, derivation of a method of estimating rainfall from satellite imagery to examine the downwind and extra-area effects, and application of dual doppler methodology in FACE. Research is being continued on cloud merger and merger models since merging clouds are the major rain producers in Florida. During the summers of 1975 and 1976, additional FACE studies are scheduled after which technology assessment and transfer are planned.

Research will be continued to determine the feasibility of suppressing or mitigating the severe



The radar reflectivity (intensity of precipitation) and heretofore unseen wind fields are revealed by dual-Doppler radar system for the 20 April 1974 tornadic storm northeast of Oklahoma City, Oklahoma. Cyclonic rotation in the region centered at



coordinate (30.0, 24.0) is evident at all levels from 1 km through 6 km. The length of the wind arrow is proportional to the wind speed. (NSSL diagrams.)

weather attending extratropical weather systems by modification treatments introduced at sub-synoptic scales. Presently the effort consists of development of a model for modification sensitivity studies, to be followed by longer-term development of a model for real-time, real-data field operations and concurrent diagnostic studies in mesoscale modification. The research is to determine the relationship between cloud and ice nuclei concentrations and climatic distribution of precipitation and to evaluate the atmospheric residence times and sedimentation rates of artificial nuclei and their efficiency in cloud glaciation. A concept in which the solar radiation flux received at the earth's surface is affected by creation of an artificial layer of cirrus clouds which in turn might suppress convection will be considered through numerical modeling and infrared remote measurements of water vapor in the upper troposphere.

The NOAA Research Facilities Center (RFC), an operational and technical support organization, has the mission of providing instrumented aircraft to meet the needs of NOAA and other qualified agencies for airborne measurements. The RFC has begun instrumenting the first P-3 aircraft received in May 1975 and the second P-3 aircraft scheduled to be delivered in January 1976. Instrumentation packages to be installed in FY 1976 are inertial/omega/doppler navigation systems, data recording systems, dropsonde systems and cloud physics instrumentation. In FY 1977 the aircraft are scheduled to receive additional instrumentation such as radar systems, cloud seeding equipment, gust probes, photo systems and other research equipment.

The importance of global atmospheric background monitoring has been dramatically underlined by the modeling of the interaction between



One of the two new P-3D aircraft recently acquired by the NOAA Research Facilities Center for atmospheric research. (Department of Commerce photo.)

stratospheric and atomic chlorine from the chlorofluorocarbons. A new layer of stratospheric dust from the eruption of the Guatemalan volcano in 1974 was detected by the monitoring lidar at the baseline observatory on Mauna Loa, Hawaii.

The U.S. network of stations continues to advance in its monitoring techniques at Mauna Loa Observatory, Hawaii; Pt. Barrow, Alaska; American Samoa; and the South Pole. In FY 1976, the South Pole observational program will have been expanded following the move of the facilities near the new South Pole station which took place in the 1974-5 austral summer. A special "clean air" facility is being constructed at the South Pole by the National Science Foundation for NOAA's baseline monitoring program and for cooperative university programs in the measurement of trace metals, chlorofluorocarbons, radioactivity, polarization, and photometry. NOAA is implementing new

ozone measuring techniques and new continuous carbon dioxide, solar radiation, and aerosol measurements and is increasing the frequency of both routine observations and calibration and quality control tests.

The Point Barrow Observatory is becoming increasingly important as a reference point for the environmental studies planned for the Arctic coastal areas of Alaska. Cooperative programs with universities and other government agencies are being increased and now include special particulate measurements, solar radiation studies with new ultra-violet instrumentation, and the use of acoustic sounders to determine atmospheric stability.

With the American Samoa observatory under construction in FY 1975, the majority of NOAA's planned monitoring programs are planned to be underway by the middle of FY 1976.

At the Mauna Loa Observatory, which conducts

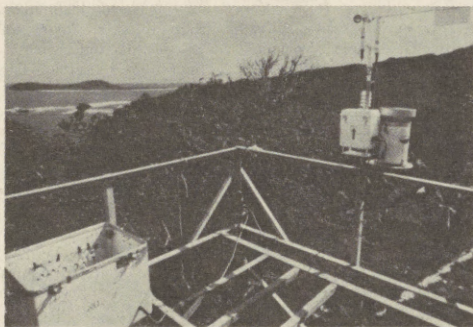


Construction in progress at the NOAA Global Monitoring for Climatic Change Station at the South Pole is shown. (Department of Commerce photo.)

the most complete monitoring program, a new pyrliometric-pyranometer system has been placed in operation and the program now includes four wavelength nephelometer, surface ozone, rain chemistry, ice nuclei and lidar measurements. An experimental program to evaluate new Aitken nuclei measurement methods and calibrations has begun.

Programs which will affect all of the stations include the further development of precipitation chemistry collection; analysis, improvement and expansion of the monitoring of chlorofluorocarbons; and improvement of the sensitivity of continuous Aitken nuclei counters which will be installed at the four observatories.

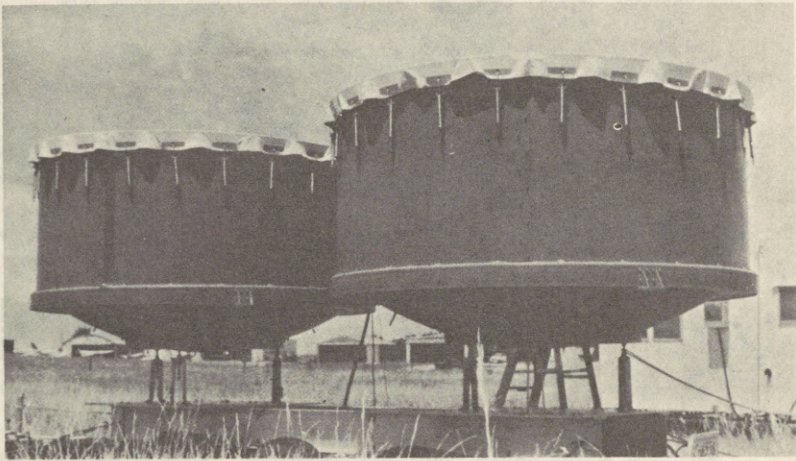
NOAA conducts further atmospheric sciences research related to the future development of intentional and inadvertent weather modification techniques and the assessment of inadvertent climate changes. Fundamental work on the mathematical modeling of atmospheric circulations, conducted within NOAA's Air Resources Laboratories and the Geophysical Fluid Dynamics Laboratory, is vital to the problem of climate change and control. Theoretical work on the structure, dynamics and energy processes of storms such as tornadoes and thunderstorms, conducted at NOAA's National Severe Storms Laboratory, is essential to the development of effective modification methods for



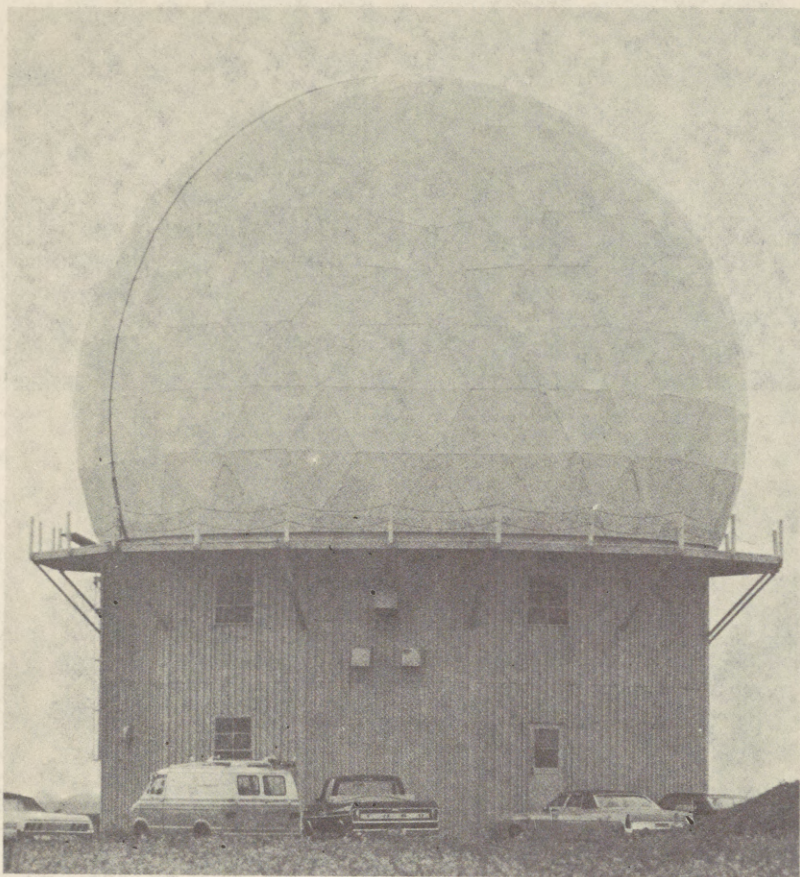
A part of the instrument installation at the NOAA Global Monitoring for Climatic Change station at Cape Matatula, American Samoa. (Department of Commerce photo.)



A system of instruments used to make intercomparisons of different precipitation chemistry. This work is being carried out by the Cornell University, under NOAA sponsorship. (Department of Commerce photo.)



The frequency modulated continuous wave radar located at the NOAA Wave Propagation Laboratory in Boulder, Colorado. (Department of Commerce photo.)



The National Severe Storms Doppler Radar at Cimmaron, Oklahoma. (NSSL photo.)

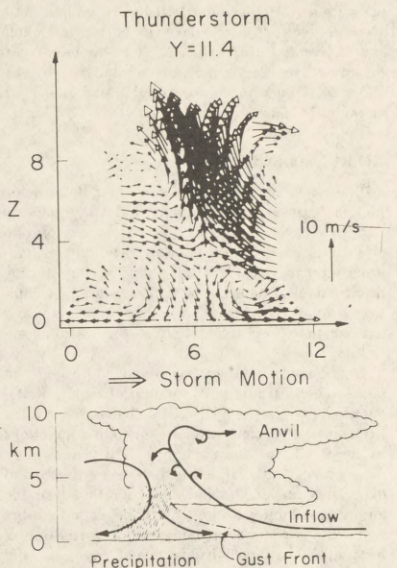
severe storms. The development of instrumentation for direct atmospheric measurements and for the remote sensing of the atmosphere, conducted at several NOAA facilities, is fundamental to all aspects of intentional and inadvertent weather modification.

Surface Based Remote Sensing Research

The Atmospheric Remote Sensing Research and Development Program in FY 1976 will include the development of new techniques, the transfer of technology and the application of techniques in field measurement programs. In the area of new techniques, the FM-CW microwave Doppler radars will be applied to measurement of structure and motion of the atmosphere in clear, cloudy and precipitating conditions. FM-CW infrared lidar Doppler technique feasibility will be studied. Feasibility of a new system to measure intra-cloud lightning discharge mechanism related to tornadic storms will be investigated. In cooperation with the Aeronomy Program, the theoretical and range limitations of the radio acoustic sounding system (RASS) for the measurements of wind, temperature and turbulence structure will be developed.

In the transfer of technology area, a visible and infra-red laser hydrometeor identifying system will be transferred to the National Weather Service for operational testing. Evaluation by the National Weather Service of acoustic sounder measurements at the El Monte Airport in the Los Angeles area will be continued.

Field measurement programs involving application of remote sensing techniques will include measuring wind velocity and divergence using a 6 km triangle of laser path-averaging wind sensors in severe storm studies. Line-of-sight crosswind and refractive turbulence profiles will be measured using two crossed coded laser beams. Precipitation effects on a laser beam will be studied to measure path-average precipitation rates. Experiments developed from physical models of wave dynamics will be applied to the measurement of acoustic emissions from severe storms. Improved pressure measurement techniques will attempt to measure predicted waves and turbulence arising from shear flow. The multi-Doppler radar system will be used extensively in three-dimensional observations of



The dual-Doppler radar system at the Wave Propagation Laboratory of NOAA has recently revealed in unprecedented detail the three-dimensional velocity structure within a severe thunderstorm during the mature and dissipating stages.

Shown in the display are projections of the vector wind field onto one of the three orthogonal planes within the storm. The xz plane represented is aligned approximately along the inflow direction. Arrow lengths are proportional to wind speed. A 10 m/s reference arrow is shown.

Despite the complexity of this pattern the display exhibits several clearly identifiable features such as the backward sloping updraft overriding a precipitation filled downdraft, middle-level intrusion of cold, dry air into which the precipitation can fall and a well-defined gust front. The schematic representation identifies these features.

An intensive analysis of these data is presently underway. Comprehensive quantitative results will soon be published. (WPL diagram.)

wind fields. Doppler lidar will measure cloud and clear air motions particularly in vortex modeling and convective cell studies. The mobile lidar system will be used in the study of clouds, aerosols, and effects of hydrometeors and lithometeors on radiation balance and insolation.

NOAA Data Buoy Program

Buoy systems are being developed to provide meteorological, oceanographic, and water quality data in support of scientific programs, exploration and use of energy sources, transportation and fisheries industries, and water pollution monitoring. Environmental data buoys will be placed in data-sparse areas over the next five years to improve and aid weather forecasting and storm warning activities.

Data buoy technology has advanced through the development, test, and evaluation of experimental data buoys of various sizes and shapes. They vary from small, inexpensive spar-shaped drifting buoys to large 40-foot discus buoys. The large buoy program was initiated to establish the hardware and experience needed to develop operational severe environment buoys and to provide data to users while the experimental buoys were at sea during test and evaluation. The objective of the small buoy program was to develop small environmental data buoys for operation in moderate-to-mild environments for limited time periods.

NOAA Data Buoy Office has been able during the past year to specify its detailed requirements, within existing and proven hardware capabilities, for an operational Prototype Environmental Buoy (PEB). These buoys are to be used to provide data from the severe environments of oceanic areas such as Gulf of Alaska in support of weather forecasting organizations. A competitive contract for the procurement of one such prototype was awarded, with the option to procure five additional buoys after successful test and evaluation of the first prototype buoy. This buoy was delivered in May 1975. The six PEB's will form the basis of a pilot operational data buoy array in the eastern North Pacific in support of the NWS and other users.

The environmental data collected and telemetered to shore for dissemination to the Na-

tional Weather Service and other operational users include: atmospheric pressure, wind direction and speed, air temperature, wave spectra, significant wave height and period, sea surface temperature, and subsurface water temperature to 300 meters depth.

The NDBO deep ocean moored buoy program consists of development, tests, and evaluation of several subsystems. Development efforts are planned during FY's 75-76 include the development, fabrication, and test of meteorological and oceanographic sensor systems and electronic components to meet the design goal of a one-year service cycle between at-sea visits; to correct known causes of in-service failures, thus enhancing performance and capability; and to reduce acquisition and operating costs. One objective of developmental efforts in FY's 75-78 is the simplification and standardization of data acquisition and control functions on board the buoy, as well as improvement in system reliability with a reduction in cost.

NDBO also has an extensive ongoing drifting buoy development program. Several types of drifting buoys are under development and test in response to a variety of users. Two types of Ice Buoy systems are under development. For meteorological drifting buoy applications, the need is focused on acquisition of the basic data required to achieve the objectives of GARP. NDBO plans to develop a drifting buoy system to make heat flux measurements for large scale air/sea interaction studies, including NORPAX.

The third major program area consists of the development of a family of Continental Shelf buoys for acquiring meteorological, oceanographic, and water quality data. Development of these kinds of systems primarily employs the technology acquired in the deep ocean moored and drifting buoy programs. However, some advancement of technology and even new technology is required in the development of various oceanographic sensors and/or data collection techniques. There are a number of users of environmental data from estuaries and the continental shelves, e.g., Bureau of Land Management, Environmental Protection Agency, Oceanographic Research Laboratories, U. S. Navy, fisheries, weather forecasting organizations, and offshore oil, mining, and construction industries.

Environmental Satellite Research

The long-term goal of the major part of the National Environmental Satellite Service (NESS) research effort is to develop an atmospheric temperature and constituent profiling system that has total global coverage and is operationally independent of the world-wide radiosonde network. The current operational Vertical Temperature Profile Radiometer (VTPR) on NOAA 3 and 4 becomes less accurate as cloudiness increases below the spacecraft and is unable to observe below a solid cloud cover. There are also problems when over land that are not satisfactorily resolved so that only temperature soundings over the oceans are being routinely provided.

Global, all-weather capability is being sought using radiation measurements in other regions of the electromagnetic spectrum than the 15 micrometer region employed by VTPR. Microwave radiometers are affected only slightly by even heavy clouds so that observations of the radiation emitted by atmospheric O_2 at 60 GHz are being studied as a solution for achieving all-weather capability. Measurements of radiation at a shorter wavelength—3.8 micrometers—have the potential, when combined with 15 micrometer observations, to solve the problems in looking down from a satellite over land areas rather than over the sea.

Interim efforts to achieve independence from the radiosonde—which is currently the standard and the only criterion for evaluation of remote sensor systems—involve the measurement of atmospheric radiation properties directly from instruments flown on balloons and aircraft. An additional program will begin in 1975 which will make use of facilities for solar observations at the Kitt Peak National Observatory and at other selected observation sites.

Data from the SMS, the first satellite in the GOES (Geostationary Operational Environmental Satellite) system, launched in May, 1974, are being used to derive wind fields from observed cloud motions. Cloud heights are deduced from temperatures determined by the infrared channel of the SMS instrument. Techniques for determining sea surface temperature using the infrared data are being developed which will lead to an operational product. The launching of the second SMS in February

1975 is providing coverage of the Eastern Pacific Ocean and Western Atlantic Ocean areas.

Studies are being continued towards the development of satellite instruments and analysis methods needed to determine global distributions of stratospheric minor constituents pertinent to climatic variability and other environmental effects.

Research instruments in Nimbus satellites are a primary source of data for evaluating potential improvements. The ITPR (Infrared Temperature Profile Radiometer), SCR (Selective Chopper Radiometer) and NEMS (Nimbus E Microwave Spectrometer) on Nimbus 5 are currently demonstrating the synergistic advantages of a multi-spectral approach to improving soundings. The HIRS (High resolution Infrared Radiation Sounder) and SCAMS (Scanning Microwave Spectrometer) on Nimbus F, due to be launched in the summer of 1975, will provide data for advancement of these concepts. The 4.3 micrometer capability of HIRS in addition to the standard 15 micrometer region will provide additional information for improving temperature soundings.

In order to become independent of the world-wide radiosonde network (and thereby ultimately replace a major part of it) the remote sounding instruments must be capable of absolute calibration. Such calibration requires a more refined knowledge of the spectroscopic parameters of the radiating gases of the atmosphere— CO_2 , O_2 , H_2O , O_3 and certain pollutant gases—than currently exists. To this end a very high resolution (0.02cm^{-1}) infrared spectrometer in the Satellite Experiment Laboratory is acquiring data needed to refine certain of these values and outside research is being supported for pioneering studies of atmospheric gases at previously unobtainable resolution (0.00005 cm^{-1}). Research is also supported outside NESS in high-resolution quantitative studies for other spectral regions.

International Field Year For The Great Lakes

The project, International Field Year for the Great Lakes (IFYGL), now under the management of the new Great Lakes Environmental Research Laboratory at Ann Arbor, Michigan, will complete, early in FY 1976, the processing and archival of the

field data obtained in 1972 and 1973. Analysis will continue in the two IFYGL atmospheric science projects, the Atmospheric Water Budget Project and the Atmospheric Boundary Layer Project, with the final scientific reports for these projects being completed near the end of FY 1976.

In the Atmospheric Water Budget Project, the studies will concentrate on: (1) Analysis of the IFYGL rawinsonde data to obtain estimates of the individual terms of the atmospheric heat and water budgets averaged over Lake Ontario; (2) Description of the typical boundary layer wind distribution over and in the vicinity of Lake Ontario together with a description of the dominant meso and synoptic scale variations; (3) Estimation of the momentum budget terms in the planetary boundary layer and middle troposphere together with an assessment of the probable error in the direct evaluation of these terms; (4) Examination of the results of the heat and water vapor budget computation to obtain a general description of the budget results for the entire period of analysis, to relate these to synoptic-scale variations in the atmospheric circulation and the surface water temperature of the lake; and to derive bulk estimates of total heat flux and evaporation from Lake Ontario.

The Atmospheric Boundary Layer Project will complete the following work: (1) Computation of lake-averaged estimates of surface fluxes of momentum, heat, and moisture using the bulk aerodynamic technique and the best estimate of the drag coefficient for Lake Ontario; (2) Computation of lake-averaged cross-products of speed with velocity vectors, lake-air temperature and moisture differences; (3) Computation of the transfer coefficients from the bulk aerodynamic formulae and evaluation of the possible variation with fetch and stability using direct measurements of fluxes by aircraft and the meteorological data from the United States and Canadian buoys.

Hurricane Research

Research on hurricanes is conducted to acquire greater knowledge of these storms for developing and improving techniques for their detection, forecasting and modification. Data will be collected from specially instrumented research aircraft,

satellites, radars and conventional surface and upper air observational networks. Studies will be made of the structure and energy processes in hurricanes and other tropical storms. Improved theoretical models of hurricanes and other tropical circulations will be developed for use in understanding hurricane dynamics and predicting hurricane motion and intensity. In the modeling effort, emphasis will be placed on the development of both symmetric and asymmetric models with advanced cloud physics parameterizations and numerical techniques. Diagnostic studies of tropical systems will be continued. The use of tracers in tropical cyclones, studies of the relationship of weather patterns over Africa and hurricane genesis in the Atlantic will contribute to the understanding of hurricane dynamics. In the above studies emphasis will be placed on the use of data obtained in the GARP Atlantic Tropical Experiment.

Research at the National Hurricane Center (NHC) will be focused on the development of methods for improving forecasting of hurricane movement and intensity. This research will include: (1) developing and testing (in collaboration with the National Meteorological Center) a multi-level, fine-mesh, diabatic and viscous, primitive-equation, limited-area dynamical model; (2) continued testing and improving a simple existing barotropic model; and (3) applying Model Output Statistics (MOS) to hurricane prediction. Diagnostic studies of the circulation features of tropical depressions will continue; these studies are expected to lead to improved techniques for predicting the formation of tropical storms and hurricanes. Analysis of the sea surface temperatures (SST) and the vertical fluxes of heat and water vapor from the ocean to the atmosphere will be carried on. Studies will continue on the application of decision theory error analysis in landfall forecasting.

Mesometeorology

Research continues on regional transport and dispersion of material released into the atmosphere. Current atmospheric trajectory and tracer programs underway, relating measured concentrations of tracers such as Freons and sulfahexafluoride to anthropogenic sources, will be applied further with

aircraft, oceanographic and land based tracer measurements, utilizing the unique combination of Northern Hemisphere rawinsonde wind data and wind vector analyses of the National Meteorological Center. Extended trajectory models incorporating vertical stability and wind shear will be developed. The study of dispersion over urban areas and irregular terrain including derivations of diffusion coefficients from tetroons will be carried out. Theoretical models of the mesoscale to include pollutant removal processes such as impaction and sedimentation will be constructed and tested.

In severe local storms research, major emphasis continues on the tornadic storm and its immediate environment. In FY1976, investigation of the thermo-hydrodynamic interactions between the convective storm and sub-synoptic scale conditions will be given special emphasis. Motion fields within and adjacent to convective storms portrayed by dual-Doppler radar will be synthesized with concurrent observations from an instrumented 500-meter tower, sub-synoptic networks of conventional surface and upper air stations, lidar-anemometers, acoustic radar, instrumented aircraft and meteorological satellites. Theoretical models of severe local storm systems will be improved as these data sources provide new insight into convective physics and as triggering mechanisms become defined. Improved storm description will also provide earlier identification of storms and more accurate warning. Extremely complicated condensation processes in relation to tornadic wind fields will be addressed through physical mathematical models including numerical vortex models.

Systems Design and Development

NOAA conducts a program in systems design and development aimed at improving its weather services. Included are the development of plans for specialized weather services and the design of the various subsystems to support these services. An equipment development program includes the development of many specialized sensors of hardware, using special purpose computers, which will handle and disseminate weather information. These include a continuing effort on the Automation of Field Operations and Services (AFOS), the

Remote Automatic Meteorological Observing System (RAMOS), and other observing equipment. The program is also concerned with the improvement of forecasting techniques in the area of public weather, aviation, severe local storm and marine forecasting.

Emphasis is planned in FY 1976 in the following systems R&D areas: Under AFOS an experimental phase will begin in the area of automating the data acquisition, handling and communication functions of NWS field operations. Further design and development of automatic meteorological observing stations and sensors will be continued with effort concentrated on RAMOS. Experimentation on radar equipment will also be expanded. The interface of AFOS and the Digitized Radar Experiments (D/RADEX) will be of major concern during FY 1976.

The goal in forecast techniques development during FY-76 is increased capability of making accurate forecasts objectively. This includes improving scheduled forecasts routinely made, such as maximum and minimum temperature, and implementing new products, such as quantitative precipitation. Severe local storm and medium range thunderstorm forecasts will be improved through use of better derived predictors, including forecasts of upper air variables from numerical models. A major effort in boundary layer modeling will provide a vital input to this work. One of the more important features of the model is simulation of the nocturnal low-level jet. Short-range precipitation and severe storms forecasts will be improved through the refinement and operational use of a computer program for identifying, tracking, and forecasting radar precipitation echoes.

In the public weather area, larger data samples than now available will be used for statistical techniques. Improved statistical models, such as the Logit, and improved numerical models, such as the Subsynchronous Update Model (SUM) will be used. New predictors will include those from other numerical models such as the Limited-Area Fine Mesh (LFM). NOAA will also concentrate on products specifically for AFOS such as computer worded forecasts.

Aviation Weather will include continued emphasis on ceiling, visibility, and wind. A

monitoring and updating method will be implemented on AFOS.

Environmental Data Research

The major environmental data research initiative planned in FY 76 will fall within the scope of the newly established Center for Climatic and Environmental Assessment (CCEA). CCEA will develop models geared to provide estimates of grain yields from meteorological data, in support of the Large Area Crop Inventory Experiment (LACIE), and will develop environmental assessment factors needed for prudent management and distribution of food resources. Methods and approaches developed by CCEA will be made available to the WMO and FAO joint activities to develop an Early Warning System for food shortages.

During FY 76 Center for Experiment Design Data Analysis (CEDDA) will continue analyzing the atmospheric water budget and boundary layer fluxes data from International Field Year for the Great Lakes (IFYGL). CEDDA will continue to coordinate and monitor U.S. data management activities for GATE. The National Processing Center activities will be completed. As a part of this, CEDDA will complete processing of the U.S. ship data. The Convection Subprogram Data Center, for which the U.S. has responsibility, will reach full-scale operations during FY 76. CEDDA will have the lead role in this activity with major involvement of National Center for Atmospheric Research (NCAR) and with contractual support from universities. CEDDA will also begin work during FY 76 on GATE research projects in the areas of: atmospheric heat, water vapor and momentum budget analysis; boundary layer structure and flux analysis; radar precipitation analysis; and oceanographic heat and salt budget analysis. CEDDA will continue during FY 76 to provide assistance in the planning stages of FGGE, POLEX, and SESAME, particularly in the areas of data management and experiment design.

The National Climatic Center's descriptive work in FY 76 will concern tropical cyclones, drought, separation of heterogeneous or mixed distributions of climatic elements into their homogeneous parts, special publications, national energy requirements, and human health.

In FY 76 the Environmental Data Service will continue to concentrate attention on the development of a working Environmental Data Index (ENDEX) which will provide rapid response to queries from scientists, engineers, and other users about the existence, type and availability of environmental data and information.

AERONOMY

NOAA conducts a research program in aeronomy to increase understanding of the solar-terrestrial environment and to develop techniques necessary for forecasting solar disturbances and their subsequent effects on the earth's environment. Theoretical and experimental research studies are conducted on the possible effects of the introduction of man-made pollutants from supersonic aircraft, space shuttle vehicles and other sources, into the upper atmosphere and on the physical, chemical and dynamic processes of the stratosphere and upper atmosphere. Research is also undertaken to understand and model the fundamental physical processes causing the following phenomena: the energy release that is observed in the form of electromagnetic and particle radiation on the solar surface during solar disturbances; the propagation and modification of this energy through space to the near-earth environment; the transfer of this energy into the earth's magnetic field (the magnetosphere); and the behavior and subsequent effects of this energy within the magnetosphere, the ionosphere, and the upper atmosphere. These studies are conducted utilizing data from satellite experiments, rocket launches and ground stations.

Solar-Terrestrial Environment

In FY 1976, NOAA, will continue development of a working model of the solar-terrestrial environment. When completed the model will permit continuous updating of computer programs (in accordance with time-varying solar, space, and magnetospheric parameters) to predict the nature of upper atmosphere and geomagnetic disturbances. Existing portions of the model will be calibrated in accordance with observations and adapted for computer processing. In FY 1976

emphasis will be placed on extending the steady-state interplanetary medium model to three dimensions and modeling the effects of fast solar wind streams. The time-dependent model for propagation of shock waves through the interplanetary medium will be extended to other types of solar wind disturbances and made continuous through the solar critical point (where the solar wind becomes supersonic). Numerical codes will be developed using the magnetohydrodynamic equations instead of the ordinary fluid dynamic equations. The existing equatorial ionospheric F region model will be extended to predict atomic oxygen and hydrogen ion densities as well as electron densities; the mid-latitude F region ionospheric storm model will be improved significantly using radio beacon total electron content data from the ATS-6 satellite. Quantitative computations will be made of energy sources and losses from a number of processes active in the thermosphere between 80 and 150 km altitude. Research will also continue on the remaining portions of the solar-terrestrial model, including testing and evaluating theories of the interaction of charged particles with plasma instabilities and waves which govern disposition of energy within the magnetosphere.

The availability of large quantities of data from several satellites will expedite development and calibration of the solar-terrestrial environmental

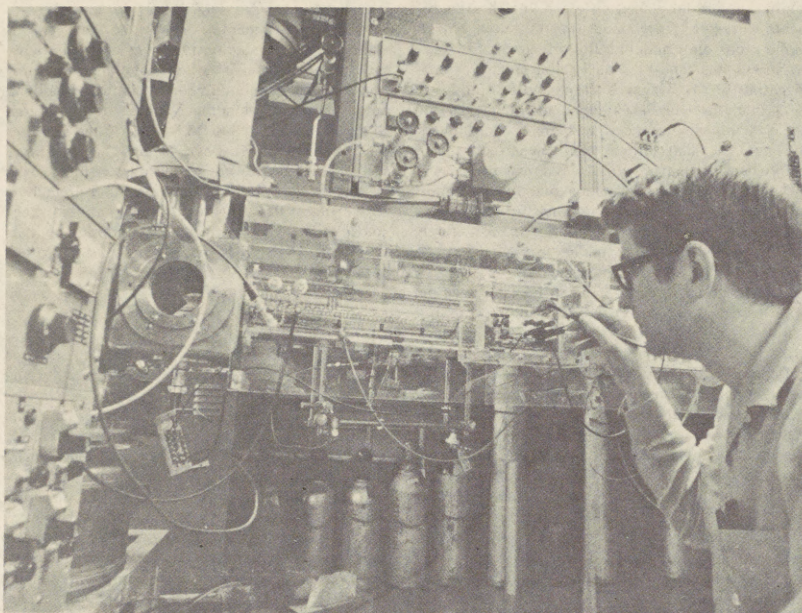
model. Included are data on proton, electron and alpha particle concentrations over a wide band of energy ranges, including pitch angle distributions; solar x-ray and magnetic field data; and radio propagation data from a number of satellites in a wide range of orbits, including NOAA satellites, three GOES satellites, ATS-6, IMP-H and -J, the Explorer 45, and SOLRAD-HI. Rocket studies will continue at high latitudes to study the occurrence and effects of ionospheric plasma instabilities, and precipitating particles. Planning for the International Magnetospheric Study (IMS) will continue in conjunction with the newly established IMS Program Office now located at NSF.

Stratospheric And Upper Atmospheric Processes

Increased emphasis will be placed on research involving fundamental processes within the stratosphere and upper atmosphere, especially the role of minor atmospheric constituents, and the effects of introducing pollutants by vehicles flying in the medium and by other sources. Studies will be conducted on modeling the effects of chloro-fluoromethanes on ozone in the stratosphere; measurements of chlorine compounds and other significant minor constituents; development of new measurement techniques for significant minor constituents; theoretical studies of turbulence from gravity waves; laboratory measurements of photochemical



The new incoherent scatter radar antenna installed by the NOAA Aeronomy Laboratory at Sunset, Colorado. (Department of Commerce photo.)



The Flow Drift Tube used by the NOAA Aeronomy Laboratory, Boulder, Colorado, for measuring atmospheric reaction rates. (Department of Commerce photo.)

reaction rates and rates for reactions involving radicals and molecules in the excited states; measurements of winds and clear air turbulence in the troposphere, stratosphere and mesosphere by remote, ground-based radar techniques; and measurements of the composition and dynamics of the neutral upper atmosphere by means of ground-based optical techniques.

Aeronomy Data Assessments And Products

The National Geophysical and Solar-Terrestrial

Data Center (NGSDC) will continue to produce special and advanced data products needed for solar-terrestrial and atmospheric research in NOAA, other federal agencies, and universities. In FY 1975 a comprehensive bibliography and key data for Solar-Terrestrial-Weather-Climate studies and Auroral Electrojet (AE) indices for 1971-1973 with 2.5 minute time resolution was published. Ten special data reports were distributed from NGSDC and other sources. In FY 1976 there will be similar work, especially in preparation for the International Magnetospheric Study (IMS).

Allocation of Funding
(in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Physical Meteorology	1,626	1,568	1,539
Dynamic Meteorology	9,612	16,723	17,308
Observation	10,643	11,314	8,501
Description	3,300	3,774	4,374
Prediction	2,913	3,016	3,133
Modification	4,695	4,505	5,055
Dissemination	63	72	92
Systems	5,452	5,023	5,664
Support	14,393	12,588	7,403
TOTAL	52,697	58,583	53,069
Aeronomy			
Aurora and Airglow	214	217	219
Ionospheric Physics	1,100	891	909
Atmospheric Chemistry	316	609	535
Atmospheric Structure	235	221	219
Energetic Particles	302	433	592
Atmospheric Geomagnetism	49	86	117
Solar Terrestrial Studies	397	215	262
Dynamic Aeronomy	—	44	44
Instrumentation, General	227	165	192
Instrumentation, Rockets	124	85	85
Instrumentation, Satellites	—	—	—
Support	147	350	417
TOTAL	3,111	3,316	3,591
PROGRAM TOTAL	55,808	61,899	56,660
Distribution of Funding			
In-house	42,322	49,236	45,512
Industry (Profit)	10,634	9,691	8,089
Colleges and Universities	2,232	2,260	2,414
Other (non-profit or not for profit organizations)	620	712	645

OFFICE OF TELECOMMUNICATIONS

INSTITUTE FOR TELECOMMUNICATION SCIENCES

The Institute for Telecommunication Sciences of the Office of Telecommunications is interested in those properties of the atmosphere which modify the characteristics of electro-magnetic waves propagating through it, and thus affect their information carrying power. Present priority within OT is to determine the effects of the atmosphere on radio waves with frequencies greater than 10 GHz.

In FY 75, OT continued laboratory studies of the transfer properties of the atmosphere in the 40-140 GHz portion of the spectrum, using the millimeter wave spectrometer to determine the detailed ab-

sorption and phase dispersion characteristics of the atmospheric oxygen lines. In addition, OT developed equipment and made field measurements of the broadband transfer properties of the natural atmosphere at frequencies near 60 GHz. These results will be related to turbulence, precipitation, and particle scatter theories.

In FY 76, OT will continue the laboratory measurements. OT field measurement equipment will be modified and measurements to determine the depolarization properties of the atmosphere, including the effects of precipitation, will be made. In addition, available data on the effects of ionospheric scintillations on satellite-earth propagation will be reviewed and planning for an experiment to measure such effects in the equatorial region will begin.

Allocation of Funding (in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Physical Meteorology.....	77	115	85
TOTAL.....	77	115	85
Aeronomy			
Ionospheric Physics.....	45	—	30
TOTAL.....	45	—	30
PROGRAM TOTAL.....	122	115	115
Distribution of Funding			
In-house.....	122	115	115

DEPARTMENT OF DEFENSE

ARMY

Atmospheric processes have a significant, often critical impact on Army field operations. The principal objective of the Army's atmospheric sciences research and development program is to develop equipment and techniques to markedly increase the effective use of weapons systems, conduct of field operations, and support of RDT&E missions. The following general areas are emphasized: aeronomy, mesometeorology, meteorological satellites, atmospheric sensing, meteorological techniques and equipment, and meteorological support activities.

AERONOMY

This research is directed to defining and interpreting the ionization phenomenology of the ambient and naturally disturbed atmosphere. Specifically, the direct measurement of the concentration of minor constituents, both positive ion and neutral, in the stratosphere will be made by means of a balloon-borne mass spectrometer and an infrared spectrometer. The Combined Stratosphere Measuring Program (COSMEP) will be initially undertaken in the mid-latitudes. Follow-on flights will occur in the polar region to measure parameters associated with auroral disturbances. Complementing this effort will be extensive measurements of natural density, temperature, pressure and, in particular, upper air winds. Concurrently, important atmospheric recovery processes will be identified and reaction rates determined in the laboratory and used to verify and clarify the direct atmospheric measurements. Utilizing the latest experimental data and theory, improved models of the upper atmosphere will be developed for the prediction of the effects of the atmosphere on military systems.

MESOMETEOROLOGY

The intensive tactical operations of the Army are affected principally by local weather phenomena, because of the relatively small area over which they are conducted. The objective of mesometeorologi-

cal research is to develop the means for providing detailed and representative information on the properties of the atmosphere within the battlefield region. Because of the short distances and/or time intervals involved in meteorological support to the tactical Army, a quick reaction capability is required which relies primarily on automated information processing. Thus, techniques and numerical models are being developed for the detailed diagnosis and prognosis of mesometeorological phenomena by automated data processing involving objective, dynamic, and variational analyses that incorporate knowledge of the behavior of mesometeorological phenomena with available data derived from terrain information as well as meteorological observations. A series of mesometeorological experiments is being performed which includes detailed observations using balloon-borne and airborne instruments and an automated mesometeorological network of observation stations. The data collected will be used to validate the utility of the various models for computing high resolution mesoscale fields of wind, clouds, and other weather phenomena over the battlefield. Studies will continue on the effects of meteorological conditions, especially as influenced and modified by terrain, on the processes of atmospheric transport and diffusion. Information obtained has direct application to problems associated with air pollution abatement.

METEOROLOGICAL SATELLITES

Meteorological satellites provide a new means of meeting certain Army mesoscale support requirements on the battlefield with increased efficiency by eliminating many meteorological personnel, equipment, and operations, and by acquiring data in battlefield areas commonly denied to surface-based observations. A system for providing fallout winds using radiometric data from meteorological satellites is being developed. Polar-orbiting sun-synchronous satellite systems are supplying Vertical Temperature Profile Radiometer (VTPR) data on an operational basis over the entire globe which



Scene of the U. S. Army Atmospheric Sciences Laboratory Optical Range located at Biggs Army Airfield, El Paso, Texas. The range was established to field test the Army laser crosswind sensing device required for direct tank fire. The range is 2KM in length. It is instrumented with an array of 20 research quality anemometers for the first 0.5KM and a total of 34 anemometers for the 2.0KM range. Various temperature and radiation measurements are also made and data processed concurrently with the wind measurements. (U. S. Army photo.)

is adequate for Army nuclear fallout prediction requirements in the clear air above clouds. New VTPR systems in the O₂ 63-GHz region will become operational in FY-76 with some penetration of satellite-derived temperature data into tropospheric clouds. The Synchronous Meteorological Satellite (SMS) now provides infrared images of local areas at frequent intervals and can fill certain Army requirements for mesoscale visibility information on the battlefield. Combination of these two satellite systems can be expected to materially improve Army battlefield capabilities in the future.

ATMOSPHERIC SENSING

For Army operations to be effective, atmospheric parameters such as wind, temperature, and visibility need to be measured as nearly as possible in real-time. Single-point sensors, which may be adversely affected by local or transient perturbations, do not always accurately represent the conditions. But developments in microwave radar, laser radar, passive radiometry, and acoustic sounding have demonstrated that it is now feasible to consider real-time atmospheric sensing systems for the combat Army. Remote sensing permits the measurement of relevant parameters of the atmosphere in one, two, or three spatial dimensions, all as a function of time, without modifying the medium, thus insuring representative observations. Although various types of systems are being considered, optical sensing represents the greatest effort. The current Army research program in remote sensing is principally concerned with the problems of measuring both crosswinds along a path and winds along an elevated trajectory. Techniques are being developed to derive crosswind data along an integrated path by analyzing two successive images of a target illuminated by a double-pulsed laser.

The feasibility of using a CO₂ Laser Doppler Velocimeter (LDV) to measure winds at heights and ranges to 500 m under varying conditions is also under study. The effectiveness of Army operations and systems is further limited by atmospheric gases and dust. To assess this limitation, the absorptive properties of atmospheric gases will be measured under varying conditions. Atmospheric dust samples from selected locations will be analyzed to determine variations of the visible and near-infrared absorption coefficient. A multiple scattering

transmittance model will be developed for inclusion in the comprehensive low-energy laser transmission research model.

METEOROLOGICAL TECHNIQUES AND EQUIPMENT

The needs of today's Army for meteorological information are only partially met with outdated manually operated equipment. Meteorological equipment and techniques that will meet the needs of the Army must provide timely and reliable meteorological information that can be integrated expeditiously and, together with other essential data, be used effectively in the planning and conduct of military operations. The effects of meteorological conditions on trafficability and all operations of dispersed mobile units in modern warfare make it imperative that the meteorological system be responsive to all types of tactical operations, and that it provide meteorological information which is representative of conditions in the area of interest to the Field Army. The output data must be sufficiently detailed and of such accuracy and representativeness relative to the supported application that the operational needs will be satisfied. In order to meet the urgent need of the Artillery to improve first-round hit accuracy, the AN/UMQ-7 Meteorological Data Sounding System is being developed on a high priority basis. Development of an Automatic Meteorological System (AMS) will be continued to supply near real-time meteorological data for artillery fire, airmobile and Army aviation, chemical and nuclear defense, and other tactical operations. Other systems that are being developed in support of the Field Army are the Forward Area Meteorological Acquisition System and the Cold Fog Dissipator.

METEOROLOGICAL SUPPORT ACTIVITIES

This program provides meteorological support to Army RDT&E activities and other organizations and to users of White Sands Missile Range, New Mexico. Detailed meteorological data are obtained from the surface to 100 km using standard and special purpose instrumentation. In FY-74 meteorological support was furnished for 668 programs of 49 Army RDT&E activities at 13 permanent sites and for 4 programs at temporary sites.

Allocation of Funding
(in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Physical Meteorology.....	360	1,015	775
Dynamic Meteorology.....	340	230	400
Observation.....	2,415	3,946	3,743
Description.....	1,244	930	1,065
Prediction.....	820	1,032	945
Modification.....	172	—	—
Dissemination.....	1,040	1,261	1,179
Systems.....	200	—	—
Support.....	3,050	4,232	4,800
TOTAL.....	9,641	12,646	12,907
Aeronomy			
Ionospheric Physics.....	100	—	—
Ionospheric Chemistry.....	140	270	270
Ionospheric Structure.....	739	830	1,077
TOTAL.....	979	1,100	1,347
PROGRAM TOTAL.....	10,620	13,746	14,254
Distribution of Funding			
In-House.....	9,460	10,712	10,886
Industry (Profit).....	820	1,804	2,693
University.....	240	855	440
Other.....	100	375	235

Meteorological support was provided for 125 RDT&E programs at White Sands Missile Range (Army, Navy, Air Force, and NASA) involving approximately 4,600 range missions. The support program includes the Army's participation in the Cooperative Meteorological Rocket Network. Support was also furnished for the Army's demilitarization and detoxification activities.

NAVY

Naval interest in the Atmospheric Sciences stems from operational requirements for improvements in communications, acoustic propagation, remote and direct sensing of the environment for meteorological prediction, including subsurface and surface sea conditions; also, electromagnetic energy propagation through the atmosphere throughout the spectrum (from x-ray, ultraviolet, and visible to longwave radio frequencies) in connection with detection procedures, surveillance, discrimination

techniques. This program seeks fundamental knowledge necessary for solving Navy and Marine Corps problems in areas such as communications, weather prediction, night vision, optical transmission through the atmosphere, and safe launching of missiles at sea beneath electrified clouds. This entails research concerning solar phenomena and emissions, the ionosphere, and the lower atmosphere. Investigations are also conducted which deal with atmospheric structure, cloud and clear-air electrical processes, the composition and distribution of atmospheric nuclei, warm fog, the trade-wind cumulus clouds, and their associated weather patterns.

Programs of the Atmospheric Sciences Naval Research Area generate scientific data leading to improved understanding of atmospheric processes as they are influenced by or related to atmospheric electrification, natural and artificial radioactivity, atmospheric optical properties, and incident extra-terrestrial radiation. This encompasses studies in

cloud physics and atmospheric dynamics, using rocket soundings and lasers to accumulate more information on the stratum between 30 and 70 km, and physics, with accent on dissipation. This basic information about the atmosphere and its phenomena assists the in Navy in designing instruments, vehicles, and systems used in fleet operations and in predicting atmospheric conditions.

Prototype automatic weather stations for unique environmental situations, such as remote cold climate and sea surface air-droppable contingency use, have been fabricated and undergone limited testing. Various critical subsystems assemblies such as sensors, power, and telemetry have been individually improved and retested in consonance with improvements in technology. Subsystems will be integrated on a hard prototype basis for a technical evaluation to identify system weak points prior to committing each system to a harsh-environment testing period. A prototype automatic weather station for shipboard use has been fabricated. Tests aboard ship completed in 1974 are being evaluated and discrepancies are being rectified prior to final testing.

A unique system of acquiring a refractive index profile in the vertical has been initiated and is in the evaluation state prior to design and fabrication of actual hardware for full prototype test. Prototype hardware will be designed, fabricated and subjected to limited usage, the data from which will be utilized by the unique processing technique to determine adjustments necessary prior to commitment for further development.

Performance of the AN/AMH-3 Microwave Refractometer under actual fleet operating conditions is excellent. Seven months of special operational use established the feasibility and desirability of a microwave refractometer under actual fleet operating conditions. This special operational use also established the feasibility and desirability of a microwave refractometer as a means of determining radar/radio wave propagation data on Navy aircraft. Current effort is directed toward developing peripheral equipment to reduce the time and manual effort involved in transforming raw refractive index data into useful operational information. A formal technical and operational evaluation of a complete system is planned for the summer of 1975.

High altitude sensors are being developed to demonstrate methods of determining the tem-

perature, pressure, and density of the upper atmosphere by means of rocket-borne instrumentation. This program will continue to investigate temperature sensors such as beads and thin film thermistors and their associated mountings by analytical means, laboratory tests, and flight tests. Successful completion will establish the configuration of a temperature sensor with such well-defined thermodynamic and aerodynamic characteristics that the temperature of the atmosphere can be accurately determined at altitudes up to 75 kilometers.

Balloon-borne instruments and techniques for measuring the water vapor, ozone and particulate content of the stratosphere are being refined. These instruments and techniques are being used to gather water vapor and ozone data of high quality at stratospheric levels. Success in this work will provide data and scientific information that are important in the formulation of more accurate models of atmospheric circulation which can then be applied to numerical weather prediction.

The Environmental Prediction Research Facility is developing techniques to extract meaningful air-sea interface information from advanced sensors aboard available environmental satellites. Emphasis is placed on tactical use of the data extracted/derived. Ways to ingest these data into the Navy's analysis and prediction system will continue to be a prime area of research. Combining data from the Defense Meteorological Satellite Program and the National System should provide a greater tactical support capability to the operating forces.

The weather modification research effort directed toward improving the Navy's capability to utilize the atmospheric environment to advantage has been reduced. Instruments and methods being developed to study fog, clouds, and natural weather processes utilizing measurements of dewpoint, liquid water distribution, cloud and fog droplet and ice particle sizes, and number of cloud condensation nuclei (CCN) will continue at a slower pace. Improvements are underway to obtain sufficient accuracy and resolution to differentiate between natural and artificially induced weather phenomena. Studies are being conducted on generation, characterization and evaluation of active agents to enhance or inhibit the formation, growth coalescence, removal, and freezing of cloud and fog water droplets, and the mechanisms and theories applicable to these processes. Numerical modelling

Allocation of Funding
(in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Physical Meteorology	685	737	788
Dynamic Meteorology	75	85	85
Observation	940	1,060	1,368
Prediction	973	983	1,148
Modification	180	180	180
TOTAL	2,853	3,045	3,569
Aeronomy			
Ionospheric Physics	171	164	180
Solar Terrestrial Studies	431	802	880
TOTAL	602	966	1,060
PROGRAM TOTAL	3,455	4,011	4,629
Distribution of Funding			
In-house	3,157	3,714	4,341
Industry	117	116	107
University	181	181	181

of the cloud, fog, or system is being used to design experiments and to define and evaluate the physical processes occurring during field experiments.

AIR FORCE

METEOROLOGY

The principal objectives in the Air Force's program in meteorological research are greater understanding of atmospheric processes and better techniques of observing, processing, displaying, forecasting, and, in some cases, modifying meteorological elements to facilitate safe and efficient operations of Air Force systems.

Direct and indirect sensing techniques are being developed. A solution to the requirement for accurate measurement of relative humidity at low humidities will be sought through calibration and flight testing of several carbon-type elements. Improved techniques of acquiring, processing, transmitting, displaying, and storing data for eventual use in the development of a weather radar system for the Air Weather Service will be pursued. An automated, lidar ceilometer, now under development, will undergo operational field tests.

Testing of an experimental lidar slant range visibility measurement system, now under development, will be initiated. Establishment of a prototype system of automated weather observations will be completed.

Another goal will be the development of instrumentation and techniques to improve the quality of weather radar measurements for both operational and research purposes. Principal activities will continue to be the development of data processing techniques for the utilization of radar reflectivity and pulse Doppler returns, application of these techniques to the identification of regions of dangerous turbulence and damaging hail, and fine-scale quantitative measurement of precipitation boundary layer, (2) analyses of turbulence data collected in field programs, and (3) the development of a numerical integration model for prediction of mean and turbulent values of wind and temperature in the boundary layer.

Another objective is an improved capability for short range (0 to 3 hours) forecasting of local weather conditions that reduce the effectiveness of Air Force operations (low ceiling and visibility, severe storms, damaging winds, and heavy rain and snow). New methods of terminal weather observation, analysis, and prediction are developed and

tested, the basic data being provided by a fully automated field facility near Hanscom AFB, MA. Field experiments planned for FY 76 are designed to (1) establish optimum techniques for automated observation and description of existing airfield visibility conditions for immediate use by the forecaster and operator, (2) develop and test improved computer techniques for short range forecasting of runway visual range, (3) establish forecasting accuracy as a function of the type, spacing, and frequency of airfield observations, and (4) develop and test new techniques for the integrated use of digital weather radar, weather satellite, and automated surface observations for forecasting of severe convective storms.

Climatological studies are conducted to provide engineers designing aerospace systems and personnel operating them with the best information on climatic conditions. In FY 76 available data will be used to prepare (1) models for estimating probability distributions of instantaneous precipitation rates, (2) a Northern Hemisphere atlas of cloud-free lines-of-sight probabilities, (3) and atlases of mean monthly observed upper winds and of surface temperature extremes. Methods for extending climatic conditional probability models to operational decision-making will be developed, as will better stochastic models of the spatial distribution of weather conditions. Techniques utilized in the preparation of Military Standard 210B, "Climatic Extremes for Military Equipment," will be applied to provide climatic design criteria for material to be used in specific geographic regions or environments.

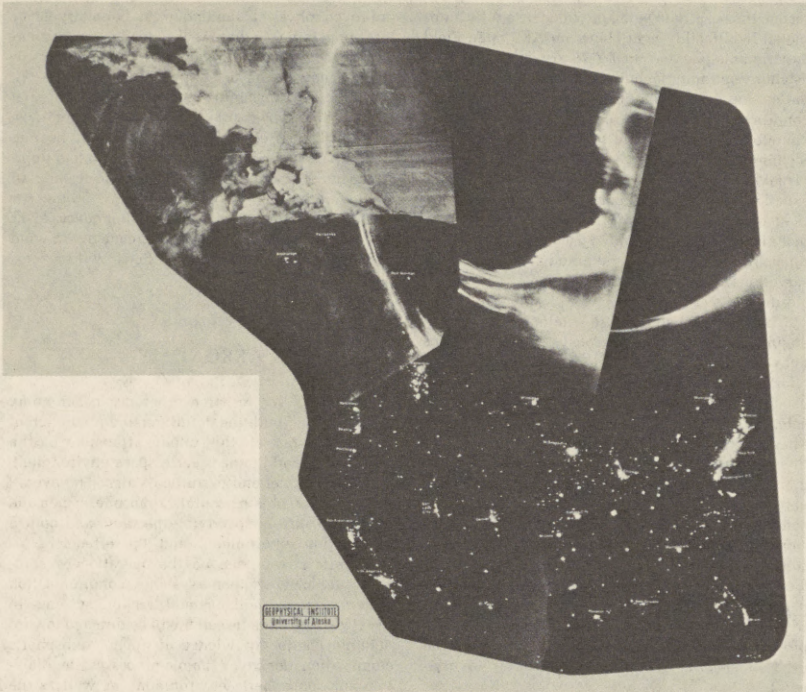
Another objective is to improve the accuracy and speed of numerical weather prediction by developing improved mathematical simulation models of the atmosphere and more accurate and efficient numerical solution procedures. More specifically the research program is oriented to (1) enhancement of the detail of forecasts by developing fine-mesh, limited-area models which are relatively free of computational instability at the lateral boundaries and thus provide a more detailed forecast over a limited area of the globe, (2) development of a method for incorporating the small-scale effects of cloud heating into a forecast model for the tropics, and (3) development of improved operational forecasts of the planetary boundary layer through

improved physical simulation in boundary layer modeling. In FY 76 there will be testing and evaluation of specialized high-order interpolation procedures now being developed for controlling the computational instability created on the artificial lateral boundaries of fine-mesh, limited-area models. The effects of convective cloud heating will be parameterized and incorporated into a tropical channel model, which will then be tested. An evaluation of the overall performance of the Air Force Global Weather Central's boundary layer forecast model, including the adequacy of the wind and temperature prediction methods, will be completed.

AERONOMY

The Air Force research programs in aeronomy are concerned with the definition and prediction of the properties of the upper atmosphere, the ionosphere, and the near-earth space environment, in both the quiet and perturbed states. The overall objective is to obtain accurate atmospheric data and models for use in specifying the radio and optical propagation environment and the effects of atmospheric phenomena on the operation of aerospace vehicles, weapons systems, communication systems, and surveillance and tracking systems. In fiscal year 1976 the research will be directed toward obtaining better knowledge of upper atmospheric composition, density, dynamic processes, the radiative and ionospheric environment, as well as the sun and the properties of the solar wind and magnetosphere.

Atmospheric density and structure to 150 km is determined by rocket experiments employing the falling sphere, Bremsstrahlung, and laser scattering techniques. Density at satellite altitudes to 200 km is obtained using satellite mounted accelerometers and ionization gauges. Ion and neutral chemistry laboratory experiments will be conducted by mass spectrometry for use in determining reaction rates during disturbed atmospheric conditions. Rocket experiments will also be carried out to obtain winds, temperatures, and diffusion coefficients. Instrumentation for missile thrust determination will be developed and installed in aircraft and flown at



A composite photograph assembled from data obtained by successive passes of the Defense Meteorological Satellite Program (DMSP). The composite was prepared by the Geophysical Institute of the University of Alaska. In the daylighted portion of the photo, upper left-hand corner, a part of Northeastern Russia and the Kamchatka Peninsula are visible. At the extreme lower right corner Florida is outlined by the lights of its coastal cities and towns. The very bright areas in the upper right-hand portion are the aurora or "northern lights". Meteorological information, e.g. the cloud system visible over the Bering Sea, obtained from DMSP is used by all of the Military Services to support their operations and training programs, as well as for research in the area of atmospheric science.

the Western Test Range. Solar ultraviolet radiation in the 150 to 1850 Angstrom and 1250 to 3000 Angstrom spectral regions will be observed by rocket and satellite-borne spectrometers. Work in the stratospheric environment will also be emphasized, particularly with regard to the impact of aircraft operations on atmospheric quality.

Infrared properties of the atmosphere will be investigated for their effects on optical/IR sensing systems. Computer code development for atmospheric transmission and emission calculation will be continued. Phenomena associated with a disturbed atmosphere at high altitudes will be measured by aircraft, balloon and rocket-borne in-

struments. The infrared, visible, and ultraviolet sky backgrounds and earth limb radiance, and their effects on surveillance and tracking systems will continue to be investigated. IR phenomenology and optical code data base development will extend the capability to predict optical/IR emission intensity from naturally and artificially disturbed atmospheres thru use of the OPTIR computer code.

In ionospheric research, measurements will be conducted in the arctic regions to observe the VLF and LF reflective properties of the high latitude ionosphere. Ionospheric absorption of signals at these frequencies will also be studied with a view toward their possible use in satellite-to-aircraft and satellite-to-ground communications. Rocket probe experiments will be flown to determine the existence of ELF windows. Radio astronomy and satellite propagation studies are to be conducted to

determine the amplitude and phase fluctuations of signals from VHF to L-Band as they traverse ionospheric irregularities and to observe variations in total electron content which produce range errors in navigation and radar detection systems. Solar radio emission measurements are conducted for predicting solar events based on unique characteristics of solar radio bursts. Examples of operationally useful radio burst signatures are the U-shaped spectrum which is a highly reliable precursor of proton events and resultant PCAs, and the integrated flux density which permits prediction of the magnitude of proton flux and severity of the PCA. Effects of steep electron density gradients and disturbed ionospheric conditions on oblique HF propagation will be determined. Airborne techniques will be developed to study morphology of signal scintillation regions. Operation of the Goose Bay Ionospheric Observatory will continue.

Allocation of Funding
(in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Physical Meteorology.....	103	90	51
Dynamic Meteorology.....	217	321	350
Observation.....	1,027	1,317	1,371
Description.....	750	972	925
Prediction.....	241	241	239
Modification.....	568	273	295
Systems.....	3,135	4,364	4,883
TOTAL.....	6,041	7,578	8,114
Aeronomy			
Aurora and Airglow.....	676	743	800
Ionospheric Physics.....	2,742	2,918	2,756
Atmospheric Chemistry.....	2,840	2,940	2,984
Atmospheric Structure.....	7,085	8,907	9,611
Energetic Particles.....	817	962	825
Atmospheric Geomagnetism.....	972	654	770
Solar Terrestrial Studies.....	3,062	2,843	2,798
Dynamic Aeronomy.....	952	1,006	998
Instrumentation, Rockets.....	1,248	1,123	1,153
TOTAL.....	20,394	22,096	22,695
PROGRAM TOTAL.....	26,435	29,674	30,809
Distribution of Funding			
In-House.....	17,800	18,134	19,075
Industry (Profit).....	3,215	4,616	4,644
University.....	5,170	6,500	6,640
Other.....	250	424	450

Magnetic prediction techniques will be developed based on real-time network observations of magnetic activity levels. In addition, horizontal ionospheric current systems will be measured during magnetic storms using sounding rockets. Magnetic activity indices and micropulsation analyses will be the basis for forecasting magnetospheric disturbances. In solar research, observational and theoretical studies of the physics of energy transfer in the solar atmosphere, the origins of the geophysically active solar disturbances, and conversion from magnetic energy to thermal and kinetic energy will be carried out. A further objective will be the study of solar activity other than flares, such as the corona, sunspots, and prominences, to clarify the role of the corona both as the site for solar activity and as the propagation medium. Ground based solar observing instruments development is still another objective. A vacuum tower telescope with spectrographic, magnetographic, and tunable birefringent filter accessories is now in full and effective operation at the Sacramento Peak Observatory. Now under development is a new photoelectric scanning coronal photometer to replace an existing bread-board model. A telescope for use in the Solar Observing Optical Network (SOON) has been designed and fabricated in-house to meet an Air Force operational requirement. Four additional telescopes for the network remain to be constructed.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

METEOROLOGY

The objective of this program is to develop techniques for evaluating the sensitivity of world climate to human actions. Emphasis is placed on the national security implications of climatic changes induced by actions of other countries. The principal research activities is the development of large general-circulation models of the atmosphere-ocean system and their use in a series of numerical experiments employing advanced computers such as ILLIAC IV. Supporting research in averaged models, parameterization of various physical processes, and climatology is also funded. During FY 75-76 extensive experiments will be continued on ILLIAC IV, including attempts to reproduce past extremes of natural climate.

AERONOMY

The principal objectives of the Strategic Technology Program are to develop a background of scientific and technical knowledge and techniques for the improvement of strategic systems, both offensive and defense; to investigate the effects of the atmosphere on strategic systems, both offensive and defensive.

Allocation of Funding (in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Description	3,462	2,700	1,475
TOTAL	3,462	2,700	1,475
Aeronomy			
Aurora and Airglow	25	—	—
Ionospheric Physics	375	185	200
Atmospheric Chemistry	15	15	—
Atmospheric Structure	210	415	400
Instrumentation, Rockets	10	10	—
TOTAL	635	625	600
PROGRAM TOTAL	4,097	3,325	2,075
Distribution of Funding			
In-house	3,712	2,885	1,625
Industry	110	365	300
University	275	75	150

DEFENSE NUCLEAR AGENCY

Mission-oriented investigations into selected areas of aeronomy by the Defense Nuclear Agency will continue to focus on the fulfillment of certain requirements associated with high priority DoD defensive systems. Since such systems must survive and operate effectively in nuclear disturbed environments, all efforts in the atmospheric sciences will be directed toward the acquisition of relevant and essential data.

In the absence of atmospheric nuclear tests by the U.S., particular aspects of certain types of geophysical disturbances (e.g. auroras, solar proton events, solar substorms, etc.) serve as useful sources of information concerning ionospheric irregularities and disturbances, as well as other pertinent atmospheric phenomena. Such information is effectively employed in the elucidation of the late-time nuclear weapon effects area, where further

knowledge is required for the formulation, improvement, and validation of predictive computer codes designed to be employed in conjunction with the operation of such defensive systems. Supporting theoretical and laboratory efforts, quite specific in nature and scope, serve to round out these investigative endeavors. In this connection, a comprehensive effort involving the investigation of certain aspects of auroral events as a source of information concerning physical and chemical processes of significance in disturbed environments was begun in 1972 and is planned for continuance well into the late 1970's time frame.

The theoretical, laboratory, and field measurement activities associated with these aeronomy investigations are conducted in cooperation with the Air Force Cambridge Research Laboratories, the U.S. Army Ballistic Research Laboratories, the Office of Naval Research, and other appropriate government laboratories or agencies.

Allocation of Funding (in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Aeronomy			
Aurora and Airglow	5,075	2,714	2,765
Atmospheric Chemistry	1,060	930	913
Atmospheric Structure	375	287	247
Energetic Particles	55	60	65
Instruments, Rockets	3,245	4,223	2,875
Instruments, Satellites	425	60	95
TOTAL	10,235	8,274	6,960
PROGRAM TOTAL	10,235	8,274	6,960
Distribution of Funding			
In-house	5,075	3,310	2,784
Industry	4,883	4,534	3,936
University	277	430	240

1. The first part of the report deals with the general situation of the country and the progress of the work during the year. It is divided into two main sections: the first section deals with the general situation of the country and the progress of the work during the year, and the second section deals with the specific results of the work.

2. The second part of the report deals with the specific results of the work. It is divided into three main sections: the first section deals with the results of the work in the field of agriculture, the second section deals with the results of the work in the field of industry, and the third section deals with the results of the work in the field of commerce.

3. The third part of the report deals with the conclusions and recommendations. It is divided into two main sections: the first section deals with the conclusions and the second section deals with the recommendations.

4. The fourth part of the report deals with the appendix. It is divided into two main sections: the first section deals with the list of names and the second section deals with the list of places.

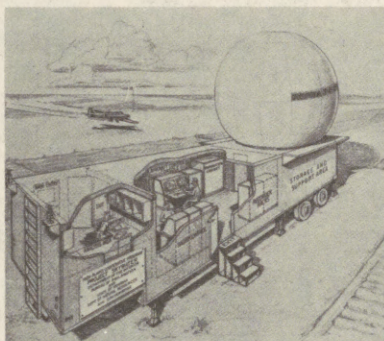
5. The fifth part of the report deals with the index. It is divided into two main sections: the first section deals with the list of names and the second section deals with the list of places.

DEPARTMENT OF THE INTERIOR

The Bureau of Reclamation, through Project Skywater, conducts weather modification research on augmenting the Nation's water supplies by cloud seeding. Research in FY 1976 and the Transitional Quarter will be directed toward three critical water resource regions:

The High Plains States where field research will be implemented at three sites—Miles City, Montana, Colby-Goodland, Kansas, and Big Spring, Texas—as part of the High Plains Cooperative Program undertaken in conjunction with State agencies to resolve critical remaining questions on seeding summer convective clouds.

The Colorado River Basin where final analyses and reports will be prepared on the completed Colorado River Basin Pilot Project and where initial State-Federal investigations into such complex problems as water ownership, repayment, and water regulation will begin.



One of two 5-cm radars with 1-degree beam width and digital recording on computer compatible tape specially designed and built for cumulus cloud seeding research in the High Plains Cooperative Program (HIPLEX). Analytical programs for the radar data will be run on the Bureau of Reclamation's CDC Cyber 74 computer system located in Denver. (Department of the Interior photo.)

SELECTED SITES
FOR HIGH PLAINS COOPERATIVE PROGRAM



Three research sites were selected from 17 localities interested in having the research conducted in their area. A total of 15 public meetings were held throughout the High Plains regions during the planning and site selection process. Each of these locations for cooperative weather modification research were recommended by the Governor of the state. (Department of the Interior photo.)

The Sierra Nevada Mountains where the completed Pyramid Lake Pilot Project will be evaluated and planning and field environmental studies for a possible winter cooperative pilot project in the northern Sierra Mountains of California and Nevada will begin.

In addition to concentrated research for these three regions, development of computerized cloud models, particularly a practical field application adaptation of two-dimensional time-dependent convective cloud models and an improved winter orographic model, and combined analysis of completed research projects will be continued. With growing public interest in using weather modification, cooperative technical assistance will be furnished operational seeding projects by aiding in design and evaluations and providing ready, low cost access to cloud models and other meteorological products on the Bureau's Environmental Computer Network. Cooperative use of radars, rain

gages, and other specialized equipment between Project Skywater and State agencies and joint funding of research studies is being increased as more States are becoming involved with weather modification.

Preparation, review and acceptance of an overall programmatic environmental impact statement for

Project Skywater is expected to be completed in FY 1976. Performing additional environmental assessment studies and undertaking a wide range of comprehensive, environmental, economic, and agricultural research on effects of additional precipitation will continue to require about 10 percent of the program funds.

Allocation of Funding
(In thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Weather Modification	\$3,900	\$4,000	\$4,649
Distribution of Funding			
In-house	800	1,000*	1,249*
University	1,000	700	800
Industry	1,300	1,400	1,500
Other (State)	800	900	1,100

* Include Bureau computer costs for High Plains data processing and analysis.

DEPARTMENT OF TRANSPORTATION

The Department of Transportation's research efforts in the atmospheric sciences relate to Departmental responsibilities for facilitating development and improvement of coordinated transportation service, for stimulating technological advances in transportation, for providing general leadership in identification and solution of transportation problems, and for developing and recommending national transportation policies and programs. Pertinent research is conducted by the Office of the Secretary, the Federal Aviation Administration, and the Federal Highway Administration.

OFFICE OF THE SECRETARY

The Climatic Impact Assessment Program (CIAP) which was to assess the environmental and meteorological effects of the projected world high-altitude aircraft fleet, including subsonic and supersonic vehicles, was completed.

CIAP has yielded much new scientific data, and has progressed considerably in drawing the data together into a better understanding of the cause-and-effect relations between aircraft effluents in the stratosphere and environmental impacts. Serious uncertainties still exist, but their magnitude has been reduced substantially so that useful conclusions are now possible.

The CIAP report concluded that there was an immediate need for development of regulations, on a national and international level, to ensure that future increases in high altitude air traffic would not be accompanied by a degradation in environmental quality.

To fulfill this need, the FAA announced the initiation of their High Altitude Pollution Program. The overall goal of this program is to provide the data and analyses required to permit continued growth of safety, efficiency, and economy in air transportation while ensuring that aircraft emissions, during high altitude cruise operations, do not result in adverse environmental effects.

FEDERAL AVIATION ADMINISTRATION

The FAA Aviation Weather Program is designed to provide the technical and operational developments required to improve the performance and utilization of existing components of weather data acquisition, transfer, processing, and display equipment to relieve immediate problems and to modify specific components for integration into the modernized configuration of the National Airspace System.

This program is expected to:

- Provide more extensive, accurate, and timely weather observation and forecast information to the aviation community to ensure safety and efficiency in the use of the airspace.
- Achieve optimum use of new and existing kinds of aviation weather services by more effectively informing pilots and traffic controller personnel about the availability of such services.
- Continue research and development, in cooperation with other Government agencies and industry, to achieve operational weather modification systems for fog dispersal in terminal areas, and to evaluate their environmental/ecological effects.
- Continue development of improved hazardous weather and turbulence detection techniques utilizing Doppler radar and other detection devices.
- Continue search for techniques and equipment for detecting and predicting clear air turbulence.
- Continue development of automated methods for producing aviation terminal forecasts with greater accuracy, timeliness, and reliability.
- Investigate possible methods of improving mass pilot briefings, and investigate the feasibility of using automatic data processing

methods to prepare flight profiles for use in briefing pilots at Flight Service Stations.

- Conduct research on aircraft wake turbulence and develop techniques and systems to sense and suppress its effect on other aircraft.
- Develop and evaluate an acoustic system for remotely measuring and displaying low-level wind and wind shear.

The FAA Aviation Weather Program is planned to provide pilots and air traffic controllers the best service possible within the state-of-the-art through in-service improvements, system modernization, and research and development in anticipation of future aviation weather requirements to increase the airport and airway system capacity. To realize the maximum return for effort expended, and in order to assure a coordinated integrated National Weather System, this Department is closely associated with, and time-phased to, other agencies' weather research programs.

Major efforts are underway or planned in the observation and dissemination of significant aviation meteorological parameters. These include: (a) a continuing research program for improvement in ceiling and visibility systems in order to present runway visual range (RVR), taxiway visual range (TVR), slant visual range (SVR), and ceiling height representative of existing airport conditions to air traffic controllers and pilots; (b) development of a more accurate system for measuring shorter distance than the present RVR for particular application to Category II and Category III visibility conditions; (c) development of a low cost weather data acquisition and display system for terminals to provide air traffic controllers with current terminal aviation weather in digital form. Additionally techniques to display hazardous flight weather on ATC radars will be developed in order to permit air traffic controllers to display contoured severe weather outlines on their radar scopes without compromising the aircraft target detection capability of their equipment. The development of

techniques for handling the wake turbulence problem continues to be emphasized.

In the weather modification area, an in-house study is being conducted to determine the most economically feasible, operationally efficient warm fog dispersal system that might satisfy the requirements of a large U.S. Airport with a major warm fog problem.

In the Systems category, funding provides for analysis, sensing, and suppression of aircraft wake turbulence through development of simulation environments, sensing devices, and airport physical modification to provide for detection, avoidance and/or suppression of hazardous wake vortices.

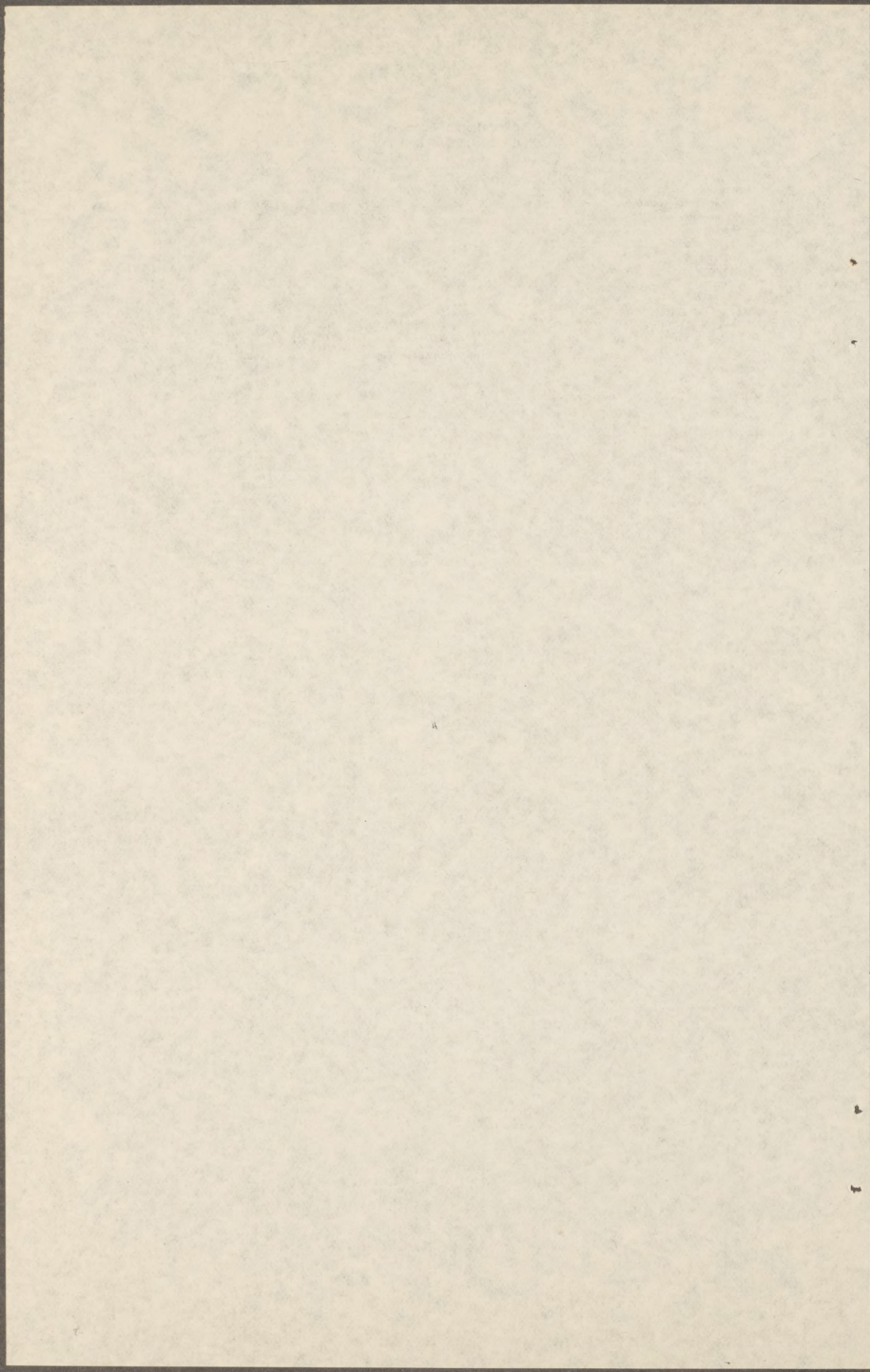
Delineation of areas of aviation hazardous weather (turbulence, rain, snow, hail, icing conditions, etc.) for use by Air Traffic Controllers to improve air traffic flow management, and the improvement of the Flight Service Station System to provide standards for better physical facilities and communications equipment for improved technical interface with the National Airspace System are the major weather dissemination efforts.

FEDERAL HIGHWAY ADMINISTRATION

The FHWA is conducting research in the field of environmental considerations in highway design and location directed toward the identification, evaluation, and quantification of those elements of the highway and its traffic that have detrimental or beneficial effect upon surrounding air quality in order to reduce detrimental impacts. Studies address the relationship between air pollution and roadway location, design, and operation. Included are field measurements and modeling of pollutant dispersal near roadways. Other studies are examining fluid dynamics in the vicinity of highway structures, the contribution of highway operations to atmospheric aerosol, particulate, and photochemical smog ingredient concentration. Control of dust during highway construction is also being investigated.

Allocation of Funding
(in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Dynamic Meteorology	1,826	1,581	650
Observation	5,402	3,648	3,096
Prediction	313	321	285
Modification	1,397	1,615	555
Dissemination	2,617	2,988	4,685
Systems	2,828	3,302	2,428
Support	848	—	50
TOTAL	15,231	13,455	11,749
PROGRAM TOTAL	15,231	13,455	11,749
Distribution of Funding			
In-house	3,697	3,454	3,491
Industry	6,536	6,196	6,388
Other	4,998	3,805	1,920



ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

Atmospheric Sciences

The goal of the ERDA atmospheric sciences program is to participate in evaluating the relationship between energy generation activities, man, and his biological and physical environments. This goal will be achieved by studies of the atmosphere's role in the movement, modification, and removal of power production pollutants, by determining the effects of power production on the atmosphere, and by studies of the effects of the atmosphere on energy-related activities.

Under the Atomic Energy Commission, the atmospheric sciences program developed a significant competence in atmospheric transport processes and atmospheric cleansing mechanisms for application to nuclear power generation and fallout from nuclear weapons. Supporting these applied areas were studies of turbulence, diffusion, cloud physics, and the chemistry and physics of gases and aerosols.

Because of this broad atmospheric sciences research base, the ERDA program is responding to the current acceleration in energy concerns associated with new energy cycles as well as with massive increases in the conventional generation modes.

The ERDA is initiating a major new program titled "Multistate Atmospheric Power Production Pollution Study" (MAP3S) centering on the region between Chicago-St. Louis and the east coast. The purposes of this program are to furnish the atmospheric information necessary to assess the biomedical, bioenvironmental, and weather modification effects of current power production practices in the Northeast United States and to apply the techniques that will be developed to the assessment of the atmospheric effects of major new fuel use strategies.

The first phase of this new program will be directed toward measuring and accounting for the temporal and spatial characteristics of the gaseous and particulate pollutant patterns that exist over the densely populated and heavily industrialized northeastern United States. This determination of pollutant patterns will involve studies of the interplay of source emissions with atmospheric transport,

chemical and physical pollutant transformations, and scavenging processes. Materials of interest will include oxides of sulfur, oxides of nitrogen, oxidants, hydrocarbons, trace metals, and radioactive gases and aerosols.

New and unique atmospheric tracers will be developed for use in studies to verify long distance transport models. The use of Krypton-85, Argon-41, and similar tracers will continue. Urban plumes will also be used as tracers to validate the transport/chemistry models at great downwind distances.

An increasing effort will be directed toward quantitative estimates of the impacts of energy pollutants upon weather and climate on all scales. New studies will define how power generation processes, both current and new, will affect natural distributions of precipitation, clouds, temperature, radiative energy balance, air flow patterns, and specific types of weather systems. These problems will be pursued through expansion of current small programs and new initiatives.

Fundamental studies in cloud and precipitation physics will continue as will studies of cooling tower plume characteristics, heat and moisture balances between cooling ponds and the atmosphere, and small scale weather effects from individual cooling systems. There is a significant concern that rejected heat and moisture from power parks, with generating capacities in the range of 20,000-30,000 MW(e), could cause thunderstorms and other relatively severe atmospheric effects. ERDA proposes a number of new studies in this area in FY76.

In the nuclear area, the Atmospheric Release Advisory Capability (ARAC) will begin a three year implementation plan that will produce a system capable of providing 24 hour atmospheric forecasting service to seven ERDA sites for use in case of nuclear incidents. ERDA will increase support to programs to investigate meteorological control of power plant emissions and will conduct research in short term forecasting to support the ARAC and other forecast and warning programs.

ERDA will continue to operate its aircraft and balloon-borne high altitude air sampling program.

and a surface air and rain sampling program in both the northern and southern hemispheres for sampling atmospheric radioactivity. Other constituents such as nitric acid vapor, nitric oxide, hydrogen chloride, and sulphate will also be measured in the stratosphere under ERDA sponsorship and by guest payloads of other agencies on these flights.

ERDA is currently making the world's only systematic measurements of chlorofluorocarbons in the lower stratosphere from a WB-57F aircraft. In response to the rapidly increasing concern over the effect of these materials on stratospheric ozone,

ERDA sponsored high altitude balloons will shortly begin measurements in the ozone layer itself.

The ERDA supports a comprehensive program in aeronomy aimed primarily at an understanding of the earth's magnetosphere and solar-terrestrial relations. Measurements of magnetospheric phenomenon, the nearby interplanetary medium, and solar and cosmic radiation are obtained from aircraft-, balloon-, rocket and satellite-borne and ground based instruments and plasma injections are made from rockets up to 500 km altitude. Field studies are supported by laboratory accelerator and vacuum ultraviolet experiments.

Allocation of Funding
(in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Physical Meteorology	1,799	2,703	3,892
Dynamic Meteorology	3,089	4,808	5,596
Observation	1,200	918	1,199
Description	253	483	507
Support	325	462	479
TOTAL	6,666	9,374	11,673
Aeronomy			
Aurora and Airglow	310	175	400
Ionospheric Physics	210	444	500
Atmospheric Chemistry	30	5	10
Atmospheric Structure	2	6	6
Energetic Particles	75	78	80
Atmospheric Geomagnetism	388	455	625
Instrumentation, General	4	4	8
TOTAL	1,019	1,167	1,629
PROGRAM TOTAL	7,685	10,541	13,302
Distribution of Funding			
In-house	2,379	3,109	3,625
Industry	222	65	30
University	809	1,560	1,961
Other	4,275	5,807	7,686

ENVIRONMENTAL PROTECTION AGENCY

The research program of the Environmental Protection Agency is in direct support of mission functions and is primarily concerned with solving high priority problems in connection with establishing and enforcing pollution control regulations and for the provision of pollution control technology.

A major thrust of current and proposed atmospheric research seeks to provide objective tools for use in the development of least cost pollution control strategies, land use and transportation planning for pollution control, pollution episode forecasting and control, and as aids to pollution monitoring networks. The development of Air Quality Simulation Models will permit EPA to:

- Describe and evaluate the impact of air pollution on urban and non-urban environments, and
- Provide quantitative description of the impact of air pollution on weather, visibility and climate

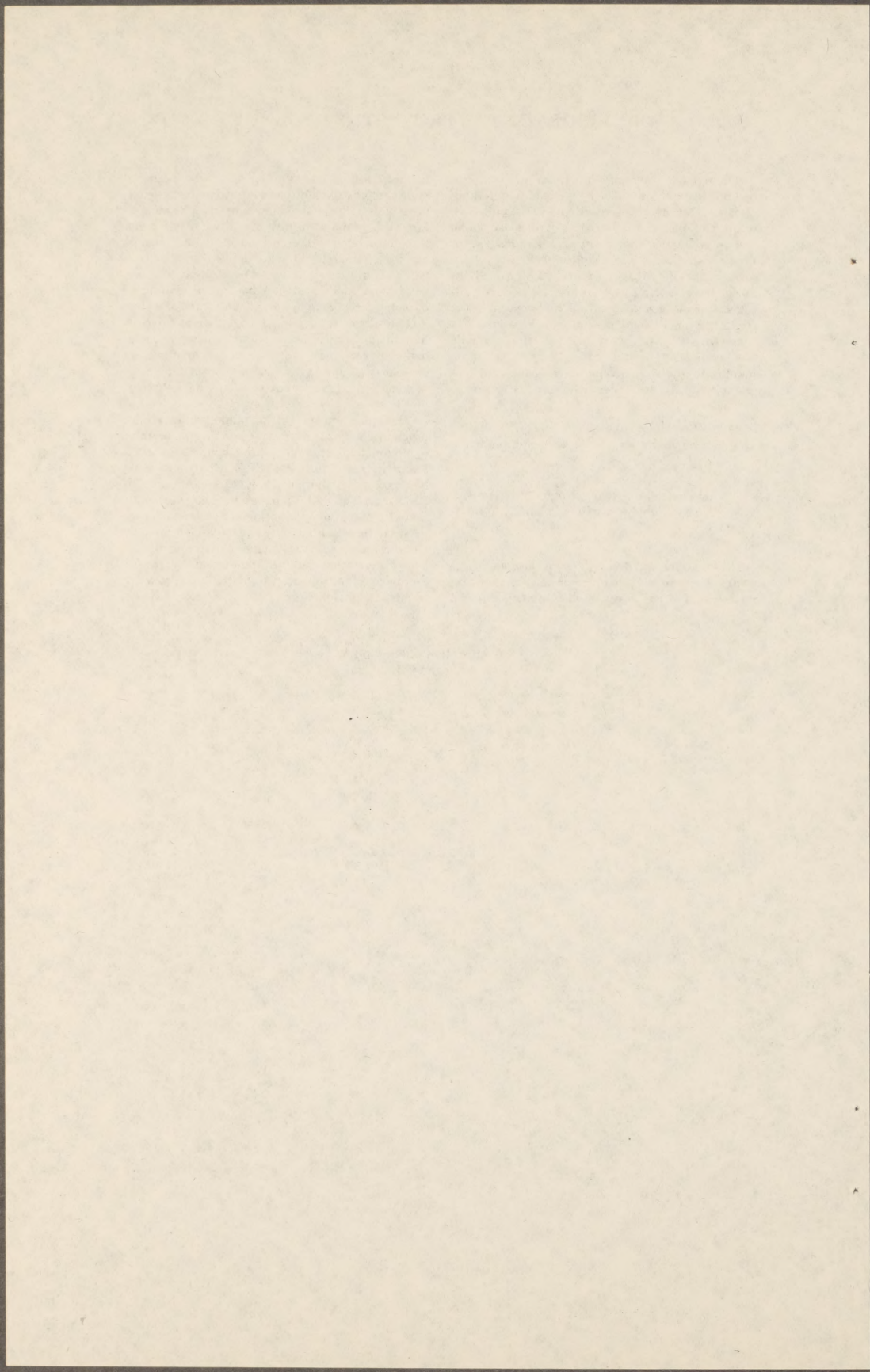
Observations and descriptions of the state of the atmosphere receive major emphasis. Approximately half of the observational funds are directed

toward defining air pollution on a urban/regional scale and providing the basic input data for development of descriptive simulation models. The remaining observational funds are divided between research related to specific urban health problems and research directed toward defining trends in urban and rural air pollution. Part of the increase in description funds will provide an acceleration of on-going research activities in the area of transformation/transport of pollutants with particular attention to sulfates, nitrates and oxidants. The remainder of the increase in description funds will be used to assess the environmental impact of halocarbon (e.g. F-11, F-12, carbon tetrachloride) emissions on the stratospheric ozone layer.

The urban and rural air pollution trend research program has been in progress for several years at approximately 250 sites throughout the United States. For FY 1976, the EPA will continue its Regional Air Pollution Study (RAPS) in the St. Louis area. The RAPS program includes the operation of a 25-station monitoring network which provides continuous air quality and meteorological data. Other research activities include the administration of a 100-station sun-photometer network for monitoring atmospheric turbidity for assessing trends in global pollution.

Allocation of Funding
(in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Physical Meteorology	350	350	350
Observation	6,180	6,480	6,480
Description	2,800	6,200	7,400
Prediction	50	50	50
TOTAL	9,380	13,080	14,280
PROGRAM TOTAL	9,380	13,080	14,280
Distribution of Funding			
In-House (Including other agencies)	3,222	3,422	3,422
Industry (Profit)	5,373	7,823	8,523
University	785	1,835	2,335



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA conducts a broad program in the atmospheric sciences in support of earth and space exploration that could lead to applications benefiting all mankind. The work includes the analysis and interpretation of data from flight research experiments, the investigation and exploration in the laboratory of new concepts for flight experiments, the laboratory determination of physical characteristics necessary for the interpretation of flight data, and theoretical studies explaining atmospheric phenomena of the earth and other planets.

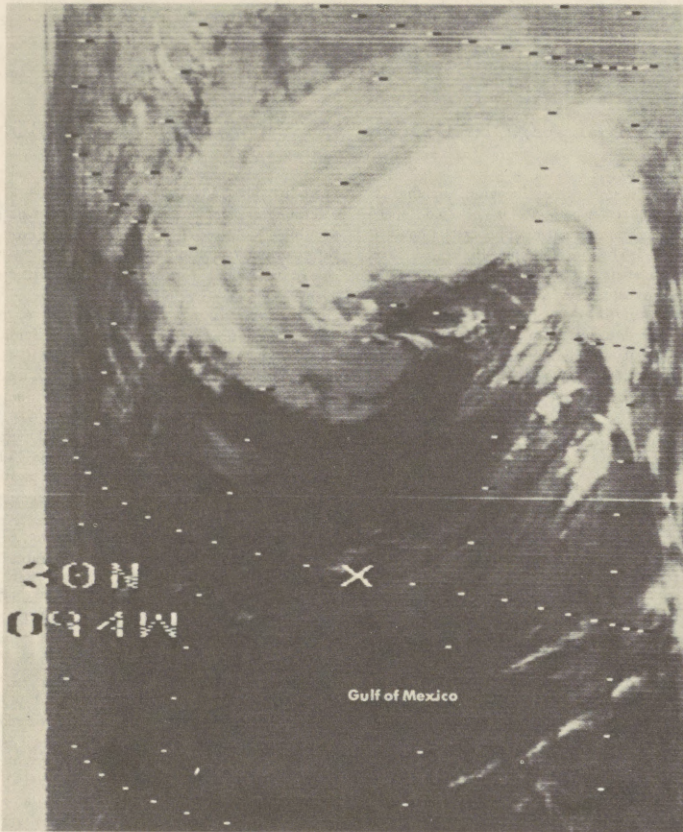
METEOROLOGY

NASA's broad, continuing program of supporting research and technology contributes directly to the improvement of meteorological satellite systems, sensors, and scientific applications. In FY 1976, the NASA research and development efforts will continue in analyses and interpretation, sensor evaluation, and sensor development to extend the satellite capabilities for measuring the environmental parameters needed to describe and predict the state of the atmosphere. These efforts include the determination of the radiative characteristics of gaseous and particulate constituents of the atmosphere and of natural surfaces in spectral regions such as ultraviolet, visible, infrared, and microwave. In addition, data extraction technique development and supporting ground systems are being emphasized in FY 1976. FY 1976 programmatic thrust is directed toward studying the application of satellite data to long-standing problems in the detection, prediction, and early warning of severe storms and the improvement of the current capability to forecast mid-range and long-range (climatic) weather features. Sensor development is directed toward parameters such as atmospheric structure and composition, aerosol content, surface conditions including soil moisture, snow and ice cover, sea state, and early identification of severe storms. Coupled with sensor development is the determination of the types of satellite data most applicable to numerical models. This research draws heavily upon the results obtained from the investigation of observations ob-

tained from TIROS, and SMS meteorological satellites and other research and development satellites, such as ATS and Numbus (formerly a series of dedicated meteorological satellites but recently expanded to include a multidisciplinary earth observations satellite).

The meteorological satellite research and development program, which, through flights of the TIROS and Nimbus satellites, has resulted in the flight of operational meteorological satellites for the National Oceanic and Atmospheric Administration (NOAA), continues its efforts to improve and increase the capability of the National Operational Environmental Satellite System (NOESS). The Improved TOS (ITOS) spacecraft series is directed toward the expansion of the operational capability of the basic TIROS Operational Satellite System for use in day-to-day, realtime weather analysis. The ITOS combines stored data and Automatic Picture Transmission (APT), both day and night, in a single, Earth-stabilized vehicle. ITOS-D was launched successfully on October 15, 1972, and was redesignated NOAA-2 upon successful injection into orbit. NOAA-2 was turned over to NOAA for operational service in November 1972. Subsequently, ITOS-F (redesignated NOAA-3) was launched on November 6, 1973, and ITOS-G (redesignated NOAA-4) was launched on November 15, 1974. The ITOS-series satellites which preceded NOAA-2 carried two Advanced Vidicon Camera Systems (AVCS) for stored-data readout, two APT cameras for realtime, and two two-channel Scanning Radiometers (SR) having one channel in the visible region and one in the thermal infrared band. Also, each has carried a secondary instrument payload consisting of a solar proton monitor and a flatplate radiometer.

On NOAA-2, as well as on the following ITOS-series satellites, the APT and AVCS cameras have been removed with their functions being assumed by the two-channel SR, and two new redundant sensors have been included to provide additional required observations. These new sensors are the Vertical Temperature Profile Radiometer (VTPR), and the two-channel Very High Resolution Radiometer (VHRR). The next major improvement



The NIMBUS 5 meteorological satellite views a tornado spawning storm on April 3, 1974. This Temperature Humidity Infrared Radiometer image shows the cloud formations over the United States at approximately 1:20 PM EDT. A few hours after this image was recorded, tornadoes devastated many areas from Alabama to Ohio. Over 300 people were killed. Of special interest to the meteorologist are the large, globular clouds to the right center of the image. Tornado activity is often associated with this type of cloud. (NASA photo.)



An ATS-6 satellite view of the Western Hemisphere. The continental United States appears at the top center of the image; much of South America can be seen in the lower right. The right-hand image was recorded by the infrared camera system, the left-hand by the visible light system. Meteorologists can infer information, such as the relative height of the clouds, by comparing the visible image with the IR image. By examining successive sets of these images motions of weather systems and groups of clouds can be determined. (NASA photo.)

is planned to occur with the forerunner of the advanced operational spacecraft required to provide the advanced technology needed for GARP and NOESS. With TIROS-N, a prototype for a third-generation operational satellite system, the emphasis will shift from the imaging of cloud cover to the quantitative measurement of the vertical structure of the atmosphere which is needed for improvements in numerical weather prediction. Attainment of this system's goal of accurate weather forecasts is absolutely dependent upon the availability of quantitative atmospheric data on a global scale.

Research and development efforts leading to potential of acquiring of meteorological data on a regular and dependable operational basis through continuous viewing from geostationary altitude started with the Applications Technology Satellite (ATS) series. ATS-1 and ATS-3 included spin-scan cameras which provided daytime cloud cover images of essentially the full disc of the earth, weather data relay experiments (WEFAX) for rapid dissemination of processed weather data, and a data collection and location experiment. The three-axis stabilized geostationary ATS-6 was placed in orbit in May 1974. Although primarily an experimental communications satellite, it carried a two-channel meteorological experiment, the Geosynchronous Very High Resolution Radiometer (GVHRR). This instrument, designed to measure reflected solar energy and emitted infrared energy, was capable of providing cloud cover imagery and surface temperatures both day and night. The principle and practicality of increased radiometric sensitivity afforded by such a 3-axis stabilized instrument was demonstrated.

Within the Synchronous Meteorological Satellite/Geostationary Operational Environmental Satellite (SMS/GOES) Program, NASA prototype operational geostationary satellites, SMS-1 (launched in May 1974) and SMS-2 (launched in February 1975) are designed to help in developing the NOAA-funded operational satellite, SMS-C/GOES-A. SMS-1 contributed to GATE in 1974, especially in the area of high resolution imagery. The satellite is now over South America above a point on the Equator at 75°W. SMS-2 is also over the Equator over a point at 115°W. These two spacecraft provide complete coverage of the 48 contiguous

states and surrounding areas. The primary instrument aboard these satellites is the Visible and Infrared Spin-Scan Radiometer (VISSR), a 16-inch aperture telescope for visible and infrared scanning. This sensor permits day- and night viewing and objective determinations of cloud types and heights, surface temperatures, and wind fields, using such methods as film loop and computerized wind-determining techniques. A major effort is underway to upgrade the VISSR to incorporate a temperature sounding capability for future implementation into the operational system. Other important capabilities of the SMS/GOES system are the retransmission of weather facsimile data (WEFAX), Space Environment Monitoring (SEM), and a system for collecting and distributing environmental data measured on data collection platforms located on land, at sea, or in the atmosphere.

The Nimbus program continues to provide R&D satellites to obtain earth observations data. In addition, the program's purposes are development and flight test of sensors and technology to obtain global quantitative measurements of the atmospheric structure. These kinds of data are necessary for research toward improving the understanding of atmospheric processes and interactions. The collection of such global data should permit the full exploitation of current developments in numerical forecasting aimed at long range weather prediction. The Nimbus spacecraft are designed with a high degree of flexibility to accommodate many types of scientific and technological experiments for use in meteorological research and for testing prior to operational application. Nimbus 4 continues in operation in orbit, more than 4 1/2 years after launch. Useful data are still regularly obtained from the Image Dissector Camera System (by direct readout only), the Interrogation, Recording, and Location System, the Backscatter Ultraviolet Experiment, and the Monitor of Ultraviolet Solar Energy. Nimbus 5 was launched December 11, 1972, and has successfully met all its objectives. Included in the experiments was the first exploratory use of the microwave region of the spectrum for atmospheric sounding. Passive microwave and infrared sensors demonstrated the feasibility of determining vertical profiles of temperature and water vapor through cloud cover to the surface. An advanced scanning microwave radiometer provided,



A hemispheric image produced by the SMS-1 synchronous meteorological satellite on September 5, 1974. The continent of Africa appears at the extreme right side of the photograph. South America is just to the left and below the center, and the United States shows in the upper left portion. The arrow to the upper left indicates Hurricane Carmen as it was moving over the Gulf of Mexico toward the Gulf Coast. (NASA photo.)

day and night mapping of liquid atmospheric water, sea and land ice and soil moisture. An advanced infrared radiometer provided improved spatial resolution and identification of surface features. Nimbus F, to be launched in CY 1975, is designed to provide improved capabilities in most of these areas, as well as improved vertical range and resolution of atmospheric sounding.

The Nimbus program has been extended with the approval of Nimbus G for launch in 1978. This mission is designed to provide spaceborne sensors applicable to studies of air pollution, oceanography, the ocean/atmosphere interface, and the earth and atmosphere heat budget.

Continued advanced studies during FY 1976 will be directed toward the STORMSAT mission. The prime objective is to observe meteorological phenomena from geostationary altitude and to acquire data whose analyses are expected to lead to the better understanding, early detection, and prediction of severe storms such as tornadoes and hurricanes. Accurate vertical temperature and moisture profile sounding plus high resolution atmospheric imagery is necessary to meet such a goal. The Advanced Atmospheric Sounding and Imaging Radiometer (AASIR) to be flown on STORMSAT is being developed to satisfy this requirement. Additional phenomena such as fog, frost and freeze conditions, dust storms, and squalls produced in the lee of lakes will also be studied using this instrument.

In FY 1975, definition was completed and procurement begun on the SEASAT, which will be dedicated to ocean dynamics applications in the late 1970's and early 1980's. The circulation of the ocean plays a major role in the control of global climate and weather; this mission will seek to demonstrate the feasibility of acquiring data applicable to monitoring and predicting physical ocean phenomena.

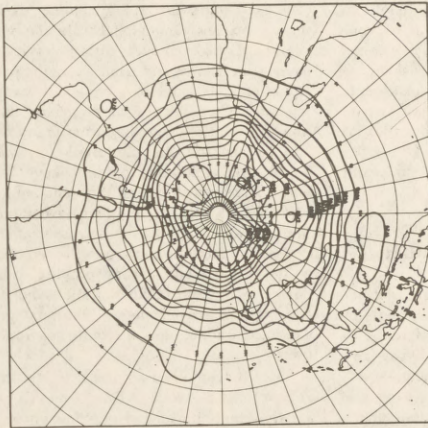
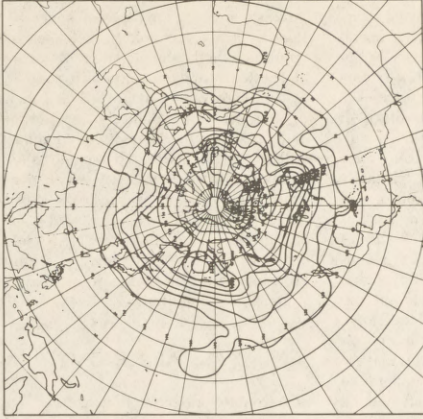
NASA participation in the Global Atmospheric Research Program (GARP) in FY 1976 will encompass the following efforts: development of the satellite systems which are designed to be used in the Global Observing System; development of space-related technology; detailed planning for the First GARP Global Experiment (FGGE); and research on simulation experiments and numerical modeling. Recent NASA support to GARP included the use of the Convair 990 instrumented aircraft

and the Vanguard tracking ship during the GARP Atlantic Tropical Experiment (GATE) of 1974 and augmenting the Global Observing System (GOS) during the May 1974 Data Systems Test (DST) with Nimbus 5 data. Development of operational satellites for the Global Observing System will include continuing production and launch of the Improved TIROS series, and completion and launch of the Geostationary Operational Satellite (SMS/GOES); these satellites are expected to provide basic observations of global and local weather conditions essential to the World Weather Watch and GARP.

Space-related technology development will include two technological problems critical to GARP: determination of wind profiles in the tropics and the determination of a reference level in the southern hemisphere. The Tropical Wind, Energy Conversion, and Reference Level Experiment (TWERLE), planned as one of the Nimbus F experiments, will address the southern hemisphere reference level problem; under development is a satellite-carrier balloon system, employing releasable dropsondes, for the determination of vertical profiles of wind in the tropics. These systems will be flight tested during a DST observational period.

During FY 1976, NASA effort will continue to be concentrated on the implementation of Data System Tests for which NASA has been assigned primary responsibility. Using the data requirements and observing-system concepts for FGGE, a concept for DST has been developed which will focus on data acquisition, data processing, and data utilization problems related to FGGE. This concept envisions the DST as simulating FGGE, but producing real and useful data at an earlier date. It is intended that the DST, although in a smaller, more limited scale than FGGE, will include representative elements of the FGGE, and will provide a test of the suitability of various components being proposed for FGGE to meet the requirements of GARP. Numerical simulation studies, and numerical experiments with real data assimilation, will be continued at the Goddard Institute for Space Studies for the optimization of observing systems and the extraction of meteorological data from satellite sensors to support DST and FGGE.

NASA is conducting a Meteorological Rocket Program to: (1) explore the atmosphere from 30 to



Analyses from the first Global Data Sets produced experimentally for the NASA Data Systems Test by the Data Assimilation Branch of NOAA's National Meteorological Center May 1974. The isolines are analyses of the height of the 300 mb surface at midnight GMT on May 29, 1974. The northern hemisphere is shown at the right; the southern at the left. (NASA diagram.)

100 km to gain a better understanding of its structure and circulation, how it affects aerospace operations, and how it reacts with and affects weather phenomena in the lower atmosphere; (2) explore the composition and chemical processes related to upper air pollution, chemical dynamics, and their effects on aerospace vehicles, climate, and man's health; (3) engage in cooperative national and international efforts to obtain and analyze mutually useful data to permit hemispheric and global analyses of upper atmospheric phenomena such as stratospheric warnings, and to stimulate the use of the data for practical applications. NASA is continuing its effort to develop sounding rocket systems for the altitude region from 30 to approximately 100 km. Through international cooperative programs, self-sustaining capabilities for coordinated launches are being established at sites that are expected to contribute valuable data. A cooperative exchange of meteorological rocket data between the Western and Eastern Hemisphere Meridional Networks is currently in progress. This is part of the U.S.-U.S.S.R. agreement for space cooperation. Correlative and calibration measurements in conjunction with satellite remote sounding will be continued. New light weight sensors which can be flown on smaller much less expensive rockets are being developed to measure the minor constituents in the stratosphere and mesosphere such as ozone, water vapor, atomic oxygen and the oxides of nitrogen. These will furnish data related to upper air pollution and their long-term effects on health and climate at much lower cost.

STRATOSPHERIC RESEARCH

NASA's stratospheric research program is structured in three general areas: (1) measurements in the stratosphere, (2) modeling of perturbations to the natural stratosphere and, (3) the physics and chemistry of the stratosphere. Areas included are parts of the Shuttle Environmental Effects Program; the application of space technology to the earth's environment, including the stratosphere; pollution from aircraft engines; and the fundamental physics and chemistry of the stratosphere. In the Shuttle Environmental Effects Program, the emphasis is on possible deleterious effects caused by chlorine con-

taining compounds in the stratosphere. The applications of space technology to the earth's environment include the development of advanced sensors and systems for global monitoring and an associated research program in *in situ* airborne measurements. In the study of pollution of aircraft engines, emphasis is on the interaction of exhaust emissions with the atmosphere and includes the Global Air Sampling Program (GASP) which consists of installing instrument packages on commercial 747 aircraft to measure NO_x , O_3 , CO , CO_2 , H_2O , hydrocarbons and particulates. NASA also supports programs at its field centers and at universities to develop models that accurately simulate stratospheric conditions.

AERONOMY

Aeronomy research is concerned with understanding the physical and chemical processes of the atmosphere, the role of the Sun for energy flow and chemical excitation of atmospheric species, and the effects of temporal and dynamical variations on these processes. On a global scale, the main energy sources result from solar ultraviolet absorption by oxygen molecules and from energetic particle precipitation and cosmic rays, especially over the polar regions. The energy absorption results in the formation of atomic oxygen, the formation of nitric oxide and ozone, and the photolysis of water vapor. Large-scale circulation patterns have been found with scale sizes of several thousands of kilometers. The research program involves the combined use of satellites and sounding rockets, associated laboratory reaction studies, and ground-based observations of the airglow and aurora, probing using meteor radars, incoherent radars and ionosondes. Balloons and aircraft have become useful for extended observations and for studies at remote geographical locations.

The Atmosphere Explorer satellite program involved three missions (AE/C, D, and E) to investigate the aeronomical and photochemical processes that control the structure and properties of the thermosphere. Explorer 51 (AE/C) has been operating successfully since December 1973, in a high inclination orbit with a controlled perigee altitude capable of excursions down to 130 km. The combined

measurements of the incoming UV flux, the local neutral and ionized atmospheric constituents, and the associated airglow and energy distributions have been made over a great many latitudes and through an extensive set of seasonal and solar-active variations. A number of correlative sounding rocket measurements have been made, extending the altitude profiles of the processes into the mesosphere while calibrating the stability of the satellite instruments.

An equatorial, Scout-launched satellite, San Marco III, was launched in February 1974, to complement the observations of Atmosphere Explorer 51. This satellite measures composition and density of the equatorial thermosphere.

In June 1974, a series of 54 sounding rockets, ALADDIN 1974, was launched from Wallops Flight Center in Virginia correlating with Explorer 51 and measuring diurnal variations to study the mechanism for molecular oxygen dissociation and formation. The significance of the dynamic effects was studied with chemical release measurements of atmospheric motions, while the composition and chemical processes were studied using mass spectrometer, solar UV absorption and airglow measurements. The program was undertaken together with the Air Force and with the Meteorological Rocket Program to extend the investigation into the stratosphere.

The program continues supporting research for laboratory experiments and the development of flight experiments. Observations from jet aircraft have proven useful for acquiring data about atmospheric motions from chemicals released from rockets and for observing airglow and aurora. The physical phenomena associated with the infrared airglow of the OH and O₂ can be studied from aircraft. With the development of laser beams for remote mapping, atmospheric constituents also can be studied from aircraft. Such development is expected to supply instruments for future satellite flights and for flights of the Space Shuttle.

Atmospheric Explorer (AE-D) is scheduled to be launched into a polar orbit later in 1975 followed by AE-E into a low-inclination orbit some months later. The Scout launched Dual Air Density Explorer includes a dual satellite in a polar orbit for measuring atmospheric composition and density

simultaneously over a range of altitudes over the entire Earth.

PLANETARY ATMOSPHERES

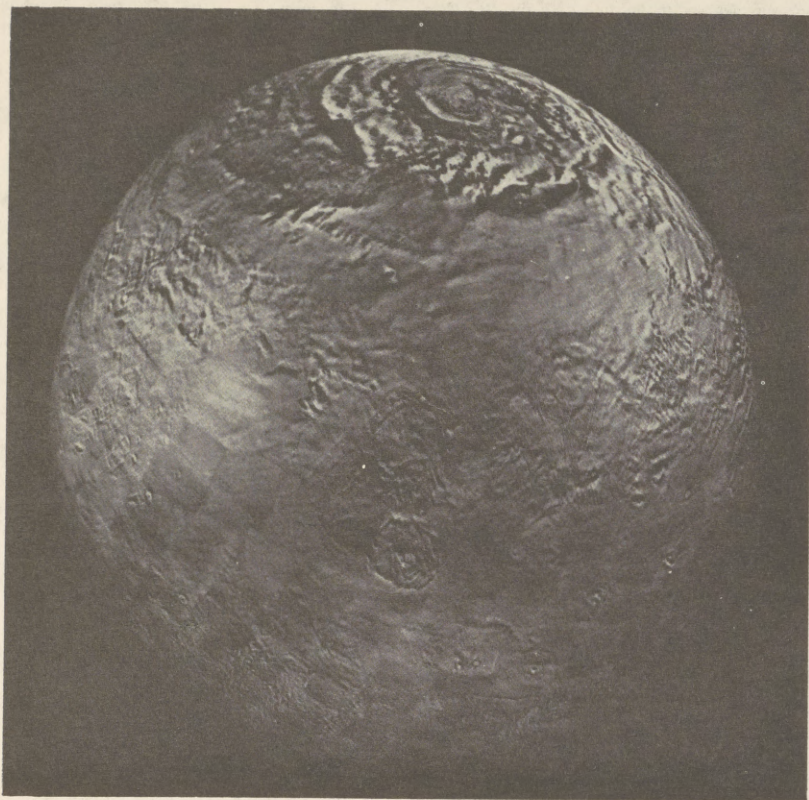
Pioneer 11 flew by Jupiter on December 3, 1974, on a trajectory designed to provide a Saturn encounter September 1979. The measurements made at Jupiter extended the observations made by Pioneer 10 a year previous. The objectives of the missions are to conduct exploratory investigations beyond the orbit of Mars of the interplanetary medium, the nature of the asteroid belt, the environmental and atmospheric characteristics of the planet Jupiter, and to advance the technology and operational capability for long duration flights to the outer planets.

The Viking Program 1975 mission to Mars consists of two spacecraft to be landed on the planet, supported by two planetary orbiters. The landers are designed to determine atmospheric profiles of composition, temperature, and pressure during descent, and after landing will perform investigations of wind velocity and of the pressure, temperature, humidity, and composition of the atmosphere of Mars.

Two Mariner-class spacecraft are being prepared for a mid-1977 launch to Jupiter and Saturn. The objectives are to conduct exploratory investigations of Jupiter and Saturn planetary systems and of the interplanetary medium out to Saturn.

The Pioneer Venus Program encompasses two spacecraft to be launched to encounter Venus during the 1978 opportunity.

The multiprobe mission consists of a spacecraft bus carrying four atmospheric entry probes. The probes will be released by the bus three weeks prior to encounter and will be separately targeted to penetrate the atmosphere to the surface at four selected points. The Orbiter mission uses a spacecraft equipped with propulsion to enable it to be placed in orbit about Venus about one week before the arrival of the probes. The orbiter is designed for a one-year operational lifetime at the planet. The objectives of the coordinated missions are to explore the planetary environment, the atmosphere, and the cloud cover of Venus.

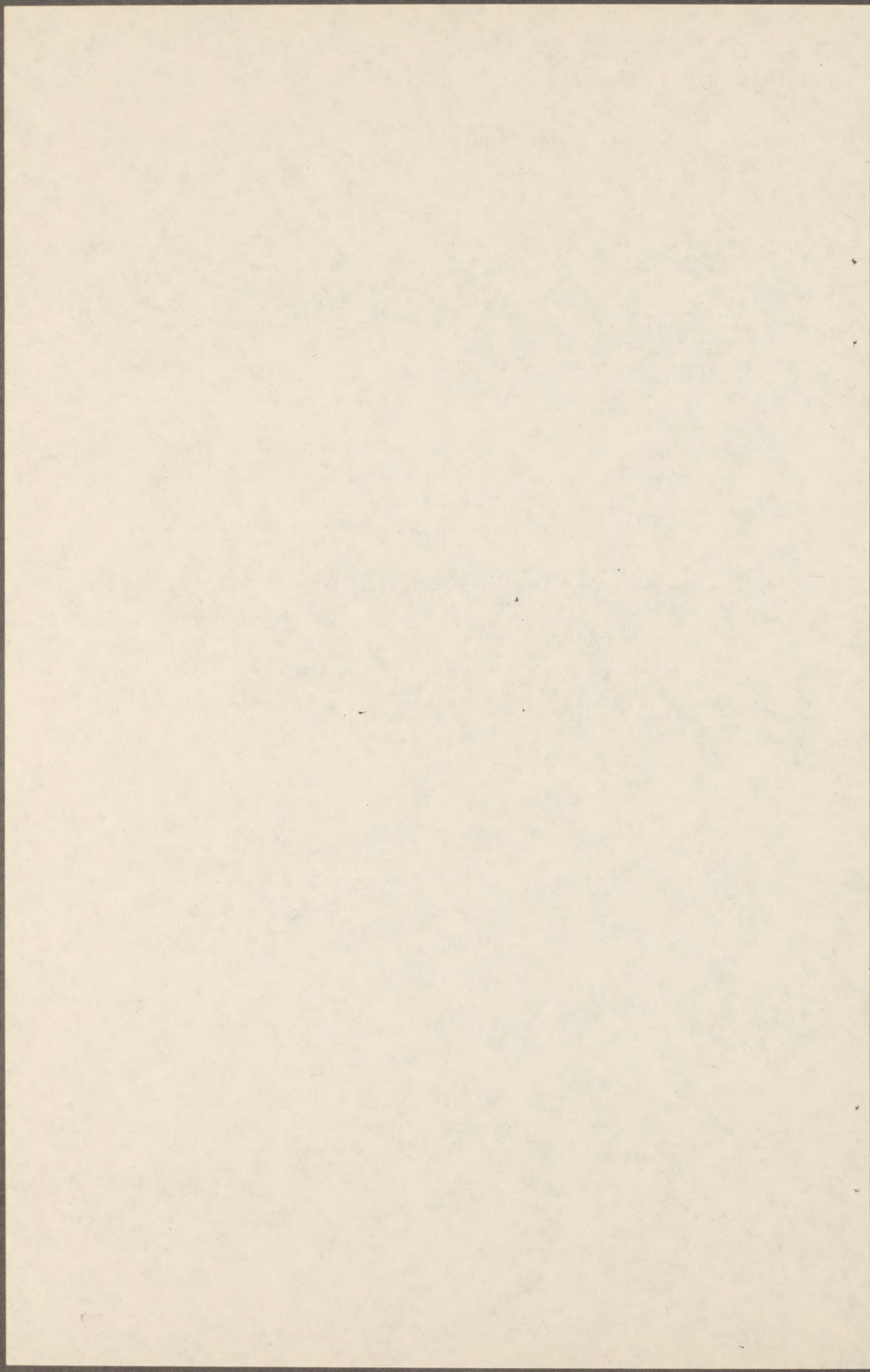


Photograph of a global mosaic of the Planet Mars. The mosaic is four feet in diameter and was constructed using more than 1500 computer corrected television pictures taken by the Mariner 9 satellite in 1971 and 1972. The residual North Pole ice cap is at the top. At lower center is the giant volcano Nix Olympica 600 km across and 25 km high. The photo globe is the first ever made of any body in the solar system and was prepared by Caltech's Jet Propulsion Laboratory which managed the Mariner project for NASA. (NASA photo.)

Allocation of Funding
(in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Physical Meteorology	3,832	5,345	5,649
Dynamic Meteorology	1,796	1,316	1,985
Observation	23,100	31,869	30,053
Systems	1,366	750	725
TOTAL	30,094	39,280	38,412
Aeronomy			
Ionospheric Physics	1,965	2,579	6,830
Atmospheric Chemistry	545	803	1,878
Atmospheric Structure	402	307	439
Energetic Particles	80	80	180
Solar-Terrestrial Studies	111	111	318
Dynamic Aeronomy	70	70	180
Instrumentation-Rockets	2,520	2,515	2,858
Instrumentation-Satellites	6,580	4,708	335
TOTAL	12,273	11,173	13,018
Planetary Atmospheres*	14,104	17,238	11,538
TOTAL PROGRAM	56,471	67,691	62,968
Distribution of Funding			
In-House	9,210	11,052	10,137
Industry	37,476	46,391	42,746
University	9,785	10,248	10,085

*NOTE: The reported increase in Planetary Atmospheres funding over prior reports reflects inclusion of Viking sensors and instrumentation inadvertently omitted from previous NASA reports to ICAS.



NATIONAL SCIENCE FOUNDATION

One of the NSF's primary functions is to foster and support strong programs of basic research. Management of these undertakings is provided by the Research, National and International Programs, and Research Applications Directorates within the Foundation. Collectively these three organizations plan to apply about \$63M (in FY 1976) to atmospheric sciences research; those dollars represent about 8% of the total NSF budget.

In addition to supporting basic research the NSF also provides leadership in international scientific undertakings. Some of the principal multi-national atmospheric science efforts that are currently being supported by the Foundation are the International Magnetospheric Study (IMS), the GARP Atlantic Tropical Experiment (GATE), the First GARP Global Experiment (FGGE), The Greenland Ice Sheet Project (GISP), and the Arctic Ice Dynamics Joint Experiment (AIDJEX). These and other international projects are described in the pages that follow.

The NSF atmospheric sciences programs are heavily involved in the current effort to assess the impact of the chlorofluoromethanes (CFM) on the atmospheric ozone layer. Through its Research Directorate the NSF has join the other agencies in supporting the National Academy of Sciences in a one year study of the CFM problem. The Foundation has also had membership on the Joint CEQ-FCST Task Force on Inadvertent Modification of the stratosphere and as well has made an important contribution to the ICAS special report to the Federal Council for Science and Technology on the possible impact of that these materials may have on our environment. In addition the NSF has initiated new research and redirected current programs in its effort to contribute to the Federal effort of research on the CFM issue.

In addition to supporting university research and major international undertakings, the NSF also supports major research facilities. These are maintained in order that university and other small group programs can utilize major capital equipment that would not otherwise be within the means of such researchers. The most notable of these

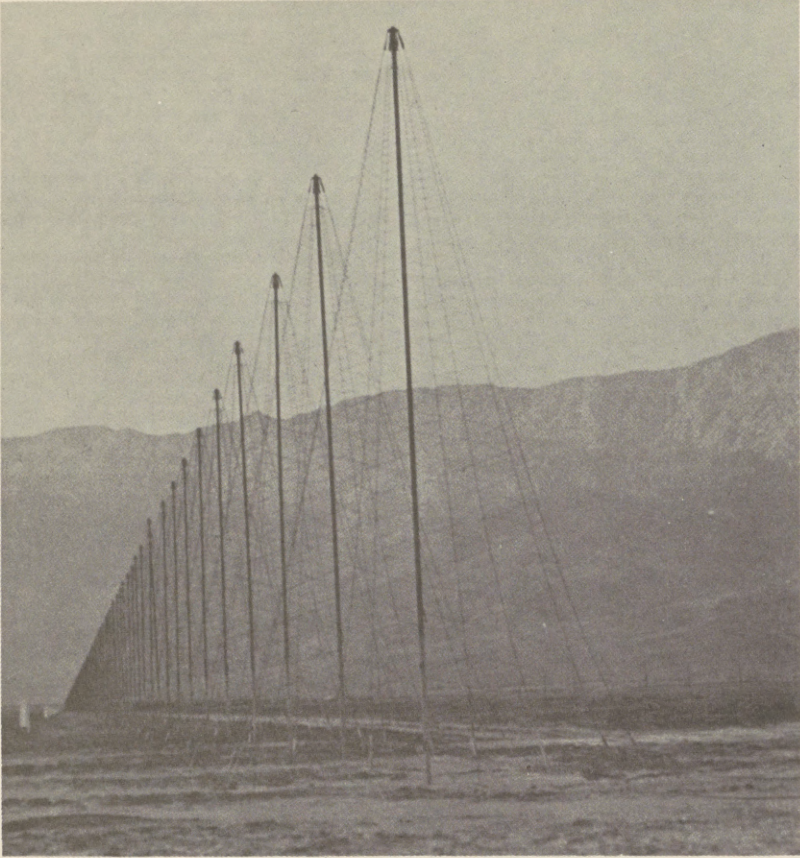
facilities are the National Center for Atmospheric Research, the Kitt Peak National Observatory, the National Aeronomy and Ionospheric Center, and the U.S. Antarctic Program. The programs of these facilities are briefly described in succeeding pages.

There will be only two major new starts in the FY 1976 budget of the NSF. One will be the full establishment of the Office for Climate Dynamics, which was begun last year. The other will be the acquisition of a 5th Generation Computer at NCAR.

METEOROLOGY

The Meteorology Program supports a broad spectrum of research into the dynamic, physical and chemical processes in the lower atmosphere and stratosphere by means of research grants, primarily to university scientists. The program aims to expand our fundamental understanding of the earth and of other planets. This understanding provides the necessary basis for success in the applied topics of weather prediction, modification, and air quality protection (which for the most part are the responsibilities of other agencies). The program is approximately equally divided between physical/chemical and dynamical meteorology. In recent years there has been an increasing emphasis on cloud physics (primarily because of the reduction of funding across the nation for weather modification research) and in mesoscale meteorology.

The Meteorology Program has traditionally supported climate related research and will continue to do so in the future. The new Office for Climate Dynamics will be the primary source of support for research on large scale and long-term climate questions. The Meteorology Program will remain involved with questions of smaller scale and regional climate. As the Climatic Impact Assessment Program of the Department of Transportation draws to a close, the Meteorology Program at NSF will remain a source of support for basic research on the physics, chemistry and dynamics of the stratosphere.



The East-West arm of the Clark Lake radio observatory. This is a low frequency broad band facility operated by the University of Maryland, under the sponsorship of the National Science Foundation and the National Aeronautics and Space Administration. Clark Lake is located just to the west of the Salton Sea in Southern California. (University of Maryland photo.)

AERONOMY

The Aeronomy Program funds investigations that aim at a better understanding of the physical, chemical, and dynamical processes in the upper atmosphere of the earth and other planets. These investigations include field experiments, laboratory experiments on atomic and molecular interaction processes relevant to the atmosphere, and theoretical studies that include modeling complex time dependent phenomena in the high atmosphere.

Emphasis is currently placed in two areas. These include studies that will provide the means for interpreting the response of the atmosphere and ionosphere to processes that occur in the distant magnetosphere. This will allow evaluation of various techniques that will be employed during the International Magnetosphere Study, an international program of intensive investigations of magnetospheric phenomena by means of satellites, rockets, and ground based observations.

A second area of emphasis is stratospheric research, from the standpoint of laboratory studies of pertinent chemical processes and the development of techniques for measurement of stratosphere constituents.

SOLAR-TERRESTRIAL PROGRAM

The Solar-Terrestrial Program supports research on the space environment of the earth and its response to solar influences. Solar-Terrestrial physics is now in a transition from the exploratory stage to one in which experiments are planned with specific objectives of understanding the cause-and-effect relationships among the dynamic processes involved. The complexities of the phenomena occurring in the earth's outer environment call for multi-instrumental investigations involving correlative studies utilizing simultaneously acquired measurements from spacecraft, rockets, balloons, and ground-based experiments as well as passive observational programs. A substantive theoretical effort is also maintained.

In support of the International Magnetospheric Study (IMS) during the coming years, emphasis in the support of research will be placed on coupling

between the earth and its space environment, determination of solar magnetic fields and their extension into interplanetary space, on interaction of the solar-wind with the magnetospheric boundary, on wave-particle interactions in the magnetosphere, and on interaction between the magnetosphere and ionosphere. There are two fundamental scientific thrusts of the IMS. The first includes the solar-terrestrial coupling of sun to solar wind; solar wind to magnetosphere; magnetosphere to ionosphere, and ionosphere to atmosphere. The second is the basic space plasma physics common to all of these interacting systems. Practical benefits related to the various Agency missions will come from a better understanding of the strong disturbances of near-earth space which affect communications, satellite environments, and ionospheric properties. Practical benefits also are likely to derive from an improved understanding of fundamental plasma physics relevant to our current energy research.

GLOBAL ATMOSPHERIC RESEARCH PROGRAM

The Global Atmospheric Research Program (GARP) is an international scientific effort to expand our understanding of both the transient behavior and statistical properties of large scale atmospheric phenomena. Such an undertaking, of necessity, uses talents from many scientific and technical disciplines. Within the United States, the National Oceanic and Atmospheric Administration (NOAA) is the lead agency for coordinating the GARP effort between the seven supporting Federal agencies (DOC, DOD, DOT, EPA, ERDA, NASA, and NSF). The primary NSF/GARP responsibility is to focus the scientific expertise of university scientists on GARP related research.

The highest priority item for the NSF/GARP during FY 1976 will be supporting the analysis of data obtained from the GARP Atlantic Tropical Experiment (GATE). In the years ahead, the analysis and interpretation of GATE data by the university community will continue to be an important component of the NSF GARP effort. All of the preliminary results indicate that the GATE observational program was very successful and that highly significant scientific findings will be forthcoming.

The First GARP Global Experiment (FGGE) is primarily a world-wide observational program currently scheduled to begin in FY 1978. NSF will support the participation of university scientists in the national and international planning for FGGE during FY 1976.

Several regional experiments are planned in conjunction with FGGE. NSF will sponsor participation in all of them. They include the Polar Experiment (POLEX), a study of the polar energy budgets; the Monsoon Experiment (MONEX), a study of the dynamics and thermodynamics of the monsoon belt; and the Indian Ocean Experiment (INDEX), a study of the physics and dynamics of the equatorial and western Indian Ocean.

NSF will continue to provide long-term support for scientists involved in the development and use of numerical models of the atmosphere and/or the ocean. The combination of numerical modeling and observational analysis and interpretation will continue to be the foundation of the GARP effort.

NATIONAL ASTRONOMY AND IONOSPHERE CENTER (NAIC)

The National Astronomy and Ionosphere Center (NAIC) is one of five national research centers sponsored by the National Science Foundation. The mission of NAIC is to provide the scientific community with advanced visitor-oriented facilities and instrumentation for frontier research in radio and radar astronomy and aeronomy.

The NAIC headquarters is located on the campus of Cornell University in Ithaca, New York. The headquarters facility contains offices, shops, and laboratories for NAIC administrative, engineering, and technical support groups. In addition, two small research complexes, the Zeman laboratory in Ithaca and the Danby laboratory, 19 miles south of Ithaca, are devoted to low noise receiver, line feed, and electronics systems design, development, and testing.

The principal observing facilities are located in Puerto Rico, about 12 miles south of the city of Arecibo. The major instrument is a 1,000-foot diameter fixed spherical antenna. This instrument, the world's largest radio/radar telescope, was recently upgraded. Over a three year period the 19.8

acres of the original wire mesh surface were replaced by 38,778 panels formed from 0.040-inch perforated aluminum sheets. Early in FY 1975, when this surface is adjusted to a sphere within an accuracy of 3.2 millimeters, the frequency range for scientific observations will have been extended by a factor of 12 to an upper frequency limit of 7,200 MHz.

During the past two years, the development of new advanced flexible line feeds, high quality receivers, and high-speed digital devices has permitted NAIC staff and visiting investigators to conduct unique detailed observations of the terrestrial ionosphere. The continuing goal of NAIC aeronomy programs is the improved understanding of the properties of the earth's upper atmosphere. The NAIC radio/radar telescope and other facilities are enabling scientists to study photochemical and dynamic processes in the atmosphere. These processes include various radiative phenomena such as photoionization and recombination; the coupling between ions, electrons and neutral particles; particle motions caused by winds, tides, gravity waves, and plasma instabilities; and energy transport mechanisms in the atmosphere.

During FY 1974, NAIC scientists and visitors applied a new ionospheric backscatter technique to measure the velocities of E-region ions. The line-of-sight velocities of these ions are measured with the feed pointing in the north, east, south, and west directions with the antenna feed offset 15 degrees from the zenith. These velocities are then resolved into their horizontal and vertical components. A single velocity vector measurement requires 75 minutes to complete. A five-pulse scheme is used with the backscatter radar operating at 40 MHz, giving a 2.4 kilometer height resolution over the region of the ionosphere between 100-170 kilometers.

On several occasions NAIC has collaborated with other ionospheric observatories in making simultaneous measurements of E-region ion temperatures and ion-neutral collision frequencies. Comparison of atmospheric tidal oscillations observed at each site has been fruitful. Velocities measured at NAIC show a clear downward phase progression in both the north-south and east-west components. The maximum velocity observed in either component is between 120 and 160 meters per second.

The NAIC data also show that Sporadic-E layers are consistently observed at layers where the vertical component of the ion velocity is zero and the gradient is such as to cause ion convergence. These measurements provide strong support for the wind-shear theory of Sporadic-E. Once a statistically significant body of data has been accumulated, the NAIC observations are expected to reveal new information about the production and destruction of Sporadic-E ions.

On several occasions during FY 1974, backscatter measurements of the ionosphere were made during an overhead pass of the Atmosphere Explorer-C satellite. These measurements provided an opportunity to compare different techniques used to measure ionospheric properties.

The satellite and ground-based backscatter data give complementary information. The satellite can measure quantities such as neutral density which the ground-based radar cannot observe directly, and the NAIC radar can measure vertical density, temperature, and wind velocity profiles and provide a detailed time history of the ionosphere over Arecibo.

Within the last year, aeronomy research at NAIC has seen increasing numbers of visiting groups of observers. The NAIC staff has been developing general observing programs so that visitors will be able to use sophisticated radar techniques for their own observations. In addition, there has been a trend toward observing programs of long duration, i.e., observations spaced over a year or years in coordination with other observatories throughout the world. These trends are expected to continue.

Among the aeronomy programs planned for FY 1976 are the following:

Standard ("Archival") Observations. Several important problems concerning the dynamics of the ionosphere and the upper atmosphere involve phenomena that fluctuate in time and position, analogous to tropospheric weather patterns. These dynamic problems are attracting increasingly more attention in aeronomy research. The study of these problems will benefit from long periods of standard observations at locations widely scattered over the globe. Ionosondes and airglow observatories, because of their relative abundance, will make important contributions to these studies. Incoherent backscatter observations will be particularly valua-

ble, because of their precision measurement capabilities.

In order to derive the greatest benefit from the few incoherent scatter stations in operation, it is necessary that their observations be coordinated. To this end a Working Group of the International Union of Radio Science started in FY 1974 to coordinate incoherent scatter observations in support of various research programs. The NAIC is taking part in this international effort. As coordination improves, all incoherent scatter observatories in the world will be measuring ionospheric properties on a regular synoptic basis.

In addition to coordinated studies of global phenomena, observations of a standard or routine nature are also valuable during times of satellite overflight. Simultaneous satellite and incoherent scatter data are complementary for studies of many problems of ionospheric structure. Further, many questions concerning measurement accuracy can benefit from simultaneous observations of a single parameter using different techniques. Standard incoherent scatter observations are also required to support special research projects involving different instrumentation at NAIC. An example of this kind is the simultaneous measurement of ion drifts by the radar and neutral winds by the Fabry-Perot interferometer.

Ionosondes and Airglow. In FY 1976 the ionosonde and airglow instruments at NAIC will become important elements in the global network of upper atmosphere monitoring stations. Steps are being taken to make the derivation of standard information from these instruments as straightforward as possible. For example, beginning in FY 1976, data from airglow instruments will be recorded on computer-compatible magnetic tape. This will permit the reduction of these data with a minimum of manual calibration effort. A planned reorganization of equipment and procedures in the airglow observatory will also upgrade the operation of that facility.

NAIC is acquiring a modern, digital ionosonde to permit computer processing of ionosonde data and to eliminate hand-scaling of ionograms. Data obtained with this device, when coordinated with backscatter radar information, will present interesting new possibilities for research. An example is the comparison of drift velocities measured by the two instruments.

F-Region Studies. In FY 1974, NAIC scientists discovered a remarkable spike in the electron density profile of the decaying F-region. This spike frequently appears soon after sunset, and persists for several hours with little or no change in shape. This layer is believed to consist of long-lived ions that are injected into the F-region at a rate that varies with the time of day. Careful studies of the behavior of this layer are planned for FY 1976 that will tell more about its constitution. The possibility of detecting this layer with a mass spectrometer on the Atmosphere Explorer satellite is being explored.

NAIC will continue efforts already underway to coordinate measurements made at Arecibo with data obtained by Atmosphere Explorer satellites. Information on the neutral composition of the ionosphere over the Arecibo site provided by the satellites, combined with radar profiles of electron density, ion and electron temperatures, and ion drift velocities, will make possible for the first time, detailed quantitative studies of the ionization and energy budgets of the F-region.

High Altitude Measurements. NAIC topside measurements are now sufficiently sensitive to determine separately the vertical drift velocities of the oxygen and hydrogen ions at altitudes where their densities are comparable. Many interesting aspects of topside behavior are related to the relative motion of these two species.

The recently developed capability to measure plasma density, temperature and drift velocities (if sufficiently large) up to altitudes of about 10,000 km presents several opportunities for research. By entering into collaborative programs with other ionospheric observatories, data obtained at NAIC will provide valuable information on the exchange of energy between the ionosphere and protonosphere. By late FY 1976, NAIC will be routinely observing the plasmopause. This will permit NAIC to develop a record of plasmopause motions that will augment the data on plasmopause morphology that has been provided by whistler observations.

KITT PEAK NATIONAL OBSERVATORY

The Kitt Peak National Observatory (KPNO) is operated under a National Science Foundation con-

tract with the Association of Universities for Research in Astronomy, Inc. (AURA), a non-profit corporation representing a consortium of twelve leading U.S. universities. KPNO headquarters is located in Tucson, Arizona. Observing facilities are located on 6800-foot Kitt Peak mountain 40 miles southwest of Tucson. Scientific and support staff at KPNO provide the necessary expertise to support research programs of visiting scientists, develop advanced instrumentation, and participate in research programs.

During FY 1976, the solar research programs will include studies of the physical characteristics of the outer layers of the solar atmosphere, including temperatures, pressures, gas motions, and magnetic fields. Staff and visiting scientists will continue to explore the coupling among gas motions, magnetic fields, and the strong radiations that give rise to solar flares and other phenomena that affect the interplanetary environment. The solar vacuum telescope and magnetograph will be used to continue determining the magnitudes and directions of motion of gases in the solar photosphere.

The planetary science research programs at KPNO in FY 1976 include theoretical and observational studies of the structure and composition of the atmospheres of Venus, Mars, and several larger planets, such as Jupiter and Saturn, whose orbits lie beyond that of Mars. Knowledge of the pressures, temperatures, and chemical compositions of the atmospheres of these bodies is essential to the understanding of the origin and evolution of the solar system. Other important projects are concerned with the properties of terrestrial airglow emissions and the physics of the earth's ionosphere. The McMath Solar Telescope will be used by staff and visitors to conduct nighttime planetary observations. The long focal length telescope, and its associated powerful spectrograph, makes it a highly effective instrument to study the atmosphere of Venus, Mars, Jupiter, and Saturn.

The reduction of data collected by KPNO's ultraviolet spectrometer aboard NASA's spacecraft, Mariner Venus/Mercury, will continue in FY 1976. The spacecraft made its encounter and initial observations of Venus on February 5, 1974. The KPNO experiment is designed to measure the ultraviolet airglow from gases in Venus' atmosphere, to provide new information on the structure and chemical

makeup of the planet's dense cloud cover. A second KPNO ultraviolet spectrometer on the spacecraft is the primary instrument used to detect the thin, but complex atmosphere surrounding Mercury. Analysis of data obtained on the first encounter with Mercury indicates that the innermost planet is enveloped by a thin atmosphere consisting in part of helium. A second encounter with the planet occurred September 20-22, 1974, with a third encounter anticipated in March 1975.

POLAR RESEARCH

The U.S. Atmospheric Science Program in the polar regions is directed toward understanding solar-terrestrial relationships and physical interactions between these regions and the global environment. The program is divided into studies of the upper atmosphere and the lower atmosphere and consists of research projects in both the Arctic and the Antarctic.

UPPER ATMOSPHERE

Upper atmospheric studies are designed to determine how the sun transmits energy and how this energy affects earth. Quantative measurements of the effects of solar particles and their associated magnetic fields on the terrestrial environment primarily are conducted in Antarctica. These include measurements of aurora, cosmic radiation, geomagnetic activity, electric fields, solar particle precipitation, and changes in the ionosphere.

A major portion of the upper atmospheric program is conducted at Siple Station, Antarctica. Siple's location (76°S., 84°W.) is ideal for studies of the plasmapause, a region of the magnetosphere in which particle densities decrease rapidly with small increases in distance from the earth. VLF radio transmissions are generated at Siple to determine how solar particles and magnetospheric waves interact. A dipole VLF antenna, 21 kilometers long, is used in a variety of transmission modes (varying power, frequency, pulse repetition rate, or pulse length) to inject waves of known characteristics into the magnetosphere. Magnetically conjugate stations in Southeast Canada monitor the Siple signals as they are ducted along the magnetosphere. These experiments will contribute to the International Magnetospheric Study (IMS), scheduled for 1976 through 1978.

Studies of aurora, cosmic radiation, and electromagnetic wave absorption will continue at South Pole Station to determine the effect of solar activity on interplanetary space.

In the Arctic, upper-atmospheric research involves other aspects of the IMS. Ground-based and balloon-borne measurements of the magnetosphere and ionosphere will be conducted from locations that are geomagnetically conjugate to U.K. and U.S. research stations in Antarctica.

Lower Atmosphere

South Pole Station, located on the relatively homogeneous platform of the Antarctic Plateau, is an excellent facility for studying the role that the antarctic ice cap plays in global atmospheric circulation. Projects at the South Pole include comprehensive studies of boundary layer (near-surface) processes and of low-level atmospheric circulation. Constant monitoring of environmental conditions also is done to determine natural and artificial background levels of atmospheric constituents. Specific activities at the South Pole include studies of the thermal radiation budget, the structure of the planetary boundary layer, the trace metals and halogens in the atmosphere, the submicron particulate matter in the stratosphere, the origin and precipitation of ice crystals, and, to determine the polar energy balance, and the energy transfer across the atmosphere/snow surface interface.

The Arctic Ice Dynamics Joint Experiment (AIDJEX) is an international, interdisciplinary effort to quantify and model the forces involved in the ocean-ice-atmospheric system. The project, though primarily concerned with ice and oceanography, has significant value and relevance to atmospheric science. Pilot studies on Arctic Ocean sea ice were done in 1970, 1971, and 1972. In spring 1974 a study of the transport of heat, moisture, and momentum across open water leads in the pack ice was made north of Barrow, Alaska.

The main AIDJEX experiment, starting in March 1975, is the culmination of 5 years of theoretical and experimental investigations, pilot studies, technical development, and planning. Four stations in the central Beaufort Sea will be staffed and operated for 14 months. Twenty automatic data buoys will be deployed in pairs along a circle 300 kilometers in radius around the main station. Other atmospheric-related studies include measurements of surface air

stress, air temperature and pressure, radiation fluxes, turbulent fluxes of momentum, heat and water vapor, and wind speed and direction.

The Greenland Ice Sheet Project (GISP), which involves U.S. and foreign institutions and several governmental agencies, is drilling and analyzing ice core, measuring chemical and physical characteristics, measuring ice thicknesses and movements, and modeling. The objective is to establish a record of prior environments and to find out how the ice sheet responded to those environments. Analyses of chemical and entrapped atmospheric constituents in ice core will enable reconstruction of past climatic trends. Shallow drilling in Southern Greenland and intermediate drilling in Northern Greenland will be done in 1976.

INTERNATIONAL DECADE OF OCEAN EXPLORATION

The National Science Foundation is responsible for planning, funding and managing the United States contribution to the International Decade of Ocean Exploration (IDOE). NSF funds support research by Federal agencies, universities, industry and other research organizations in four major categories of human interaction with the oceans. These are:

- Environmental Quality
- Seabed Assessment
- Living Resources
- Environmental Forecasting

Research having application to the atmospheric sciences is conducted in four projects. Under the Living Resources program, the Coastal Upwelling Ecosystem Analysis (CUEA) project includes a physical component to study the processes responsible for upwelling of cold, nutrient-rich subsurface water. Since coastal upwelling usually occurs in response to favorable winds, measurements of meteorological variables are made by satellites, aircraft, ships, and buoys. The CUEA project began in FY 1971, and has conducted experiments off

Oregon, Mexican and Northwest African coasts. An experiment off Peru is being planned for FY 76 and 77.

Under the Environmental Forecasting project, the North Pacific Experiment (NORPAX) is a study of long-period, large-scale ocean-atmosphere coupling. NORPAX includes atmospheric measurements from Pacific islands, buoys, ships and aircraft, as well as the interpretation of satellite data. NORPAX, begun in FY 1973, should continue for ten years, and will result in a better understanding of North American weather and climate and hence permit a better long term prediction capability. NORPAX is being jointly funded and managed by NSF and the Office of Naval Research.

A series of experiments in physical oceanography entitled the International Southern Ocean Studies (ISOS) began in 1974. These experiments are an effort to obtain a deeper understanding of dynamical processes in the Southern Ocean in order to advance our knowledge of the interaction between global atmospheric and oceanic circulation. The first study concentrates on the large-scale, time-dependent dynamics of the circumpolar current in the vicinity of the Drake Passage. Atmospheric measurements from ships, satellites, and local land stations will be studied to determine the role of the atmosphere in forcing the circumpolar current.

The "Climate: Long-range Investigations and Mapping and Prediction" (CLIMAP) project is a study of environmental conditions during past ice ages. Charts of sea surface temperature are derived by studying fossils in deep-sea sediment cores. These charts, along with ice margin, albedo and sea level data, will be used in a numerical climate model to simulate atmospheric conditions, and possibly learn some of the causes of climate change.

RESEARCH APPLIED TO NATIONAL NEEDS (RANN)

The primary emphasis on atmospheric science within NSF/RANN is in the Weather Modification Program whose goal is the support of specific research and development activities directed toward the fulfillment of societal needs.

The program consists of five major sections. (1) Societal Utilization activities relate the impact of weather on man, provide goal orientation for the program, and achieve the societal interface necessary for successful weather modification applications; (2) Weather Hazard Mitigation studies include various weather hazards such as hail, thunderstorms, lightning and tornadoes in an attempt to prevent damage from such storms; (3) Inadvertent Weather Modification investigations delineate the cause, extent and impact of urban-industrial influences such as heat, moisture, and aerosols on atmospheric phenomena including thunderstorms, rain and hail; (4) the Weather Modification Technology program develops improved tools to modify the weather and to evaluate the results of modification efforts; and (5) a new program in the Agricultural Weather Modification area including techniques for exerting influence on agricultural systems at critical points during the planting, growing and harvesting seasons to expand agricultural production.

The major NSF/RANN program in the Atmospheric Sciences is the National Hail Research Experiment (NHRE) conducted by NCAR in North-east Colorado. The goal of NHRE is to determine the potential for suppressing hail damage by cloud seeding, and the extent to which hail suppression can be accomplished effectively on an operational basis. A statistical experiment to determine the efficacy of hail suppression, and a broad-based but highly focused research program aimed at understanding the mechanisms of both natural hail development and the effects of seeding on hail growth are being conducted. There was no field program during 1975 in order to analyze data and reevaluate the program in light of data from the first three summers in the field (1972-1974). NHRE will resume full operations during the spring of 1976.

The Metropolitan Meteorological Experiment (METROMEX) is being conducted to investigate the inadvertent weather effects caused by an urban-industrial complex such as St. Louis. The summer of 1975 is the final effort in the field (the fifth year), to be followed by a year of data analysis and report preparation.

The Weather Modification program is coordinated with the programs of other Federal agencies

through the Interdepartmental Committee for Atmospheric Sciences' Panel on Weather Modification and through frequent contacts with other Federal agencies.

RANN also supports atmospheric sciences projects dealing with air quality and the transport of trace contaminants. The emphasis here continues to be directed toward the successful combination of excellent research coupled with societal needs and the decision-making components of society.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

The National Center for Atmospheric Research (NCAR) is a national research laboratory operated under contract with the Foundation by the University Corporation for Atmospheric Research (UCAR). The Center was established in 1960 in order to provide a focus for research efforts by the university community on the atmospheres of the earth and the sun, and on the interactions between the two. NCAR's major research facilities are located in and near Boulder, Colorado. Temporary field locations include a solar observing site on Mauna Loa, Hawaii, a small balloon launch site at Christchurch, New Zealand, and the field headquarters of the National Hail Research Experiment near Grover, Colorado.

ATMOSPHERIC ANALYSIS AND PREDICTION

Global Atmospheric Research Program—NCAR efforts in the international GARP program during FY 1976 will include three areas of emphasis:

—The field phase of the Tropical Wind, Energy Conversion and Reference Level Experiment (TWERLE). This experiment, necessitated by the sparseness of weather stations in the Southern Hemisphere, will provide wind, temperature and pressure data sets for use in numerical studies of atmospheric motions and in GARP numerical prediction experiments. It is a joint project of NASA, the University of Wisconsin, and NCAR. Operations were begun in March, and continue through September, 1975, with launches from New Zealand,

Ascension Island, Ghana, and American Samoa.

- GATE data analysis. Several promising cases of data episodes during the GATE experiment will be selected for early study, and subjective and objective analyses will be conducted on these cases. Long-range, more refined analysis of the overall data will also proceed.
- The GARP Data Systems Test (DST). Using data from GATE, DST will produce redefined data sets with grid-points compatible with the NCAR general circulation model, and conduct forecast studies of the predictability and impact of the observing systems and the techniques required to assimilate the gathered data into numerical prediction experiments.

Small-Scale Analysis and Prediction Project—

Development of a quality mesoscale model is the unifying concept of this project. This effort will continue by incorporating wind data and moisture related processes as well as parameterizations of small-scale effects, including the boundary layer and clear-air turbulence. Boundary layer turbulence and diffusion studies will continue with: modeling of cloud-subcloud interactions in three dimensions using initial conditions similar to the GATE region; modeling of the equilibrium vertical distribution of large dust particles in the mixed layer of the troposphere; and analysis of Electra aircraft data from AMTEX. Deep convection cloud modeling will continue with testing in two dimensions of numerical accuracy and use of an expanding grid. Development of formulations for turbulence will proceed in a three dimensional framework.

Climatic Studies—During FY 1976, work in the NCAR Climate Project will continue to center on the predictability of climatic events through the use of numerical modeling. The strategy to be employed will be to use currently available data for systematic studies of climate variability, and to investigate the extent to which this variability is reproduced within the NCAR General Circulation Model. Due to the long time-scales involved in dealing with questions of climate changes, a new shortened version of the GCM will be developed. The model will be tested by introducing historical climate data sets and statistics which have been ac-

cumulated and developed at NCAR as part of the overall study of climate and climate change.

Oceanography—NCAR began a new program in physical oceanography during FY 1975. This is a theoretical program, primarily concerned with numerical modeling of ocean circulations while at the same time maintaining close collaboration with major oceanographic field programs. The ultimate aim is to develop an ocean circulation model to be coupled with the NCAR general circulation model for both GCM and climate experiments. The program in FY 1976 will concentrate its efforts on the role of meso-scale eddies and latent heat release on general ocean circulation, and the continuing development of a numerical model of a multi-layer ocean basin with bottom topography.

ATMOSPHERIC QUALITY AND MODIFICATION

Cloud Microphysics—This project will continue to work in close cooperation with the National Hail Research Experiment (NHRE). Laboratory and field studies of hail will continue using an instrumented NOAA-owned sailplane. Investigations of the dispersion and the effectiveness of silver iodide cloud seeding techniques will proceed as well as measurements of ice crystal grain sizes in hailstones which indicate growth temperatures and trajectories.

Atmospheric Aerosol Project—This project will investigate dust storms in the southwestern U.S., with emphasis on the role dust plays in precipitation processes in large-scale organized outbreaks of severe weather during the spring in the midwest. Predictions will be made of likely storm developments 2-3 days in advance by isentropic analysis of meteorological conditions.

Upper Atmospheric Project—In FY 1976, work in this project will include analysis of NCAR directed satellite-borne experiments as well as *in-situ* measurements to determine the chemical composition of the upper atmosphere; development and studies with models of stratospheric and mesospheric circulations, with emphasis on chemical and dynamical processes unique to this region; further development of models of the circulation of the thermosphere and its coupling with the ionosphere.

Solar Physics and Solar-Terrestrial Effects—

The importance of transient events as one of the basic structuring processes in the solar corona has gained widespread recognition. In FY 1976 construction of the Mark III K-coronameter and the full limb prominence monitor will commence. These instruments will provide simultaneous coverage in time and space of coronal transients, with higher spatial and temporal resolutions, and extending over a broader field of view, then currently possible with ground-based facilities. Coronal-interplanetary modeling will continue in FY 1976 with a magnetohydrodynamic extension of a 3-dimensional hydrodynamic model of the solar wind. Work will start on an effort to determine the 3-dimensional temperature in the inner corona by comparing the EUV spectrum in various solar regions with theoretical predictions. Codes to calculate coronal magnetic fields from coronal emission line polarimeter data will be completed and a simultaneous coronal observation program to increase the accuracy of coronal magnetic measurements will be initiated.

POSTDOCTORAL EDUCATION AND SPECIAL STUDIES

NCAR's Advanced Study Program (ASP) conducts visitor and educational activities that promote long-term interactions between the university community and NCAR, and which help to develop scientific talent and interests needed to solve major atmospheric research problems. The program includes postdoctoral appointments for junior and senior scientists; UCAR fellowships for graduate students; summer fellowships for minority students; and summer colloquia and workshops. The postdoctoral fellowship program has proven useful in fostering long-term interactions between the fellows and the NCAR research program extending beyond the fellowship year, through continued use of NCAR facilities, collaborative research with NCAR staff, and subsequent work at NCAR during subsequent visits or through regular appointments. The UCAR fellowship program and the minority student activities attract talented students to atmospheric science and allow them contacts with NCAR staff and the use of NCAR facilities, to further their studies and research. Summer colloquia bring NCAR staff, university scientists, and

graduate students together to define and discuss major fundamental atmospheric research problems and to relate their own work to the research strategies of the community.

FACILITY OPERATION AND DEVELOPMENT

Aviation Facility—NCAR Research Aviation Facility provides NCAR and university scientists with instrumented research aircraft, consisting of three NSF-owned aircraft and a leased Lockheed Electra Turboprop. The Electra was modified and instrumented primarily for use in the GATE during FY 1974-75. The aircraft has proved itself as an important research tool in programs requiring long range research flights, and in joint programs where multiple instruments must be flown simultaneously. The NSF-owned aircraft consist of two twin-engine Beechcraft Queen Airc and a twin-jet North American Sabreliner. These aircraft are used in support of the National Hail Research Experiment, university users, and NCAR research projects. In addition the facility operates a Schweizer sailplane, loaned to NCAR by the National Oceanic and Atmospheric Administration.

Computing Facility—The NCAR Computing Facility provides computing capabilities and services required by major atmospheric research projects. The system presently consists of an NSF-owned Control Data 6600 system and a leased Control Data 7600 system. A comprehensive augmentation of NCAR's computing capability was undertaken in FY 1975 and will continue in FY 1976. A remote job entry system became operational during FY 1975, and will be expanded in FY 1976, to permit access to the facility by university users without their having to travel to Boulder. A fifth-generation array-processing computer will be ordered in FY 1976 in order to ensure its delivery in time for NCAR to take an active role in FGGE data processing and to conduct prediction experiments with FGGE data. In order to process efficiently the vast amounts of data involved in large field experiments, and to use these data in numerical prediction experiments, funds were provided in FY 1975 to begin the addition of a mass-storage subsystem with completion of this capability in FY 1976.

Field Observing Facility (FOF)—FOF is primarily responsible for the development and operation of unique and sophisticated data collection

systems needed by the atmospheric research committee for research program support. In FY 1976, FOF plans to improve and expand its radar facilities by developing two mobile C-band radars. These radars are being developed as independent systems capable of being operated independently (in experiments where one component of velocity is required) or combined in a dual-doppler mode for calculation and display of three dimensional wind fields. The development of the C-band radar capability will have important applications in studies of the physics of precipitation; studies of severe weather including convective storms, tornadoes, and hurricanes; weather modification and cloud physics studies.

Research Systems Facility (RSF)—NCAR's development of major observing, measuring, data management, and control systems is centralized in the RSF. In FY 1976, RSF's major development will be a portable automated mesonet system composed of remote sensing stations and a control base station to provide real-time display, analysis, and archiving of data. The system will be useful in pollution, boundary layer, and precipitation studies, and as a reference standard for large-scale programs using several different data collection systems. Also, the systems real-time display capability will give investigators the opportunity for on-the-spot operational decisions and program adjustments.

NATIONAL HAIL RESEARCH EXPERIMENT (NHRE)

The overall goal of NHRE is to determine the potential for suppressing hail damage by cloud seeding and the extent to which hail suppression can be accomplished effectively on an operational basis. The objectives are:

- To conduct a statistical experiment aimed at proving or disproving the efficacy of suppression of hail by the introduction of artificial seeding material such as silver iodide into the storm systems.
- To conduct a broad-based but highly focused and integrated research program aimed at understanding the mechanisms of both natural hail development and the effects of seeding on hail growth.

—To conduct economic, social, and legal studies relevant to the ultimate implementation of an operational hail suppression program.

Efforts in FY 1975 will be dedicated to the reduction, analysis and synthesis of data, to the redefinition and refinement of the suppression hypothesis and to a limited field program. During the summer of 1976, (FY 1976), NHRE will conduct the fourth of six planned field investigations in northeast Colorado as part of the suppression experiment.

CLIMATE DYNAMICS PROGRAM

The Climate Dynamics Program of the National Science Foundation, presently managed by the Office for Climate Dynamics (OCD) consists of four areas of major emphasis: (1) Climate Data Assembly and Analysis; (2) Climate Index Design Monitoring, and Forecasting; (3) Climate Simulation and Prediction, and (4) Climate Impact Assessment.

CLIMATE DATA ASSEMBLY AND ANALYSIS

Climate data of past and present reside in archives and are being acquired from a host of sources throughout the world. Little of the older data has been studied using modern digital computers. Of the new data, much is being obtained for other purposes and is stored or destroyed without being examined from the climate point of view. Measurement and monitoring techniques that are presently available are not being used. Studies will be supported to assess and analyze data from these great reserves. It is anticipated that such studies will bring to light synchrony of climate events worldwide, and possibly will uncover causal connections among such events.

CLIMATE INDEX DESIGN, MONITORING, AND FORECASTING

At present no one knows with certainty whether the climate of earth is warming, cooling, or holding steady. It is thought that the even climate of the past 30 years is giving way to more severe short term variations characteristic of the previous century.

Studies to assess present climate, and to search for premonitory indices of future climate change—both short-term and long-term are planned for 1976.

Sponsorship of periodic Climate Diagnostic Symposia at which scientists bring together data, analyses, interpretation, and theories to form the best possible up-to-date assessments of present climate and possibilities for the future will be an important part of the Climate Assessment Program.

CLIMATE SIMULATION AND PREDICTION

Field experiments to understand climate are just getting under way. None is yet of truly appropriate spatial scale—covering the whole globe. It will be some time before such ambitious plans are realized. In the meantime, much can be accomplished in the modern computer with digital or analogue simulations. Although development of such models already is severely restricted by absence of suitable data, particularly from the oceans, progress is being made. Answers to many pressing questions regarding climate may be obtained by computer modeling. Eventually it may be possible to forecast climate by operating these models in the predictive mode.

Other serious restrictions exist. Oceanic model development lags far behind that of atmospheric models, because of the scarcity of suitable oceanic data and the consequently crude understanding of the natural behavior of oceans. Attempts to couple atmospheric and oceanic models have been less than rewarding because of this disparity. Until equally sophisticated oceanic and atmospheric models are available and can be coupled, progress will be slow. This restriction is more serious than the demands of climate models for computer power. OCD plans major support for the development of climate models.

CLIMATE IMPACT ASSESSMENT

The human species and climate constitute an interactive system. Little is known about the impact of human activity on climate or the impact of climate on human behavior. These impacts must be assessed systematically. As an ability is developed to predict climate change, it is vital to investigate the response of society to such predictions. Studies on individual, social, economic, and political aspects of climate and climate predictions will continue as an important area of research.

ALLOCATION OF FUNDING
(in thousands of dollars)

	FY 1974	FY 1975	FY 1976
Meteorology			
Physical Meteorology	6,697	7,031	8,091
Dynamic Meteorology	9,127	11,406	15,949
Observations	6,836	6,524	6,467
Description	3,067	3,330	3,917
Prediction	305	260	560
Modification	5,081	4,880	6,470
Systems	400	300	200
Support	3,500	3,550	4,220
TOTAL	35,013	37,281	45,874
Aeronomy			
Aurora and Airglow	1,485	1,640	1,810
Ionospheric Physics	2,345	2,570	2,815
Atmospheric Chemistry	285	600	910
Atmospheric Structure	1,175	1,300	1,500
Energetic Particles	825	900	850
Atmospheric Geomagnetism	690	800	940
Solar-Terrestrial Studies	3,230	3,510	3,940
Dynamic Aeronomy	405	530	640
Instruments, General	1,160	1,123	1,403
Instruments, Satellite	310	310	170
Support	1,170	1,160	1,200
TOTAL	13,080	14,453	16,178
Planetary Atmosphere	1,135	1,245	1,370
PROGRAM TOTAL	49,228	52,979	63,422
Distribution of Funding			
Industry	3,210	490	920
University	19,435	25,195	28,462
Other	26,583	27,294	34,040

APPENDIX I

Subordinate Organizations of the ICAS

To adequately and efficiently address specific problem areas, the ICAS over the years has seen fit to establish a number of panels and subcommittees, some standing and other *ad hoc*. These organizations are assigned tasks by the Chairman of the ICAS with the advice and consent of the members. The members of the subordinate groups are, in general, working level personnel with special understanding or expertise in the field or fields upon which deliberations are intended.

In recognition of the importance of the IMS and of the increasing involvement of the ICAS member

agencies in the IMS, the ICAS formed a standing Panel on the IMS, chaired by the newly established IMS Coordinator.

The membership of the subordinate groups is fluid, to allow the injection of needed capabilities into the efforts being carried out. The names of persons currently serving as members can be obtained at any time from the Executive Secretary of the ICAS upon request.

PANEL ON WEATHER MODIFICATION

Member agencies and purpose remain unchanged from ICAS Report No. 18.

Member representatives:

Dr. Ronald L. Lavoie, DOC, Chairman
 Dr. Robert Morris, DOS
 Mr. Currie Downey, NSF
 Col. Albert J. Kaehn, DOD
 Mr. James L. Kerr, DOI
 Mr. Charles F. Roberts, DOA
 Mr. Albert C. Trakowski, EPA
 Capt. Hugh W. Albers, ICAS

Activity report CY 1974

In December 1973 the Panel was charged by the ICAS with looking into the impending curtailment, for lack of sufficient funding support, of the Colorado State University ice nucleus calibration facility; evaluating the desirability of continuing such a facility; and recommending procedures by which it might be retained or replaced. At a meeting of the Panel on January 18 there was general agreement that the Cloud Simulation Laboratory has fulfilled an important need by providing a standard testing procedure by which meaningful values of the relative effectiveness of nucleating generators can be obtained. Panel members also agreed that

continued availability of this service is desirable and recommended that Federal support be provided with the cost being distributed among the four primary user agencies, the National Science Foundation and the Departments of the Interior, Defense, and Commerce. The Chairman of the Panel reported to the ICAS on 26 March 1974 that, through the cooperation of the above agencies funds had been identified to continue the Laboratory in operation through FY 1975 and that the need for further continuation and support would be evaluated before the end of that period.

Several meetings of the Panel were held during the year to develop a report tentatively entitled, "Analysis of the Federal Effort in Weather Modification," in response to a task assigned late in CY 1973. A draft of the report was presented to the ICAS on 15 November, 1974. The stated purpose of the report is to analyze the current Federal effort in weather modification, to identify deficiencies and problems, and to propose solutions or changes required to make the Federal effort consistent with National needs and interests.

Finally, the Panel reviewed and approved, in July 1974, the tentative agenda for the 16th Interagency Conference on Weather Modification at Ft. Lauderdale, Fla., scheduled for November 21-23, 1974.

PANEL ON INADVERTENT MODIFICATION OF WEATHER AND CLIMATE

The Department of Transportation was added as a member agency in 1974. The Panel's purpose remains unchanged from ICAS Report No. 18.

Member representatives:

Dr. Lester Machta, DOC, Chairman
Mr. Robert Beadle, AEC
Dr. H. Frank Eden, NSF
Dr. Ronald Greenwood, NASA
Mr. James L. Kerr, DOI
Dr. James D. Lawrence, NASA
Col John S. Perry, ARPA
Dr. Robert Papetti, EPA
Mr. Charles Roberts, DOA
Dr. Alan J. Grobecker, DOT

Observers:

Dr. J. Murray Mitchell, Jr., DOC
Dr. William A. Sprigg, DOC

Activity Report CY 1974

The Panel met in July 1974, to consider activities planned by the Federal government as a follow-on to the Department of Transportation's Climatic Impact Assessment Program, which was completed in early 1975. The Panel's report was forwarded to the Chairman of ICAS in August 1974.

Plans for CY 1975

The Panel will continue to review recommendations for research, survey present and planned Federal research activities, and assess the Federal effort in studies of inadvertent climate modification. A report on this review, and specifically on the questions concerning fluorocarbon/ozone stratospheric photochemistry, was submitted to the ICAS in June 1975; it is entitled: "The Possible Impact of Fluorocarbons and Halocarbons on Ozone", ICAS Report 18a.

PANEL ON THE ST. LOUIS AIR POLLUTION STUDY

Established December, 1971.

Purpose remains unchanged from ICAS Report No. 18.

Chairing Agency—Environmental Protection Agency

Member representatives:

Dr. Herbert L. Wiser, EPA, Chairman
Dr. Richard Strombotne, DOT
Dr. Rudolph J. Englemann, ERDA
Mr. Donald H. Pack, NOAA
Dr. Larry Tombaugh, NSF

Activity report CY 1974

The Environmental Protection Agency has been conducting a five-year comprehensive Regional Air Pollution Study (RAPS) in the St. Louis area since July 1972. The overall objectives of the RAPS program are: (1) to obtain a comprehensive data

base on air pollutant measurement and meteorological parameters, and (2) to develop, evaluate, and validate air quality simulation models. A twenty-five ground-station regional air monitoring systems (RAMS) network has been fully instrumented and made operational in CY 1974. The RAMS network, with the support of two instrumented helicopters, will be able to provide complete temporal and spatial mappings of air pollutant and meteorological parameters throughout the St. Louis area.

During CY 1974, the RAPS program completed two special field experiments. These experiments have provided important scientific information on air pollutant transport and transformation processes and urban/rural atmospheric boundary layer structure. The most important scientific results, thus far obtained from these field studies, have been associated with elucidating atmospheric conversion rates

of SO₂ to sulfate contrasting the different rates of conversion in coal/oil-fired power plant plumes and urban palls.

In CY 1974, ERDA, NSF and the Illinois State Water Supply have continued their joint sponsorship of the METROMEX program in the St. Louis area. The METROMEX program has an overall objective to determine impact of urban thermal and air pollutant emissions on local weather patterns (e.g., precipitation, cloud formation). As a result of recent field experiments, the METROMEX investigators have clearly indicated that an urban area can exhibit a measurable impact on the amount and distribution of local precipitation.

The Department of Transportation has continued to provide emission factor data associated with a variety of mobile sources. The emission data will represent an important component to the overall pollutant emission inventory for the St. Louis area.

DOT has completed an emission inventory analysis associated with river traffic patterns.

Plans for CY 1975

The research activities for all major participating agencies are expected to continue according to schedule. The EPA research effort in St. Louis will include at least two major field experiments. With the RAMS network fully operational, it is anticipated that field experiments will provide the first complete aerometric data base for modelers. METROMEX investigators plan to complete their final series of field experiments on the impact of urban centers on inadvertent weather modification. DOT plans to complete a detailed emission inventory analysis associated with airport and railroad emissions.

JOINT COMMITTEE FOR SPACE ENVIRONMENTAL FORECASTING

Established October, 1964, continuing committee
Member representatives:

Dr. D. J. Williams, DOC (NOAA), Chairman
Mr. P. B. Docker, DOC (NOAA)*
Mr. W. Berning, Mr. R. Skrwamek, Mr. H. Ballard
Major F. Powers,* Mr. D. Levine, (DOD)
Mr. A. Hilsenrod, DOT (FAA)
Dr. A. Timothy, NASA
Dr. H. Argo, ERDA
Dr. R. Megill, NSF

*Represent operational program and not research

Observers:

Observers from related commercial and university programs frequently attended JCSEF meetings.

Member agencies and purpose remain unchanged from ICAS Report No. 18.

Activity report CY 1973

In sharp contrast to previous years, only one meeting was held (Boulder, November 29, 1973). The major subjects considered were—(a) the need for a U.S. supported operational ionospheric monitoring program, and (b) the need for strong U.S. support to the IMS program.

Plans for CY 1974

One meeting was held in Boulder (November 1974). Principal subjects discussed were (a) the need for a ground based operational solar flare patrol network to support IMS, national space programs, and worldwide operational/research needs, and (b) the need for JCSEF to reexamine their recommendations of 1964 for SEF with emphasis upon the needs of U.S. programs in the 1980's.

Plans for CY 1975

A major meeting (several days duration) is planned for the summer. Emphasis will be upon the for-

mulation of guidelines for operational SEF programs in the 1975-85 period.

PANEL ON AERONOMY

The purpose and agency membership of the Panel remains as stated in ICAS Report 18.

Member representatives:

Mr. Warren W. Berning, DOD, Chairman
 Dr. Rudolf J. Englemann, ERDA
 Dr. Alan Grobecker, DOT
 Dr. Philip Mange, DOD
 Dr. Frank E. Niles, DOD
 Dr. George C. Reid, DOC
 Dr. Erwin R. Schmerling, NASA
 Dr. Cris G. Sturgis, DOD
 Dr. Lawrence R. Megill, NSF

The Panel's major effort during the past year was devoted to coordination of the U.S. participation in the International Magnetospheric Study. In June of 1975 that function was reassigned to a newly created ICAS Panel on the IMS. In the coming year the Panel on Aeronomy plans to review that report that was submitted to the ICAS in 1972 on the subject of stratospheric research, emphasizing those aspects of stratospheric research that bear on the questions associated with the possible impact of fluorocarbons and halocarbons on ozone.

ICAS PANEL ON THE INTERNATIONAL MAGNETOSPHERIC STUDY (IMS)

During the past year an Ad-Hoc Panel on the IMS was chaired by Mr. Warren Berning of Defense Nuclear Agency (DNA) and a number of working sub-groups were organized to plan technical aspects of the IMS. In June, 1975 the Standing Panel on the IMS was established with the following charter:

Charter

I. Purpose

This Panel is hereby established to maintain a current assessment of the U.S. participation in the International Magnetospheric Study (IMS), and to report to ICAS as appropriate on the state of this participation. The Panel should, through its assessment and activities, be especially alert to the prompt identification of gaps and other deficiencies in such participation by the Federal Agencies and

should promptly make recommendations to the ICAS concerning the correction of identified gaps or other deficiencies.

II. Composition

The Panel will consist of members appointed by each ICAS Member Agency that plans participation in the IMS or has an established or potential interest in the IMS and is prepared to participate actively in the efforts, deliberations, and decisions of the Panel. The member appointed by each agency will serve as a focal point and liaison for that agency's participation in the IMS. It is likely that several working groups will be sponsored by the IMS Panel.

III. Chairman

The Chairman of the Panel will be U.S. Coordinator of the IMS.

IV. Duration and Convening of the Panel

The Panel will function on a continuing basis and will exist until the formal announcement of the completion of the IMS field operating phase, now forecast to be through 1979. The ICAS may terminate it at an earlier date should circumstances warrant.

The Panel will meet at the call of its Chairman or of the Chairman of the ICAS. Except in unusual circumstances, the Panel will meet only after notice of the meeting has been mailed to members at least ten days prior to the proposed meeting date.

Activity Report—Past Year

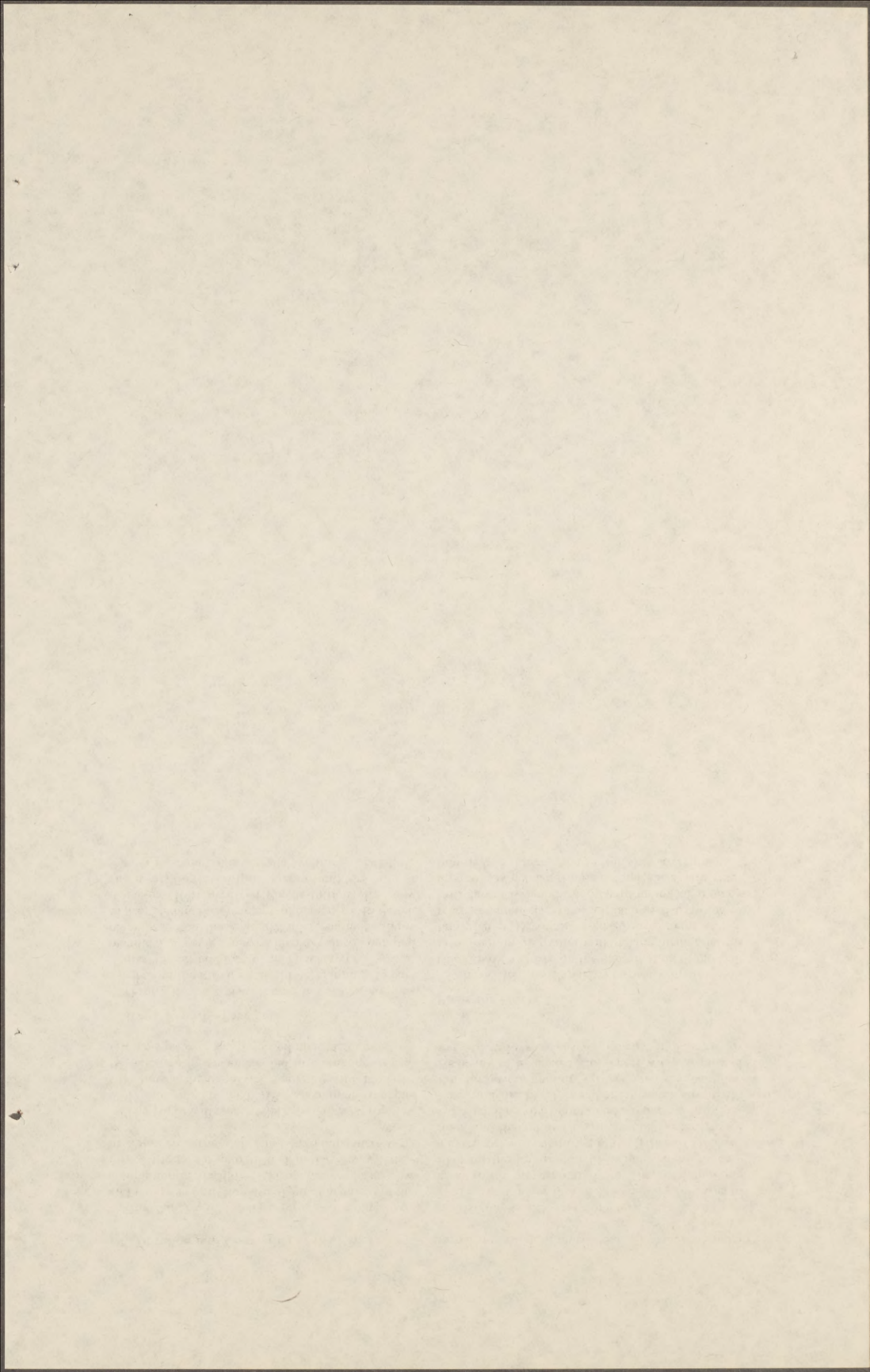
During the past year, the ad-hoc IMS panel has carried out the initial Federal IMS planning. In particular, the ad-hoc IMS panel sponsored a series of technical working groups which developed detailed plans based on the general IMS recommendations as provided by the Academy of Sciences IMS Panel. A major effort involved the definition of a new chain of digital-output magnetometers and a system for data collection via synchronous satellite.

Initial definition studies were also made of radio and radar instruments, optical arrays of instruments, ionosondes, and riometers.

A second major task of the ad-hoc Panel was to assist in the preparation of the "Government-Wide Plan for the International Magnetospheric Study." This report was submitted to the Office of Management and Budget by Dr. Guyford Stever as Science Adviser; the report contained supporting information from the FCST Member Agencies, the ICAS, the IMS Coordination Office, and the National Academy of Sciences. The report was transmitted to OMB and was released for distribution in February 1975.

Plans for Future Year

The ICAS IMS Panel will work with the IMS Coordination Office on the coordination of the U.S. IMS program. Activities will include further definition of new IMS ground-based instrument arrays, recommendations on the format and distribution of IMS data, assessment and coordination of Agency programs which contribute to the IMS, and distribution of IMS information within the Government.



APPENDIX II

Classification System

The following definitions are those prescribed in the ICAS/ICAMR* Common Reporting System and apply to all program descriptions:

Atmospheric Sciences: The sciences concerned with the physical and chemical properties, the composition, behavior and processes of the planetary atmospheres of the solar system.

Meteorology: The portion of the atmospheric sciences concerned with the physics and chemistry of the earth's atmosphere as a continuum. This includes problems of the troposphere, the stratosphere, and the mesosphere, and studies of such phenomena as the general circulation, weather systems, precipitation processes, turbulence, diffusion, and atmosphere/surface interactions. Meteorology areas of interest extend from the surface of the earth to approximately 100 km.

Aeronomy: The portion of the atmospheric sciences concerned with the physics and chemistry of the earth's upper atmosphere. This includes problems of the mesosphere and thermosphere including the ionosphere, and studies of such phenomena as airglow, aurorae, magnetic fields, radiation belts and solar terrestrial relationships. Aeronomy areas of interest extend from outer space to approximately 50 km above the earth's surface.

Planetary Atmospheres: The portion of the atmospheric sciences concerned with the studies of extra-terrestrial atmospheres.

Meteorology

Physical Meteorology: The study of the optical, electrical, accoustical, and thermodynamic phenomena of the atmosphere; its chemical composition, the laws of radiation; and the explanation of clouds and precipitation.

Dynamic Meteorology: The study of atmospheric motions as solutions of the fundamental equations of hydrodynamics or other systems or equations appropriate to special situations, as in the statistical theory of turbulence.

Observation: The functions of sensing, measuring, or otherwise determining the state of the atmosphere and the magnitude of its phenomena. Computations, recordings, interfacing with communications systems and observations directly associated with these actions are part of this category.

Description: The functions of analyzing meteorological variables and describing the existing state of the atmosphere whether done by manual or automated methods and including related operations such as data plotting, forecast verification, interfacing with communications systems and further including climatology as related to the study of long-term manifestations of weather and the application of climatic data analysis to the solution of specific design or operational problems.

Prediction: The function of preparing forecasts of meteorological variables and phenomena whether done by manual or automated methods and including related operations such as interfacing with communications systems.

Dissemination: The functions of communicating meteorological information, displaying it and disseminating required service products to users, including message composition, handling, relaying and editing, preparation of local area meteorological charts, and presentation of briefing and forecasts to users.

Modification: The functions (1) intended to modify the atmosphere through artificial means including, but not limited to, seeding of clouds and fog

*The interdepartmental Committee for Applied Meteorological Research, a committee of the Federal Coordinator for Meteorological Services and Supporting Research.

to influence the natural development cycle, intentional initiation of large heat sources or fires to influence convective circulation or evaporate fog, intentional modification of solar radiation exchange of the earth or clouds through the release of gases, dusts, liquids or aerosols in the atmosphere, intentional modification of the energy transfer characteristics of the earth's land or water surface by dusting with powders, liquid sprays or dyes, etc., (2) of research which does not directly involve intentional modification but is carried on with the primary intent to apply its results to such activities, and (3) of research in inadvertent modification such as the monitoring of atmospheric constituents and studies of their modifying influences on the weather.

Systems: The integration of efforts in the various functional categories of meteorology into a coherent research pattern or organized set of development procedures.

Support: The provision of support to research, development, test and evaluation activities.

Aeronomy

Aurora and Airglow: All phenomena associated directly with luminescence in the high atmosphere, including the size, shape, structure, geographical distribution, and composition of the elements or agents comprising or causing these phenomena.

Ionospheric Physics: Ionization and related phenomena, including electromagnetic propagation and ionospheric motions.

Atmospheric Chemistry: The chemical composition, chemical reactions and their distribution.

Atmospheric Structure: Temperature, pressure, density, winds, turbulence and other dynamic and kinetic properties of the upper atmosphere.

Energetic Particles: Trapped radiation, cosmic rays and their interaction with the atmosphere.

Atmospheric Geomagnetism: Magnetic fields and their variations as influenced by the earth's and solar atmospheres.

Solar-Terrestrial Studies: Solar activities as they affect the atmosphere of the earth.

Dynamic Aeronomy: The study of upper atmospheric motions as solutions of the fundamental equations of hydrodynamics or other systems of equations appropriate to special situations.

Instrumentation, General: Research and development of upper atmosphere sensors (including indirect or balloon-borne systems) and directly associated telemetering and control systems.

Instrumentation, Rockets: Research and development of upper atmosphere sensors and directly associated rocket guidance, telemetering and booster systems.

Instrumentation, Satellites: Research and development of upper atmosphere sensors and directly associated satellite guidance, telemetering and booster systems.

Support: The provision of support to research development, test, and evaluation activities.

Observers

John Carey
Office of Management and Budget

John R. Sievers
National Academy of Sciences—
Committee on Atmospheric Sciences

Pierce S. Corden
U.S. Arms Control and Disarmament
Agency

Ugo Morelli
Office of Emergency Preparedness

Douglas H. Sargeant
Interagency Committee for World
Weather Program

Fernand de Percin
Department of Defense—Army

Louis B. C. Fong
National Aeronautics and Space
Administration

Charles Blank
Defense Nuclear Agency

George E. Winzer
Department of Housing and Urban
Development

Ronald L. Lavoie
Department of Commerce

Gerald A. Petersen
Interdepartmental Committee for
Applied Meteorological Research

F. Gilman Blake
Policy Office Science and Technology

Warren R. Muir
Council on Environmental Quality

Henry Tilmans
Department of Defense—Air Force

Robert H. Martin
Department of Defense—Navy

R. G. Hebenstreit
Department of Defense—Air Force

Alden Bestul
Department of Commerce

Hugh W. Albers
Executive Secretary

Senator BELLMON. Which agencies are members of the interdepartmental committee?

Dr. EGGERS. The member agencies are the National Science Foundation, the Department of Agriculture, the Department of Commerce, the Environmental Protection Agency, the Department of the Interior, the Energy Research and Development Administration, the Department of State.

Senator BELLMON. Is there a lead agency?

Dr. EGGERS. There is not a lead agency, sir. There is a chairman. The chairmanship rotates. Prior to this year the chairman was Jim Wakeland of the Department of Commerce. This year it's Dr. Edward Todd, of the NSF. And the chairmanship alters periodically on, let's say, a 1- to 2-year basis.

Senator BELLMON. In your opinion, does the committee do about the same job or have the responsibility that S. 2705 envisions for the Commission?

Dr. EGGERS. It does many of those activities, and I believe its history points out that it discharges many of those responsibilities and has done so in a very effective fashion.

I did suggest, however, that the Commission proposal in that bill can be an important undertaking on behalf of the Congress.

The question in my mind is one of timing. We have just come out with this major study which involved all the agencies under the Domestic Council, and I would think it would be very important to profit fully from what has been learned there.

I do see a commission being an important undertaking here, and perhaps in another year or thereabouts, I do think all the agencies at the Federal level should have an involvement there.

I do think it should be independently chartered, and I do think consideration should be given to other membership, of course, including perhaps leading State activities in this area.

Senator BELLMON. As presently established, the committee does not involve either the private sector, nor the State sector, nor the States, nor people from universities. Is that true?

Dr. EGGERS. I believe that is correct. But let me ask Dr. Downie to go into that in more detail.

Dr. DOWNIE. It is composed of membership only from the Federal establishment. However, they are supporting much research in the private sector and certainly the universities and so forth.

Dr. EGGERS. I believe they do bring in consultants, too, from the private sector, as well as from other agencies.

Senator BELLMON. Now, from what you said about your work with hail suppression, you seem at this time to be rather disenchanted with the results you have had. Is that true?

Dr. EGGERS. Well, you never like to try hard at something and not win. And we have tried very hard. It was a major national

effort, and we did not win. And we're truly put in a state of increased respect for and modesty about just how much we understand about it.

I mentioned to the chairman earlier about the work in South Africa on hail suppression. That is an activity that is being paid for by the South Africans. It is being carried forward by a very respected commercial cloudseeder in the United States, and there is a feeling that that is paying off.

And when it became evident to us that the techniques we were using, after this analysis I described, simply were not cutting the mustard, if you will, there was a feeling that maybe we ought to switch over and use the different techniques employed in the South African work that I described.

I must say, I think we weren't justified in doing something like that, because we were no more sure that the early evidence from the South African work would hold up under continuing scrutiny and perform than we were many years ago regarding the Russian effort.

We need to get a handle on just what is going on in those clouds and our ability to separate out cause-and-effect phenomena from, if you will, casual phenomena.

Senator BELLMON. How do you propose to go about getting that handle?

Dr. EGGERS. We need to increase the activity, to penetrate these clouds and gather data on the fringes of the clouds in the early portion of the nuclei formation that verify that that is, in fact, what's happening on the fringes.

And then, after we have a good handle on that and it is shown by the repetitive experiments that it is in the fringe areas, then we will go into some limited seeding experiments, and see if we can track in a controlled fashion the development of the nuclei into ice crystals.

I think we have got to get a handle like that, or we can chase these clouds all over and have very little to show for our experiments.

With regard to rainfall augmentation, to date, to my knowledge, there have been no controlled statistical experiments of the type that we carried out on the hail suppression, carried out in the rainfall area.

And I would, in fact, refer you to a finding in this document of the Domestic Council that I believe is very important. It's on page 9. And they are talking about work carried out on summer convective clouds. This has to do with rainfall augmentation.

Four years of seeding research in Florida over an area of 900 miles have shown that the variability of convective rainfall is greater than the additional rainfall expected from seeding.

This is one of the three areas in terms of seeding for precipitation enhancement that are highlighted in this report. When you are

working with something that clearly at this time we have not developed the tools to show true cause-and-effect relationships in which the effect that you think you perceive is yielding smaller variations than the long-term natural variations, it's difficult to perceive how you can say you have deliberately caused something to happen, and it did not happen.

Senator BELLMON. The purpose of S. 2706 is to set up a 10-year program that would be monitored and would provide opportunity for various approaches and get at the data so we would know whether or not they were.

How do we proceed from this point?

Dr. EGGERS. I feel we need to achieve the objective, because of where the less than well-advanced state-of-the-art in the weather modification is at this point in time.

As a matter of general principle, I believe the continued multi-pronged thrust that has characterized the efforts up to this point in time is likely to be most effective in giving us that special kind of visibility that we need to get in certain areas where the potential for a breakthrough exists, and then we move ahead aggressively with a strong program with a well-defined lead agency.

But at this time I believe moving with the proven method of the several agencies working together under ICAS indeed offers us the most likely opportunity for a breakthrough in one or another form of precipitation augmentation.

Senator BELLMON. According to your chart, you have been spending—between \$12 and \$16 million per year, however the chart does not include Agriculture or Defense.

Do you feel we're getting the maximum benefit from this expenditure now? Are these programs all carefully coordinated and monitored, so that we're getting as good a result as we might?

Dr. EGGERS. I believe they are. And I believe the coordinating committee is doing a fine job.

I do have a concern, though, and I expressed that in my testimony, that we need closer ties between the Federal effort and the various State efforts that are underway. There is a good deal of that through the mechanisms of the same people being involved in these programs. But I believe there is a need to formalize that and in line with your bill in an effective fashion, so that we harness our effort.

I am concerned about the tie between the Federal and State levels and not the ties across the Federal levels.

Senator BELLMON. Would you bring in the private sector as well?

Dr. EGGERS. Yes, sir.

Senator BELLMON. I have other questions which I may refer to you in a letter.

Senator PEARSON. Has that Domestic Council report been published?

Dr. EGGERS. Yes, sir. It has.

Senator PEARSON. Would you send us a copy of that?

Dr. EGGERS. Yes, sir. We will be glad to provide you with a copy for the record.

Senator PEARSON. Thank you very much.

Dr. EGGERS. Thank you.

Senator PEARSON. Dr. White? Before you start, very generally, what other areas in the world, what other countries, are participating in these sorts of weather modification programs?

Do we have any treaty arrangements? What is the international scope? What is the interrelationship between the various programs carried out around the world?

**STATEMENT OF DR. ROBERT M. WHITE, ADMINISTRATOR,
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION**

Dr. WHITE. There are many countries that carry out programs of weather modification. They include the Soviet Union, Israel, France, and other countries.

It's fairly widespread. The programs are not coordinated in the sense that one would coordinate a national program. But there is a body called the World Meteorological Organization which seeks to coordinate or exchange information about weather modification activities that take place in the various countries.

That organization at its last congress has proposed an international weather modification experiment, one in which a number of countries would bring their resources together at one or two locations to carry out a long-term experimentation program such that the controversy about the effectiveness of this activity which takes place internationally could possibly be resolved.

In addition to that, the United Nations environmental program, located in Nairobi, has become interested in the international legal aspects of weather modification, and they have had a number of studies of this underway. And as you know, in connection with the disarmament conferences going on, there are proposed treaties for dealing with weather modification and other activities as weapons of war; these discussions are presently underway in Geneva.

Senator PEARSON. There have been no confrontations so far between nations as to weather modification programs?

Dr. WHITE. No. There has not been.

Senator PEARSON. Thank you. Go ahead with your statement.

Dr. WHITE. I am pleased to be able to participate in the committee's deliberations on weather modification.

The bills before the Senate are interesting in that they cover the gamut of possible weather modification options available to us.

The first of these, S. 2705, proposes that a Commission be established to study what should be done by our Government to foster the development and application of weather modification.

The second bill, S. 2706, proposes that a long-term program of research and experimentation be initiated to determine whether it is feasible to alleviate drought by weather modification.

The last bill, S. 2707, proposes that the Federal Government provide financial assistance to the States to carry out operational weather modification programs to alleviate drought.

The question is, what is the best option for the United States in the light of our present scientific knowledge of weather modification on one hand, and drought conditions on the other?

First, let me say something about the work of the National Oceanic and Atmospheric Administration in weather modification and allied fields.

NOAA has been active in weather modification research and development since 1946. We conduct major programs of weather modification research and development directed at modifying severe storms such as hurricanes, increasing rainfall from tropical cloud systems, and suppressing lightning in thunderstorms.

For fiscal year 1977, we are requesting \$7.048 million for weather modification research development. With your permission, I would like to submit for the record a brief account of our work with some indication of the results which we have obtained in these areas.

Senator PEARSON. We will incorporate that into the record.

[The information follows:]

SYNOPSIS OF CURRENT WEATHER MODIFICATION RESEARCH IN NOAA

NOAA's largest effort in weather modification is project STORMFURY, aimed at developing effective methods for moderating the most destructive peak winds in hurricanes. This project was first undertaken in partnership with the Department of Defense in 1962. The most successful experiments were conducted in 1969 on hurricane Debbie when the storm and circumstances combined to allow a good test of the modification hypothesis. In one case peak winds decreased by 31 percent a few hours after seeding the appointed area of the storm. In the second case, maximum winds were observed to decay temporarily by 15 percent. Still, such changes do occur naturally at times. Greater understanding and additional successful experiments are needed to establish the capability of beneficially altering hurricane winds without affecting the valuable rainfalls associated with these storms.

In 1972 NOAA embarked on a long-range program to develop the tools needed to properly and thoroughly test the STORMFURY hypothesis. Our current target date for resuming field experiments in hurricane modification is summer 1978.

NOAA's next most important weather modification project measured in terms of longevity and funding levels, has been aimed at stimulating increased rainfall from tropical cumulus clouds. In contrast with most cloud seeding activities undertaken since the mid-1940's, this project utilizes a "massive" seeding technique whereby one kilogram of silver iodide is introduced into every seeded cloud by dropping pyrotechnic flares from aircraft. This method is the "dynamic" approach to cloud modification. The experiment has been active in Florida since 1967 and has progressed through several milestones.

The first stage of this project consisted of carefully designed experiments to examine the effects of massive seeding with silver iodide on the structure and dynamics of selected individual cumulus clouds. These experiments, conducted over South Florida in 1968 and 1970, demonstrated conclusively that "dynamic" seeding of selected individual convective clouds is effective in increasing cloud size, prolonging its duration and, consequently, increasing its precipitation production by an average factor of three.

However, the rain produced by several single cumulonimbus clouds, seeded or natural, is small compared to that received from an equivalent number of clouds merged into a larger organized cluster of towers which has the ability to regenerate new cells and sustain itself for several hours. For that reason the Florida dynamic cloud seeding experimental efforts were redirected in 1970 toward two new goals. The first is to determine if dynamic seeding could be used to induce the merger and growth of several cumulus towers growing in near proximity of one another, thereby increasing precipitation from the larger cloud system. The second objective is to determine if a net rainfall increase over a large target area can be achieved by promoting the growth of better organized cloud and rain systems in that area through dynamic seeding.

NOAA has conducted randomized multiple cloud seeding experiments to maximize cloud organization and produce cloud merger during the summers of 1970, 1971, 1973, and 1975. Evaluation of rainfall data available to date from both the experimental cloud clusters (floating targets) themselves and the total target area suggests that mean rainfall is greater as a result of seeding. These results are not statistically significant, however. We anticipate that at least one additional summer experiment will be required to uncover a significant rain enhancement effect with a sufficiently high level of confidence in the result. Seeding experiments are planned during the summer of 1976 in Florida.

NOAA also has a small experimental effort in lightning suppression using very fine metalized nylon fibers (chaff) as a seeding agent. This effort, based on a theoretical model developed over the past several years, was initiated as a field program in 1972 aimed at testing the chaff seeding concept and determining the effect of such seeding on the electric fields of nascent thunderstorms. In these experiments thunderstorms were seeded from below with chaff, and the number of lightning occurrences was observed to be about 25 percent of that observed in the control storms (based on an analysis of data from 10 seeded thunderstorms and 18 unseeded control storms). Although the experiments were not strictly randomized, statistical evaluation indicated that the observed difference between seeded and control storms was significant. Further research on this technique is planned during 1976 at Cape Canaveral, Florida, in collaboration with several other agencies.

Dr. WHITE. In 1971, Congress assigned to the Secretary of Commerce the responsibility to record all weather modification activities in the United States, so that a central source of information on weather modification projects carried out in the United States and its territories could be available.

Public Law 92-205, which requires the reporting of all weather modification activities, is currently the only Federal weather modification statute.

This law requires an annual report on weather modification activities in the United States, and with your permission, I can submit the latest report for the information of the committee.

[The report follows:]



Weather Modification Activity Reports Calendar Year 1974

Environmental Modification Office
Rockville, Maryland
March 1975

U.S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

OFFICE OF ENVIRONMENTAL
MONITORING AND PREDICTION

U. S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration

Office of Environmental Monitoring and Prediction

WEATHER MODIFICATION ACTIVITY REPORTS

Calendar Year 1974



Environmental Modification Office
Rockville, Maryland

March 1975

CONTENTS

	<u>Page</u>
Abstract	1
Introduction	1
Data base	2
Summary of data	2
Number of activities	3
Operators	3
Sponsors	4
Purpose of activity	5
Target areas and their locations	7
Techniques and apparatus	7
Agents and dispensing rates	8
Interim and final report data	10
Project safety and environmental data	11
Federal activities	12
Environmental impact statements	12
Environmental information	12
Safety procedures	12
Nonfederal activities	13
Environmental impact statements	13
Environmental information	14
Safety procedures	14
Concluding remarks	16
References	17
Appendix A - List of reported activities	18

WEATHER MODIFICATION ACTIVITY REPORTS, CY 1974*

ABSTRACT

By law, nonfederally sponsored weather modification activities must be reported to the National Oceanic and Atmospheric Administration (NOAA); Federal projects are also reported by agreement with applicable agencies. Reports of activities conducted at 74 locations in the United States during CY 1974 are summarized herein. The analysis covers the purpose of the weather modification project, location, sponsors, operators, modification equipment, techniques, target areas, seeding agents, seeding duration, and target areas. Discussions of environmental impact and project safety are also included. Some trends in nonfederal activities from CY 1973 to CY 1974 are indicated. A list of reported activities is given in an appendix.

INTRODUCTION

Under Public Law 92-205, December 18, 1971, all nonfederally sponsored weather modification activities in the United States must be reported to the Secretary of Commerce. The Law further specifies that the Secretary shall publish summaries of these activities from time to time. On November 1, 1972, the National Oceanic and Atmospheric Administration (NOAA) initiated a reporting program on behalf of the Secretary of Commerce. Federal agencies began to report their weather modification projects to NOAA by interagency agreement as of November 1, 1973. Therefore, NOAA's reporting program is the central mechanism for obtaining information on all weather modification activities underway in the United States and its territories.

The reporting procedures were amended on February 15, 1974, to cover safety and environmental aspects of field activities and to consider possible interference with Federal research projects. Copies of the reporting law, reporting rules and forms, the amendments, and the Federal reporting procedures are contained in a summary report by Charak and DiGiulian (1974). Requests for information on the reporting program should be directed to:

Environmental Modification Office (EM-5)
NOAA
6010 Executive Blvd.
Rockville, Maryland 20852

*This report was prepared by Mason T. Charak of the Environmental Modification Office.

This summary report covers weather modification activities carried out in CY 1974, and includes nonfederal projects and Federally sponsored activities. The report describes the projects that were initiated during 1974 and the projects active during the year but started prior to January 1, 1974. It includes analyses of data on project purpose, sponsors, operators, target locations, target areas, and modification techniques, apparatus, agents, and dispersing rates. Additional information is provided on modification days, missions, duration of seeding activities, and amounts of seeding agents. Also included is a discussion of reported information on operational safeguards and environmental impact associated with the weather modification activities.

DATA BASE

The initial, interim, and final reports submitted to NOAA provide the data base for this summary of weather modification activities. Each activity is assigned a NOAA file number upon receipt of an initial report from a project official; appendix A is a list of 88 reports analyzed herein for CY 1974. An interim report is required on October 1st of each year unless the project was terminated before that date and a final report is due on completion of a project. A weather modification project is considered active until a final report is filed with NOAA. Since operators have up to 90 days to submit a final report, some of the projects considered "active" may have ended before December 31, 1974.

All reports are reviewed and requests are sent to the operators when the data are incomplete; replies are usually prompt. To date, experience with the reporting program shows that the information most often requiring a follow-up request concerns sponsor and operator identification, target area maps, aircraft used, dispersal rates of modification agents, date on which final weather modification activity occurred, and signature.

SUMMARY OF DATA

The reported information has been grouped into several categories for convenience in analyzing the data. These categories are discussed in the following sections.

Number of Activities

Although 88 weather modification projects were recorded in NOAA's reporting program (appendix A), only 74 separate and distinct activities were carried out at separate locations in CY 1974. Thirteen projects were completed early in the year, but later 14 similar projects were reinstated at the same locations. Appendix A shows that project number 74-097, with both aircraft and ground-based techniques, was reported as two projects when reinstated under numbers 75-121 (aircraft) and 75-122 (ground-based).

Appendix A lists 13 continuing activities (longer than a year). Operators are required only to file interim reports and to update their initial reports if changes occur. A final report is sent to NOAA upon completion of the project or if a long delay is expected. The continuing projects are 73-002, 73-010, 73-014, 73-015, 73-029, 74-062 through 74-066, 74-075, 74-101, and 74-113.

Table 1 gives a breakdown of the 74 nonduplicative projects to be summarized in this report. Note that the nonduplicative data from all 88 reports were included in this summary.

Table 1.--Active, nonduplicative weather modification projects in the United States in CY 1974

Nonfederal projects	65
Federally sponsored projects	9
Active projects on January 1, 1974	36
Active projects on December 31, 1974	32
Projects active on January 1 and December 31, 1974	25
Projects initiated in CY 1974	38
Projects completed in CY 1974	42

Operators

Table 2 shows the number of activities or projects undertaken by different types of operators. One commercial weather modification concern carried out 21 of the 74 modification projects, another company was responsible for eight projects, one firm undertook five projects, and two companies carried out four projects each during the reporting period.

Table 2.--Operators of weather modification activities

<u>Type</u>	<u>Operators</u>	<u>Activities</u>
Commercial weather modifiers	19	56
Universities	5	5
Individuals	4	4
Municipal districts	3	3
Federal	2	3
Community associations	1	1
Power companies	1	2
Total	35	74

Sponsors

The types of sponsors of the reported activities and the number of their activities are given in table 3. Some activities have multiple sponsors, especially at airports. The sponsors of the Federal projects included the Air Force, Navy, National Science Foundation, National Oceanic and Atmospheric Administration, and the Bureau of Reclamation (Department of the Interior). South Dakota and Kansas were the only two states sponsoring programs. Municipal districts were generally concerned with water resources. In North Dakota, groups of counties banded together to sponsor activities that were supported by local taxes. However, in States such as Oklahoma and South Dakota, counties formed associations to sponsor projects that were funded by voluntary donations.

Table 3.--Sponsors of weather modification activities

<u>Type</u>	<u>Sponsors</u>	<u>Activities</u>
Community associations	23	24
Airlines/airports	10	9
Federal	5	9
Municipal districts	9	7
States	2	8
Power companies	2	3
Private sector	6	6
Cities	3	4
Counties	8	3
Universities	1	1
Total	69	74

Purpose of Activity

A summary of the activity reports shows that four objectives were specified: precipitation increase (rainfall and snowfall), fog dispersal, hail decrease, and weather modification research. Table 4 lists the number of activities with respect to their purpose and sponsorship. The total is larger than the number of nonduplicative projects (74) because some projects have two purposes.

Of the 89 purposes, 53 were devoted to increasing precipitation (mostly rain) and 15 to dispersing fog (predominantly cold fog). In many cases, hail decrease was coupled with the purpose of increasing rainfall. Of the seven research projects, four dealt with management of water resources (increasing precipitation) one with lightning suppression, one with hail suppression, and one with testing particle generators and techniques for weather modification.

Table 4 also shows that Federal activities are generally devoted to research or cold fog dispersal. Airlines and airport authorities are concerned only with dispersing fog. Community associations, county authorities, and States sponsor activities directed toward precipitation increase and hail decrease. Municipal districts and power companies seek to increase precipitation and thereby augment water resources in their areas.

Table 4.--Purpose and sponsorship of weather modification activities

Sponsors	Increase		Precipitation	Disperse Fog		Decrease Hail	Research
	Rain	Snow		Cold	Warm		
Community associations	4		19			5	
Airlines/airports				10	2		
Federal agencies				2			7
Municipal districts	5	2	1				
States	7					6	
Power companies		3	1				
Private sector		1	5				
Cities			1	1			
Counties	1		2			3	
Universities			1				
TOTALS	17	6	30	13	2	14	7

Target Areas and Their Locations

Table 5 shows 75 weather modification activities by location and total target area. For the year, 22 States and the Commonwealth of Puerto Rico are represented in the data. The target area of one activity in Michigan extended into one county of Indiana, accounting for the "extra" activity in table 5. For purposes of identification, the geographical distribution of all 88 reported projects is shown in figure 1 at the approximate locations of their target areas.

In cases where an activity has been repeated during the year at the same location, the target area was not included for the second time in arriving at the total amount of target area. For one project in Colorado where the target was a lightning storm within a 250-mi radius of the base airport, a representative area of 100 mi^2 was chosen for the movable target.

About 75 percent of the weather modification activities were carried out in the western United States, where the only states with no activities were Arizona and New Mexico. Oklahoma had the greatest number of activities (12), and California followed with 8. In the east, Michigan led with nine projects.

The total of target areas was about 5 percent of the combined areas of the 50 States, the District of Columbia, and Puerto Rico. Federal activities accounted for about 5 percent of the total target area and commercial operators, 95 percent. North Dakota has 32 percent of its area subject to modification activities, Utah 50 percent, and South Dakota 55 percent.

Techniques and Apparatus

Analysis of the reported data shows that ground-based techniques were to be used in 42 activities and aircraft methods in 37. The total is more than 74 because 5 projects dispensed the seeding material from both the ground and the air.

Liquid-fueled silver iodide generators or burners were the most common type of weather modification apparatus, being used in 14 ground-based projects and 14 aircraft seeding activities. Propane or acetone were normally used as fuel. The arc-type silver iodide burner was used exclusively at ground level in 21 activities. Pyrotechnic devices including flares, rockets, and Very pistols were employed in 21 projects. Other apparatus used in modification activities were dispensers for solids and liquids, spray nozzles, and "cloud busters" consisting of pipes grounded into a water supply.

Table 5.--Location and size of target areas

<u>Location</u>	<u>Activities</u>	<u>Target area (mi²)</u>
Alaska	2	103
California	8	7,693
Colorado	3	2,000
Idaho	2	164
Illinois	1	2
Indiana	2	1,250
Iowa	3	430
Kansas	1	3,000
Michigan	9	5,870
Montana	1	5
Nebraska	1	2
Nevada	2	5
New York	1	-
North Dakota	5	22,105
Oklahoma	12	12,291
Oregon	2	7,821
Puerto Rico	1	207
Pennsylvania	1	200
South Dakota	6	43,136
Texas	3	5,900
Utah	3	41,510
Washington	4	210
Wyoming	2	196
Totals	75	154,100

Agents and Dispensing Rates

The active agents used for the reported activities are silver iodide, crushed frozen carbon dioxide (dry ice), polyelectrolytes, propane, urea, hexadecanol, water, sodium chloride, 1-5 DN (1-5-dihydroxynaphthalene), and combinations of silver iodide with other liquids or solids. A polyelectrolyte can be defined as a polymeric material having an electrical charge. Chaff (metallic fibers) was dispensed from aircraft in the lightning suppression project.

Silver iodide, by itself or in combined form, was the agent in 56 activities. Dry ice was planned for use in 14 activities, propane in 3, and polyelectrolytes in 2. In several activities, more than one agent was used.

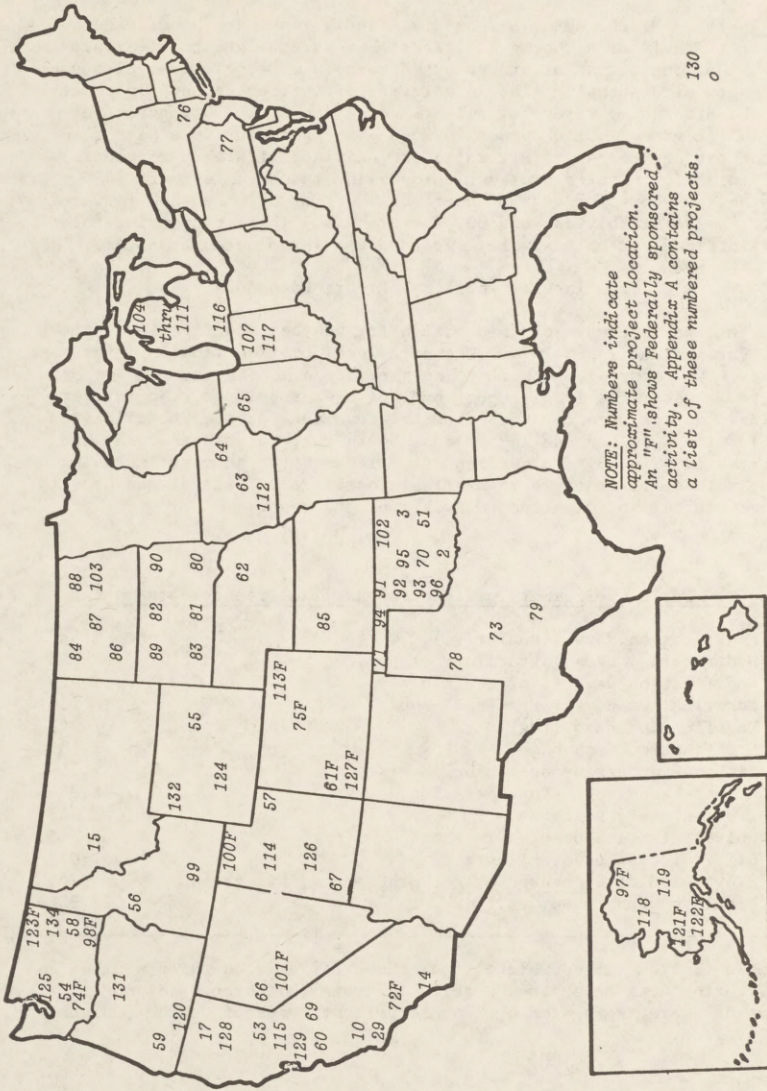


Figure 1.--Federal and nonfederal weather modification activities in the United States, CY 1974.

Inspection of the data in appendix A indicates that the dispensing rates for a unit of airborne modification apparatus are considerably higher than the rates for ground-based burners or generators, although the length of dispensing time in aircraft activities is usually shorter. The dispensing rates for silver iodide range from 0.5 grams per hour in one ground-based burner to 3000 grams per hour in a set of pyrotechnic devices on an aircraft; an individual flare (pyrotechnic) burns for a few minutes or less. Dispensing rates range up to 4500 kilograms per hour for sodium chloride, 1300 for dry ice, 500 for urea, 300 for polyelectrolytes, and 300 for propane. These dispensing rates are maintained for only several seconds or a few minutes at a time.

Interim and Final Report Data

Table 6 is a summary of information for weather modification activities carried out in CY 1974. The data were compiled from 13 interim and 52 final reports; 8 other projects reported no seeding. An interim report was used if a final report had not been submitted. No interim or final reports were received from the remainder of the 88 activities on file with NOAA because 14 projects began very late in the year and one activity (74-066) did not report. Although the summary in table 6 is incomplete, it is the best available estimate of Federal and non-federal weather modification activity for the year.

Table 6.--Summary of interim and final report data

(a) Modification days (cumulative)	2,540
(b) Modification days (stratiform clouds)	286
(c) Modification days (isolated clouds)	1,475
(d) Modification days (organized clouds)	738
(e) Modification days (fog)	43
(f) Modification missions	2,403
(g) Airborne apparatus operation, hours	4,559
(h) Ground-based apparatus operation, hours	46,366
(i) Dry ice used, kilograms	21,055
(j) Polyelectrolyte used, kilograms	45
(k) Silver iodide used, kilograms	1,019
(l) Silver iodide dispensed by airborne means, kilograms	763
(m) Liquid propane used, gallons	13,356

Table 6, item (a) shows the total number of days on which weather modification activities took place. In items (b) through (e) modification days are segregated by the predominant types of weather phenomena involved.

The total of entires in (a) does not equal the total of (b) through (e) because the data are incomplete and because on some days more than one cloud system was involved in the operation.

Although silver iodide was the most popular seeding agent, the quantity of dry ice dispensed was about 20 times more than the weight of silver iodide. The dry ice was used primarily in cold fog dispersal; polyelectrolytes and liquid propane were also used for that purpose.

The number of fog modification days is less than 2 percent of the cumulative number of modification days. However, 14 of the 74 distinct weather modification activities (19 percent) were fog dispersal activities. The analysis indicates, therefore, that fog of the type suited to the modification technique was not prevalent at the 14 project airports during the year. In fact, no modification activity was reported for seven of the airports (73-054, 74-056, 74-062, 74-063, 74-064, 74-065, and 74-066).

PROJECT SAFETY AND ENVIRONMENTAL DATA

On February 15, 1974, the reporting rules were amended to obtain information on environmental impact of the proposed weather modification activity and on safety procedures associated with a project's operations. The following questions were added as item 8 of the initial report form:

1. Has an Environmental Impact Statement, Federal or State been filed? If yes, please furnish a copy as applicable.
2. Have provisions been made to acquire the latest forecasts, advisories, warnings, etc. of the National Weather Service, Forest Service, or others when issued prior to and during operations? If yes, please specify on a separate sheet.
3. Have any safety procedures (operational constraints, provisions for suspension of operations, monitoring methods, etc) and any environmental guidelines (related to the possible effects of the operations) been included in the operational plans? If yes, please furnish copies or a description of the specific procedures and guidelines.

For convenience in preparing this report, the answers to these questions were separated into Federal and nonfederal activities. For projects that began before the effective date of the amendments but were to be continued into 1975, an updated initial report was requested.

Federal Activities

Under the amended rules, only 6 of the 9 Federally sponsored projects were required to report on safety and environmental factors.

Environmental Impact Statements

The National Environmental Policy Act of 1969 (NEPA) requires that all agencies of the Federal government include an environmental impact statement (EIS) in proposed "major Federal actions significantly affecting the quality of the human environment". Such EIS reports are filed with the Council on Environmental Quality. The key words in the NEPA requirement are "major" and "significantly". All 6 initial reports of Federal projects submitted after February 15, 1974, indicated that an EIS had been filed. However, two of these activities involved small-scale fog dispersal at Air Force Bases where the actions were not considered to "significantly" affect the human environment. Accordingly, the documentation on environmental impact for these two projects was filed with the Department of Defense.

Environmental Information

Question 2 deals with information that was available to the operators with respect to possibly dangerous environmental conditions such as severe storms, floods, avalanches, or dry forests, prior to and during operations. In all six activities, meteorologists either were part of the project team or, in the case of fog dispersal, were contacted at the airbase. Generally these specialists prepared forecasts for the modification program and monitored National Weather Service (NWS) forecasts. For some projects, weather observations were made with standard instruments, including radiosondes or rawinsondes. Hourly surface aviation observations, upper air data, notices to airmen (NOTAMS), and other related information are often provided by long-line teletypewriter systems (Service A and Service C). Other data are sometimes supplied by the National Facsimile Network (NAFAX) and Radar Facsimile (RAFAX). Occasionally remote weather stations or a radar terminal display are connected with the central project office. As part of his duties, a project meteorologist may contact the National Weather Service, the Forest Service, or other groups for reports on weather and other environmental conditions. These various sources of environmental information, in part or totally, were basic ingredients of the federally-sponsored weather modification activities.

Safety Procedures

Question 3 covers safety provisions and environmental guidelines related to the possible effects of the activity. Since no two weather modification projects are alike, answers to the question differ. For

some air operations, potential air traffic control problems must be coordinated with the local Federal Aviation Administration office. A few projects suspend operations when severe storms are over the target area; however, hail suppression activities are carried out only in severe local storm situations. Seeding rockets launched from aircraft are not used around airports or in densely populated areas. Seeding is suspended when snowpack is much above the long-term average, when avalanche conditions are forecast, or when there is flood danger. In some cases, operations are suspended if there are high winds in the target zone.

The effects of the weather modification activities on people, places, and the ecology are prime considerations in planning and carrying out the projects. Seeding with silver iodide will not cause serious ecological consequences. Crushed dry ice soon disappears, and the propane concentration used in fog dispersal is below the danger limit of 100 ppm. Metallic chaff fibers dispensed during lightning experiments have no known impact on the ground environment. Project leaders minimize such dangers by careful planning and by monitoring forecast and warning services.

Nonfederal Activities

The information on safety and environmental considerations associated with 57 nonfederally sponsored weather modification activities has been reviewed to determine common factors and trends. The other eight nonfederal projects were completed early in 1974, before operators were required to update their Initial Reports by answering questions on safety and environment. Operators with several projects usually submitted the same answers to the questions for all projects with similar operational characteristics.

Environmental Impact Statements

Nonfederal projects are not subject to the requirements of NEPA for filing a Federal EIS. However, some States seem to be moving toward a similar requirement. For example, California's Environmental Quality Act requires that an Environmental Impact Report (EIR) be provided for any project proposed by a public agency "which may have a significant effect on the environment". In this connection, one California project filed an exemption declaration with the State on the basis that the only impact the cloud seeding program has on the environment is to increase rainfall and runoff and that the increase is not significant compared with natural variations. South Dakota also requires an EIS in conformity with its Environmental Policy Act.

Environmental Information

Generally, the National Weather Service (NWS) teletypewriter circuits (Service A), and facsimile circuits provided the basic environmental information for project planning and decision making, either at the target area or project headquarters. In a few locations, project personnel made and used radar and rawinsonde observations. Some projects supplemented the meteorological information with data from Flight Service Stations of the Federal Aviation Administration or local Air Force Base weather offices. In addition, many operators employed meteorologists at either the project office or company laboratory to provide meteorological advice during operations.

For some activities involving water storage, private and public utility personnel provided observations of environmental conditions in the watershed area. According to one operator, public service data are insufficient for operations. In a few cases, additional information was obtained from hydrographers, dam tenders, and project pilots. The Federal/State River Forecast Service has also supplied quantitative precipitation forecasts, freezing levels, and indices of basin wetness. Another source of information has been the Bureau of Reclamation with data on reservoir conditions. The Forest Service Avalanche Field Office has been contacted by project personnel to determine avalanche potential in the target area.

Safety Procedures

The number and extent of safety precautions varied directly with the scope and type of the operation. The greatest need for safety procedures is in projects involving precipitation increase. The commercial firm with the largest number of projects in this field has the option of stopping the activity if continuation could have a detrimental effect on persons or property in or near the target areas. Their clients can also suspend or terminate their local programs at any time.

Two large companies reported their precautions with respect to possible flood hazards. One stated that no seeding was begun if the dams could not contain the expected runoff; if rain was expected above 8,000 feet MSL after snowpack accumulation began; or if cloud top temperature was colder than -31°C . Another activity conducted seeding when meteorological and hydrological conditions were suitable or until a storm total of 5 inches of rainfall is recorded at the dam site; this project also avoided influencing precipitation in areas that had experienced recent burns or earthquakes. One project terminated operations when river flows were expected to exceed 135 percent of normal. Generally, operations were suspended during storms with flood-producing potential, when snowpack was above normal, or when an avalanche threat existed; these procedures require constant surveillance of watershed and mountain conditions. (Snowpack is monitored by the U.S. Soil Conservation Service.)

For the South Dakota cloud seeding program, "safeguards or fail-safe mechanisms are a means of termination, temporary or permanent, of seeding operations to avoid contributing to a hazardous condition. In fact, it is important to extend this concept to avoid even the appearance of contributing or having caused a hazardous condition. This task becomes particularly difficult since a part of the goal of the program is to suppress hail. The meteorological conditions which produce hail also are conducive to wind, heavy precipitation and tornadoes. Even if all the hail is suppressed, economic loss can result from other factors". Criteria for the program are that tornadoes are not to be seeded in areas where damage to residences may result; that cloud seeding will terminate on storms which are producing large amounts of rainfall; that no seeding for rain increase will be conducted if county representatives identify excessive soil moisture that inhibits farming; and that operations may be suspended at the discretion of the area meteorologist when other hazardous conditions exist.

Safety guidelines for operators are minimal for fog clearing at airports, where the target areas are small and people, property, and the environment are not usually endangered by dry ice, propane, or poly-electrolytes. In addition to NWS forecasts and observations, pilot-to-tower radio contact is generally prescribed. Two projects use continuous radar monitoring of the seeding aircraft and one of these limits flights over congested areas. Another operator allows local authorities to decide on fog modification after consideration of possible criticism and/or liability that might result from the seeding operation. In one activity, the operator alerts the State Police Patrol to possible fallout of precipitation and seeding agents on roads and highways; seeding flights are suspended if operations are unsafe.

This review of safeguards associated with nonfederal weather modification activities shows that the larger projects involving precipitation increase and/or hail decrease generally have a large number of safety guidelines. On the other hand, precautions are usually few in fog dispersal activities, especially at small airports.

During the reporting period, there were no instances of apparent interference of a Federal research program by a nonfederal activity.

CONCLUDING REMARKS

The required reports of weather modification activities in the United States and its territories for CY 1974 have been summarized in this publication. Of the 74 nonduplicative activities, 9 were Federally sponsored and 65 were nonfederal.

Analysis of the reports shows that about one-fourth of the projects were carried out by one commercial operator; nearly one-third were sponsored by local community associations that often combined two or more contiguous counties; nearly two-thirds were intended to increase precipitation as rain or snow; one-fifth were to decrease hail; and one-fifth to disperse fog.

For the year, 22 States and the Commonwealth of Puerto Rico had some planned activity, while Oklahoma, Michigan, and California led in total number of projects. The total target area for the reported activities was about 154,000 mi², with South Dakota, Utah, and North Dakota having the largest total target areas. Commercial weather modification accounted for 95 percent of the total target area.

Further examination of the reported data indicated that ground-based techniques were used slightly more than aircraft methods and that the liquid fueled generator or burner was the most common type of weather modification apparatus operated from the ground and in the air. Silver iodide was the most popular seeding agent and was used in 56 projects while dry ice was used in 14 activities.

The cumulative total of modification days was estimated at 2,500 for the year. Ground-based weather modification apparatus operated for 46,000 hours and airborne apparatus for 4,500 hours. About 1,000 kilograms of silver iodide was used with nearly three-fourths dispensed from aircraft. Fog modification consumed 21,000 kilograms of dry ice and 13,000 gallons of liquid propane.

Only a gross comparison can be made between the data and results in this report for CY 1974 and the information given in the previous summary report (Charak and DiGiulian 1974). The reporting periods were slightly different in length, and Federal projects did not begin to report until the last two months of 1973. However, examination of the original data for nonduplicative, nonfederal projects reported in CY 1973 provides some basis for comparison and, thus, an indication of trends in nonfederal weather modification.

From 1973 to 1974, the number of nonfederal projects increased from 59 to 65 (10 percent), nonfederal operators from 27 to 34 (26 percent), nonfederal sponsors from 51 to 64 (26 percent), total nonfederal target area from 130,000 to 146,000 mi² (12 percent), and the number of states with nonfederal activity from 18 to 22 (22 percent).

The data from the interim and final reports showed that, except for fog dispersal, the number of modification days in 1974 increased slightly over the totals for 1973. The number of missions reported in 1974 decreased, but the hours of operation for ground-based and airborne apparatus both increased over totals for 1973. The amount of dry ice used increased, the quantity of polyelectrolyte dispensed decreased, and the weight of silver iodide used was about the same for both years.

Information submitted on project safety and environmental impact showed awareness of and concern for these aspects of weather modification. In most activities, the consequences of the operations or experiments were carefully considered and steps taken to minimize the hazard to people, property, and environment.

REFERENCES

- Charak, M. T. and DiGiulian, M. T., Weather Modification Activity Reports - November 1, 1972, to December 31, 1973, National Oceanic and Atmospheric Administration, Rockville, Md., March 1974, 38 pp. —

APPENDIX A. List of Reported Activities

Weather Modification Activity Reports for CY 1974

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target amount (ml)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
73-002	Irving P. Krick, Inc. of Texas 611 South Palm Whittaker City Hall Pasadena, CA 92262	City of Lawton c/o Mayor Dan Whittaker City Hall Lawton, OK 73501	Precipitation increase 11/1/72-11/3/75	11/72-	Lakes Lawtonka and Ellsworth, OK	400	Ground- based dispensers	Arc-type burners	AgI	0.5
73-003	"	Okla. State U. Stillwater, OK 74074	Precipitation increase 11/1/72-5/15/77	11/72-8/15/74	Lake Blackwell, OK	225	"	"	"	"
73-010	North American Weather Consultants Suite 100 Municipal Airport Goleta, CA 93017	S. California Edison Co. c/o Box 800 Redwood, CA 91770	Precipitation increase 11/1/72-	11/72-	Upper San Joaquin River, CA	1,200	"	Propane generators (12) (AGNH ₄ I)	"	6
73-014	L.A. County Flood Control District P.O. Box 2418 Terminal Annex Los Angeles, CA 90051	L.A. County Flood Control District P.O. Box 2418 Terminal Annex Los Angeles, CA 90051	Precipitation increase 12/5/72- continuing	12/72-	Areas N. of Pasadena and Glendora, CA	407	"	Propane burners (16)	"	135 6 at each generator
73-015	Johnson Flying Service P.O. Box 1366 Missoula, MT 59801	Northwest Airlines Johnson-Bell Aircraft Missoula, MT 59801	Cold fog dispersal 11/1/73 continuing	10/72-	Missoula County Airport, MT	5	Aircraft dispensers	Dispensed by hand from tray mounted on aircraft floor	CO ₂ (dry ice)	107,144

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
73-017	Pacific Gas and Electric Co. 245 Market St. San Francisco, CA 94106	Pacific Gas and Electric Co. 77 Beale St. San Francisco, CA 94106	Snowpack increase 11/1/74 continuing	11/1/72-5/1/74	Lake Almanor, CA	500	Ground-based dispensers	Generators (8)	AgI	25
73-029	Atmospherics, Inc. 3532 East Dayton Fresno, CA 93727	Kings River Conservation District 4886 East Jensen Fresno, CA 93727	Rainfall and snowpack increase 10/1/73 continuing	11/1/72-	East of Fresno, CA	1,600	Aircraft dispensers (1) and ground-based generators (15)	Pyrotechnics and liquid fuel generators	AgI smoke particles	14 to 240
73-051	Irving P. Krick, Inc. 611 South Palm Canyon Drive Suite 216 Palm Springs, CA 92262	Carter, Murray, Johnston, Love & Johnson Counties c/o Robert T. Scott 926 SW Manor Hall Ardmore, OK 73401	Precipitation increase 8/15/73-12/31/74	8/15/73-8/14/74	Carter, Murray, Johnston, Love and Jefferson Counties, OK	3,172	Ground-based dispensers	Arc-type burners	AgI	0.5
73-053	Sacramento Municipal Utility District 6201 South St. Sacramento, CA 95813	Sacramento Municipal Utility District 6201 South St. Sacramento, CA 95813	Snowpack increase 10/15/73-5/15/74	11/1/73-5/1/74	SW. of Lake Tahoe, CA	236	"	Propane burners (6)	AgI suspended in mixture of NH ₄ I and acetone	25
73-054 (Con.) 73-001	Aero-Ryne Corp. 300-400 Airport Blvd. Renton, WA 98055	Port of Seattle Seattle-Tacoma International Airport Seattle, WA	Worm fog dispersal 10/1/73-3/29/74	10/73-Completed	Seattle-Tacoma Airport Runways, WA	Less than 1	Aircraft dispensers and blowers	Metered hoppers and blowers	Polyelectrolyte	136,200

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
74-055 (Con. of 73-019)	U. of Wyoming Dept. of Atmospheric Resources P.O. Box 3038 Univ. Station Laramie, WY 82070	Eden Farson Irrigation District Farson, WY 82932	Precipitation Increase 12/1/73-4/15/74	12/19/73-4/2/74	Big Sandy River Drainage, WY	180	Ground-based dispensers	Propane dispensers	Agl-NH ₄	10-15
74-056	Capital Flying Service, Inc. Boise Municipal Airport 3033 Airport Way Boise, ID 83705	Boise Municipal Airport 3000 Airport Way Boise, ID 83705	Disperse super-cooled fog 11/10/73-4/1/74	Final report states no modification conducted	Boise Air Terminal, ID	2	Aircraft dispensers	Dispensing funnel	Dry Ice	56,750
74-057 (Con. of 73-018)	Interwest Aviation Inc. AMF53 Salt Lake International Airport Salt Lake City, UT 84101	United, Western, American, Frontier, Texas International, and Hughes Air Lines Salt Lake City, UT International Airport Salt Lake City, UT 84101	Cold fog dispersal (approx.) 11/20/73-3/21/74	1/74-2/28/74	International Airport, Salt Lake City, UT	10 (approx.)	Aircraft dispensers	Modified spreader	Dry Ice	8,173 to 11,350 g/2 min. run
74-058	Executive Air Corporation P.O. Box 19187 Spokane, WA 99219	Spokane Airports Board P.O. Box 19186 Spokane, WA 99219	Cold/warm fog dispersal 11/8/73-4/15/74	10/1/73-4/15/74	Spokane International Airport, WA	4.7	"	Dispensing hopper	Dry Ice and Skyllite polyelec-trolyte	22,700 g/min. 907 g/min.

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
#74-059 (Con. of 73-021)	Logan and Reavis Air, Inc. Airport Road Medford, OR 97501	Air West and United Airlines c/o United Airlines P.O. Box 66100 Chicago, IL 60666	Cold fog dispersal 11/19/73-2/28/74	10/1/73-2/28/74	Medford-Jackson County Airport, OR	1	" (2)	Suction tube	Dry Ice	45,400
#74-060 (Con. of 73-023)	Santa Clara County Flood Control of Water District 5750 Almaden Expressway San Jose, CA 95118	Santa Clara County Flood Control Water District 5750 Almaden Expressway San Jose, CA 95118	Belief in increase 11/17/73-4/74	10/15/73-4/15/74	Part of Santa Clara County, CA	700	Ground-based dispenser	Generators	Silver Iodide	25
74-061F	ES&G, Inc. Environmental Services Operation P.O. Box 58 Durango, CO 81301	Bureau of Reclamation Bldg. 67 Denver Federal Center Denver, CO 80225	Weather modification research and precipitation increase 11/22/73-5/15/74	11/73-5/74	SE San Juan Mountains, CO	1,300	"	Generators (15 remote-ly and 20 manually operated and 1.25% ator controlled)	Acetone solution of AgI generator	20 to 140 g/min.
#74-062	Des Moines Flying Service, Inc. Municipal Airport Des Moines, IA 50315	United Airlines P.O. Box 8800 O'Hare International Airport Chicago, IL 60666	Cold fog dispersal continuing		Epley Field Omaha, NE	2	Aircraft dispensers	Electric reverse supercharger dispenser equipped w/ a 100-lb capacity hopper	Dry Ice	22,700 g/min.
#74-063	"	"	"	"	Des Moines Municipal Airport Des Moines, IA	"	"	"	"	"

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
*74-064	"	"	"	"	Cedar Rapids Municipal Airport Cedar Rapids, IA	"	"	"	"	"
*74-065	"	"	"	"	Quad-City Airport, Moline, IL	"	"	"	"	"
*74-066	Aviation Service, Inc. c/o Norman R. Sahm 1880 Genesee Reno, NV 89502	City of Reno Reno International Airport Reno, NV 89502	Gold fog dispersal 12/10/73 "Unknown"		Reno International Airport Reno, NV	4 - 6	"	Ice crusher ejects to airstream	"	Estimate 400,000
*74-067	North American Weather Consultants Santa Barbara Municipal Airport Goleta, CA 93017	Southern Utah Water Development Corp. Centerfield, UT 84622	Rainfall Increase 1/1/74-5/30/74	1/1/74-4/30/74	Beaver, Emery, Garfield, Iron, Juab, Kane, Millard, Plute, Sanpete, Sevier, Wasatch-Cache National Forest Wayne Counties In SW, UT	40,000	Ground-based dispensers	Propane generators	AgI	6
*74-068F	"	Bonneville Power Administration P.O. Box 382 Portland, OR 97208	Precipitation Increase 1/1/74-4/30/74	Not initiated	South Fork of Flathead River above Hungry Horse Dam, MT	1,654	"	"	"	"

* A report number beginning with 74 indicates an activity reported after November 1, 1973

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Start of CY 1974	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
74-069	Pacific Gas and Electric Co. 245 Market St. San Francisco, CA 94106		Pacific Gas and Electric Co. 775 Market St. San Francisco, CA 94106	Snowpack increase 2/1/74	2/12/74-3/12/74	Central Sierra Nevada Mountains, CA	250	Ground-buried dispensers	Propane- acetone silver iodide generator and sodium iodide generators (3)	AgI	25
74-070 (Con. of 73-006)	Irving P. Krick, Inc. of Texas 611 South Palm Canyon Dr. Suite 216 Palm Springs, CA 92262		Cotton County Service, Inc. c/o James W. Kinder, Sr., President Route 1 Randlett, OK 73562	Precipitation increase 1/1/74	1/1/74-11/15/74	Cotton County, OK	629	"	Arc-type burners	"	0.5
74-071 (Con. of 73-027)	"		Henry C. Hitch Ranch, Inc. Henry C. Hitch, Jr. P.O. Box 308 Guyton, OK 73942	Precipitation increase 3/15/74-10/15/74	3/15/74-10/15/74	South Central Texas County, OK	90 (approx.)	"	"	"	"
74-072F	North American Weather Consultants Santa Barbara Municipal Airport Goleta, CA 93017		Naval Weapons Center China Lake, CA 93555	Testing of cloud seeding generators and weather modification techniques 11/1/73-4/30/74	11/1/73-4/30/74	Extreme South San Luis Obispo Co. and Santa Barbara Co., CA	2,800	" and aircraft dispensers	Proto-type burner	Ag(NH ₄)I-acetone solution	Ground: 5.8 g/min. Air: 11.7 g/min.

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
74-073 Plains Weather Improvement (Cont.) U.S. Weather Bureau 73-032 P.O. Box 1627 Plainview, TX 79072	Plains Weather Improvement Assoc., Inc. P.O. Box 1627 Plainview, TX 79072	Plains Weather Improvement Assoc., Inc. P.O. Box 1627 Plainview, TX 79072	Hail decrease 4/1/74-11/30/74	4/1/74-11/30/74	Texas high-plains, TX	1,200	Aircraft dispensers	End burning Agl flares mounted on wing racks		17 to 50 g/min.
74-074F Dept. of Atmospheric Sciences U. of Washington AK-40 Seattle, WA 98195	Div. of Atmospheric Sciences Bureau of Reclamation Denver, CO 80225	Study of precipitation in winter cyclonic storms over the Cascade Mountains 11/1/73-2/74	10/73-2/74	150	Snoqualmie Pass, WA	(1)	End burning flares, ejection nozzles, and dry ice dispenser			8 g/min. 10 g/5 min. 2,000 g/hr.
74-075F National Oceanic and Atmospheric Administration 325 Broadway Boulder, CO 80302	Atmospheric Chemistry and Physics Lab. National Oceanic and Atmospheric Administration 325 Broadway Boulder, CO 80302	Investigate feasibility of lightning suppression through chaff seeding 11/1/73-9/78	250 mile radius of Broomfield, CO	200,000			Chaff dispenser	Aluminized nylon chaff dispenser 2 or 3 passes 1 mil in diameter along a 10 cm long track & 1,000 g dispensed in each pass 10,000 g = approx. 10.8 million fibers)		

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
74-076 (Con. of 73-044)	Edward W. Peil 3110 Stanton Ave. P.O. Box 104 Ottsville, PA 19462	Oranur Research Laboratories Ottsville, PA 18942	Removal of "deadly organic radiation" 4/1/74-10/31/74	5/5/74-9/7/74	Lawrence, Long Island, NY	Indeterminate	"Cloud-buster"	10 aluminum tubes and 10 lengths of cables connecting tubes to pool of water	-	-
74-077	Richard A. Blasband Red Hill Road Box 104 Ottsville, PA 18942	Richard A. Blasband Red Hill Road Box 104 Ottsville, PA 18942	Pollution dispersal and removal of "radioactive radiation" 4/20/74-10/30/74		Bucks County, PA	200	"	10' to 18', 1" diameter aluminum tubes grounded to well or stream by Greenfield cables	-	-
74-078 (Con. of 73-028)	Atmospherics, Inc. 5652 East Dayton of "Fresno, CA 93727	Better Weather, Inc. c/o Dale Stanley Route 1 Littlefield, TX 79339	Hail decrease and rainfall increase 5/1/74-10/30/74	5/1/74-10/31/74	Lamb County, TX and adjacent counties	1,200	Aircraft dispensers (3)	Pyrotechnics and fuel generators using Ag/NE ₄ /acetone solution	AgI	120 g/hr 600
74-079 (Con. of 73-031)	"	Colorado River Municipal Water District P. O. Box 869 Big Spring, TX 75620	Rainfall increase 4/15/74-10/15/74	4/15/74-10/15/74	Howard and adjacent counties around Big Spring, TX	3,500	" (1)	Pyrotechnics	"	120 g/hr 600

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (lb/hr/unit)
74-080 (Con. of 73-034)	Atmospherics, Inc. (Con. 6552 Elm Street, Fresno, CA 93727	State of South Dakota Div. of Weather Modification Dept. of Natural Resources Development Pierre, SD 57501	Hail decrease and rainfall increase 5/1/74-8/31/74	10/1/73-8/31/74	SE. SD	9,000	Aircraft dispensers (4)	Pyrotechnics and liquid fuel generators using acetone, 40% acetone solution	AgI	
74-081 (Con. of 73-035)	"	"	"	10/1/73-9/30/74	South Central SD	7,500	" (3)	"	"	
74-082 (Con. of 73-036)	"	"	"	10/1/73-9/30/74	North Central SD	7,000	" (3)	"	"	
74-083 (Con. of 73-040)	Metrodata Systems, Inc. P. O. Box 1397 Norman, OK 73069	State of South Dakota Div. of Weather Modification Office Building #2 Pierre, SD 57501	Hail decrease and rainfall increase 4/15/74-8/31/74	4/15/74-9/1/74	SW. SD (Rapid City area)	5,136	" (2)	Ammonium iodide-acetone burners Pyrotechnic flares	2 1/2 solution of AgI AgI	2.5 gal/hr. 190, 100, 40 or 20 g. flares, each to be burned in 30 sec. to 1 min. 10 gm/min.

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
74-084 (Con. of 73-041)	Edwin I. Boyd 211 Ray Ann Ct. Rapid City, SD 57701	Walter Yuly, Chairman Board of Directors Ward County Weather Modification Authority 417 NW 25 Minot, ND 58701	Hail decrease and rainfall increase 5/15/74-8/31/74	6/1/74-8/31/74	McKenzie, Mountrail, and Ward Counties, ND	6,600	Aircraft dispensers (4)	Generators	AgI In acetone solution with ammonium iodide	For rain: 10 to 20g for hail: 380g per aircraft
74-085	Atmospherics, Inc. 5652 East Dayton Fresno, CA 93727	Kansas Water Resources Board 109 West 9th St. 4th Floor Mills Building Topeka, KA	Rainfall increase 4/25/74-6/30/74	10/1/73-9/30/74	60 mi radius of Scott City, KA	3,000	" (2)	Pyrotechnics mounted on wing racks	AgI	2g/min.
74-086 (Con. of 73-037)	Weather Modification, Inc. 301 1st St. West Bowman, ND 58623	Kenneth Rajewski Bowman, ND 58623 County Weather Modification Authority	Hail decrease and rainfall increase 5/1/74-8/1/74	4/1/74-8/31/74	Adams, Bowen, Hettinger, and Slope Counties, ND	4,800	"	300 lb. capacity hygroscopic nuclei container mounted over a motor driven auger device	NaCl	32,320-72,640 g/min.
74-087 (Partially completed 73-043)	"	Jack Adams Central Dakota Weather Modification Assn., Steele, ND	"	4/15/74-8/19/74	Burlington, Wadena, and N. Emmons Counties, ND	625	"	2 liquid acetone generators mounted on aircraft (4)	AgI	681

Weather Modification Activity Reports for CY 1974. (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
74-088 (Con. of 73-038)	Weather Modification, Inc. 301 1st St. West Bowman, ND 58623	Ray Zittleman Secretary, County Weather Modification Association Farmers and Merchants Bank Valley City, ND	Hail decrease and rainfall increase 5/1/74-8/1/74	5/1/74-8/25/74	Barnes, Eddy, Foster, Griggs, E. Kidder, Nelson, Steele, Stutsman, and Wells Counties, ND	9,000	Aircraft dispensers	2 liquid acetone dispensers per aircraft (5) 12-mount flare racks on 2 aircraft	AgI	681 2,400
74-089 (Con. of 73-038)	"	South Dakota Weather Modification Commission State Office Building, #1 Pierre, SD 57501	"	5/1/74-8/23/74	Carson, Harding, and Perkins Counties, SD	6,000	"	"	"	"
74-090 (Con. of 73-038)	"	"	"	5/1/74-8/28/74	Beadle, Brookings, E. Brown, Clark, Day, Codington, Hamlin, Marshall, Roberts, and S. and E. Spink Counties, SD	8,500	"	"	"	"
74-091 (Con. of 73-004)	Irving P. Krick, Inc. of Texas 611 South Palm Canyon Drive Suite 216 Palm Springs, CA 92262	Harper County Weather Modification, Inc. P.O. Box 44 Buffalo, OK 73834	Precipitation increase 4/15/74-10/15/75		Harper County, OK	1,034	Ground-based dispensers	Arc-type generators	AgI	0.5 or 2

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit) or
74-092 (Con. of 73-026)	Irving P. Krick, Inc. of Texas 611 South Palm Canyon Drive Suite 216 Palm Springs, CA 92262	Woodward County Cloudseeding Assoc. 10000 Highway 100 Sharon, OK 73857	Precipitation increase 4/15/74-10/15/75		Woodward County, OK	1,235	Ground-based dispensers	Arc-type generators	AgI	0.5 or 2
74-093 (Con. of 73-025)	"	Ellis County Weather, Inc. Harmon, OK 73845	"		Ellis County, OK	1,222	"	"	"	"
74-094 (Con. of 73-005)	"	Beaver County Weather, Inc. Knowles, OK 73847	Precipitation increase 4/15/74-10/15/74	4/15/74-10/15/74	Beaver County, OK	1,793	"	"	"	"
74-095 (Con. of 73-008)	"	Washita County Weather Modification Assoc. P.O. Box 344 Cordell, OK 73632	Precipitation increase 4/15/74-10/15/75	4/25/74-6/13/74	Washita County, OK	1,009	"	"	"	"
74-096 (Con. of 73-024)	"	Kiowa County Weather Modification Assoc. 523 North Broadway Hobart, OK 73651	"		Kiowa County, OK	1,032	"	"	"	"

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
74-097F	Alaskan Air Command U. S. Air Force Fairchild AFB Elmendorf AFB Anchorage, AK 99506	Alaskan Air Command U. S. Air Force Fairchild AFB Elmendorf AFB Anchorage, AK 99506	Supercooled fog dispersal 11/1/73-3/31/74	11/1/73-3/15/74	Elmendorf AFB, AK runway complex	2	Airborne dispensers	Ice crusher propane tank with discharge chute	Dry Ice	820 Kg (Est.)
74-098F	92nd Bombardment Wing (SAC) U. S. Air Force Fairchild AFB Spokane, WA 99011	Det 3, 3 Wg (MAC) U. S. Air Force Fairchild AFB Spokane, WA 99011	Cold fog dispersal 11/1/73-3/15/74	11/1/73-3/15/74	Fairchild AFB, WA	5	" (23)	Ground-based dispensers (19) 1,000 gal. propane tank with 20 ft. mast 500 gal. propane tank with 20 ft. mast	Propane "	10 gal/hr. (approx.) "
74-099	Ronald H. Campbell Sublett Route Malta, ID 83342	Black Pine Precipitation Management Group c/o Ronald Campbell Sublett Route Malta, ID 83342	Hail decrease and rainfall increase 6/5/74-9/31/74	6/5/74-9/31/74	Juniper and Black Pine, ID	162	Aircraft dispensers	Pyrotechnic flares	AgI Dry Ice Urea Liquid Anhydrous Ammonia Propane	180 20kg. 500kg. 20kg. 20kg.
74-100F	Geoffrey Hill Utah Water Research Laboratory Utah State University Logan, UT 84321	Dr. Archie Kahan Department of the Interior Bureau of Reclamation Bldg. 67 Denver Federal Center Denver, CO 80225	Precipitation management techniques 11/27/73-3/1/74	10/1/73-4/30/74	N. Wasatch, east of Logan, UT	1,500	Ground-based dispensers	Particle generator	Hexadecanol	5kg.
							"	Model 300 units (3)	23 AgI In acetone precipitation with H ₂ O and NaOH ₄	25

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
74-101F (Con. of 73-026)	Patrick Squires Desert Research Institute SAGE Building Stead Campus University of Nevada Reno, NV 89507	Dr. Archie Kahan Department of the Interior Bureau of Reclamation Bldg. 67 Denver Federal Center Denver, CO 80225	Precipitation Increase research 10/16/72-5/15/75		Lake Tahoe and Truckee River Water- shed, NV	1,500	Ground- based dispensers	2 USBR propane generators or iso- propylamine solution	AgI in acetone or iso- propylamine solution	42.6
74-102 (Con. of 73-026)	Irving P. Krick, Inc. of Texas 611 South Palm Canyon Drive Suite 216 Palm Springs, CA 92262	Woodward County Cloudseeding Assoc. Sharon, OK 73857	Precipitation Increase 6/15/74-10/15/74	6/15/74-10/15/74	Western Woods Co., OK	450 (approx.)	"	Arct-type generators	AgI	0.5 or 2.0
74-103	Aviation Services, Inc. 2105-5th St., N.W. Minot, ND 58701	Nelson County Weather Authority c/o James Vasilcdek Michigan, ND 58701	Hail decrease and rainfall increase 6/1/74-8/31/74	6/1/74-9/15/74	East Central ND	1,080	Aircraft dispenser (1)	Lchse ace- tone gen- erators (2)	22 AgI/ NH ₄ I in each acetone ator	123.47 in each gener- ator
74-104 (Con. of 73-046)	Irving P. Krick, Inc. of Texas 611 South Palm Canyon Drive Suite 216 Palm Springs, CA 92262	Griatol County Weather Modifi- cation, LTD c/o John R. Mac- County Courthouse Ithaca, MI 48847	Precipitation Increase 6/15/74-9/1/74	7/1/74-9/3/74	Most of Griatol Co., MI	530	Ground- based dispensers	Pyrotech- nic fusee holders (24 holders)	TB-1 TB-2	1,008 25
								Arct-type generators	AgI	0.5 or 2.0

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit) or
74-105	Irving P. Krick, Inc. of Texas 611 South Palm Canyon Drive Suite 216 Pasadena Springs, CA 92362	M-Card, Inc. c/o James Crosby 617 N. State Rd. Stanton, MI 48888	Precipitation Increase 6/15/74-9/1/74	6/15/74-9/3/74	Montcalm Co. and part of Kent Co., MI	856	Ground-based dispensers	Arc-type generators	AgI	0.5 or 2.0
74-106	"	South Central Michigan Weather Modification, Inc. c/o Ted Landis 16300 - 13 Mile Rd. Battle Creek, MI 49017	"	6/15/74-9/13/74	Most of Calhoun City, and part of Jackson City, MI	817	"	"	"	"
74-107	"	Michigan Weather, Inc. c/o Warren Wooden R 5 Brownsville St. Cassopolis, MI 49031	"	6/15/74-9/13/74	Cass County, part of Berrien Co., MI, and part of Elkhart, Co., IN	764	"	"	"	"
74-108	"	Rain Seekers, Inc. c/o Roger Carr RTE #2 Burr Oak, MI 49030	"	6/15/74-9/13/74	St.-Joseph City and parts of Berrien and Kalamazoo City, MI	688	"	"	"	"
74-109	"	I-Card, Inc. c/o Lyle Thompson Corp. Extension Rte. 1 Isabella City Bldg. Mt. Pleasant, MI 48858	"	6/15/74-9/3/74	South half of Isabella Co., MI	288	"	"	"	"

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
74-110	Irving P. Krick, Inc. of Texas 611 South Palm Canyon Drive Suite 216 Palm Springs, CA 92262	Weather Modification Assoc. of Branch Co., MI c/o Ramus Rigg R.R. #1 Coldwater, MI 49036	Precipitation increase 6/15/74-9/1/74	6/15/74-9/13/74	Branch Co., MI	506	Ground-based dispensers	Arc-type generators	AgI	0.5 2.0
74-111	"	Barry Weather, Inc. c/o Arthur Steeby-301 S. Michigan Ave. Hastings, MI 49058	"	6/15/74-9/12/74	Barry County and part of Kalamazoo Co., MI	585	"	"	"	"
74-112	"	Adams County Weather Modification Corp. c/o Donald Drennan Mt. Etna Star Rt. Corning, IA 50841	" 7/10/74-9/30/74	7/1/74-9/30/74	Adams County, IA	426	"	"	"	0.5
74-113F	National Mail Research Experiment National Center for Atmospheric Research 1850 Table Mesa Dr. Boulder, CO 80302	National Science Foundation 1800 G Street Washington, D.C. 20550	Mail suppression research 11/1/75-9/76		NW of Sterling, CO	600	Aircraft dispensers	flare racks & rocket launchers	"	100g/90 sec./unit

A-16

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (lb/hr/unit)
74-114 (Con. 74-057)	Harlon W. Benent Interwest Aviation 3063 East Millcreek Rd., Salt Lake City, Utah 84109	WAL-UAL-Frontier- Texas Int.-AM- Hughes AM Airlines Salt Lake Internat. Airport, Salt Lake City, Utah 84122	Cold Fog Dispersion 11/17/74-3/31/75		International Airport Salt Lake City, Utah	10	Aircraft Dispensed	Spreader	Dry Ice	272 Kg (Est.)
75-115 (Con. 73-013 and 73-053)	Sacramento Municipal Utility District (SMUD) 6201 S Street Box 15830 Sacramento, CA 95813	SMUD	Snow Pack Increase 10/15/74-5/15/75		Lake Areas SW of Lake Tahoe, CA	236	Ground- Based Burners Dispensers	Propane Burners (6)	AgI	25 at each Burner
75-116	Daniel Beck 211 N. Glenhurst Birmingham, MI 48009	Daniel Beck 211 N. Glenhurst Birmingham, MI 48009	Weather Modifi- cation Research 6/24/74-7/7/74	6/24/74-7/7/74	Pontiac- Oakland County, MI	861	Ground- Based	2 Steel Pipes Connected to Water	-	-
75-117	AEROMET, Inc. Box 47 Norman, OK 73069	Porter County Farm Bureau Cooperative, Valparaiso, IND 46383	8/11/74-8/13/74 Increase rain	8/12/74-8/13/74	Porter and Lake Counties, IND.	1225	Aircraft Dispensed	Very Pistols, 40 gm Cartridges	AgI	
75-118 (Con. 75-119)	Alaska Air Service, Inc., P.O. Box 4-469 Anchorage, AK 99505	Air Facilitation Committee P.O. Box 6027 Anchorage, AK 99502	Cold Fog Dispersion 11/17/74-3/15/75		Runway Com- plex Anchorage International Airport, AK	1	Aircraft Dispensed	Chuze In A/c	Dry Ice	545 kg (Est.)

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
75-119	Reeve Aleutian Airways, Inc. P.O. Box 6027 Anchorage, AK 99502	Air Facilitation Committee P.O. Box 6027 Anchorage, AK 99502	Cold Fog Dispersal 10/15/73-3/15/74	10/15/73-3/15/74	Runway Complex Anchorage International Airport, AK	1	Aircraft Dispensed	Chute in A/C	Dry Ice	545 Kg (Est.)
75-120	Logan and-Reavis (Con.) Alf. Inc. Airport Road Medford, OR 97501	Air West and United Airlines c/o United Airlines P.O. Box 66110 Chicago, ILL. 60666	Cold Fog Dispersal 11/1/74-2/28/75	11/1/74-2/28/75	Medford-Jackson County Airport, OR	1	Aircraft Dispensed	Suction Tube	Dry Ice	45.4 Kg
75-121	11th Weather Sq. F. Air Weather Service (Con.) Elmendorf AFB of Anchorage, AK 74-097 99506	Alaskan Air Command U.S. Air Force, XP Elmendorf AFB Anchorage, AK 99506	Cold Fog Dispersal 11/1/74-3/31/75		Elmendorf AFB Runway Complex, AK	50	Airborne Dispensers	Ice Crusher and Discharge Chute	Dry Ice	820 Kg (Est.)
75-122	11th Weather Sq. F. Air Weather Service (Con.) Elmendorf AFB of Anchorage, AK 79-097 99506	21st Composite Wing U.S. Air Force Elmendorf AFB Anchorage, AK 99506	Cold Fog Dispersal 11/1/74-3/31/75		Elmendorf AFB Runway Complex, AK	50	Ground-Based Dispensers (19)	Tank, Mast Nozzle	Propane	10 gal/hr. (Approx)
75-123	Det. 3. 3 Wd Weather Service (Con.) Fairchild AFB of Spokane, WA 74-098 99011	92 Bombardment Wg. U.S. Air Force Fairchild AFB Spokane, WA 99011	Cold Fog Dispersal 11/1/74-3/31/75		Fairchild AFB, Runways, WA	50	Ground-Based Dispensers (23)	Tank Mast Nozzle	Propane	10 gal/hr. (Approx)

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Asent	Dispensing rate (g/hr/unit)
75-124 (Con. of 74-055)	U. of Wyoming Resources P.O. Box 3038 Laramie, WY 82070	Eden Farnon Irrigation District of Farnon, WY 82531	Snow Increase 12/1/74-4/15/75		Big Sandy River Drainage, WY	180	Ground-Based Dispensers	Propane Dispensers	AgI-NH ₄	10-15
75-125 (Con. of 73-054)	Aero-Dyne Corp. 200 Airport Way, Renton, WA 98055	Port of Seattle Seattle-Tacoma Airport Seattle, WA 98188	Warm Fog Dispersal 10/1/74-2/28/75		Seattle-Tacoma Airport, WA	1	Aircraft Dispensers	Metered Hopper & Blower	Poly-electrolyte (Est.)	300 kg
75-126 (Con. of 74-067)	North American Weather Consultants, Santa Barbara Municipal Airport Goleta, CA 93017	South Utah Water Development Corp. Centerfield, UT 84622	Rainfall Increase 12/1/74-4/30/75		Southwest Utah	40,000	Ground-Based	Propane Generators	AgI	6
75-127F (Con. of 74-061)	ES&G, Inc. P.O. Box 58 Durango, CO 81301 (Con. of 74-061F)	Bureau of Reclamation Building 67 Denver Federal Center, Denver, CO 80225	Research and Precipitation Increase 11/6/74-5/16/75		Southeast San Juan Mountains CO	1,300	Ground-Based	Generators (15 Remotely Controlled, 20 Manual)	AgI	20 to 140 each generator
75-128 (Con. of 73-017)	Pacific Gas and Electric Company 245 Market Street San Francisco, CA 94106	Pacific Gas and Electric Company 77 Beale Street San Francisco, CA 94106	Snowpack Increase 11/1/74-5/31/75		Lake Almanor, Nevada Mountains CA	500	Ground-Based	Propane-Acetone Generators (8)	AgI	25
75-129 (Con. of 74-069)	Pacific Gas and Electric Company 245 Market Street San Francisco, CA 94106	Pacific Gas and Electric Company 77 Beale Street San Francisco, CA 94106	Snowpack Increase 11/1/74-5/31/75		Central Sierra Nevada Mountains (Hokelumme) CA	250	Ground-Based	Propane-Acetone Generators (3)	AgI	25

Weather Modification Activity Reports for CY 1974 (Cont.)

Report	Operator and address	Sponsor and address	Purpose and proposed operation dates	Actual operation dates	Target location	Target area (mi ²)	Technique	Apparatus	Agent	Dispensing rate (g/hr/unit)
75-130	Atmospherics, Inc. 5652 East Dayton Fresno, CA 93727	Puerto Rico Aqueduct and Sewer Authority P.O. Box 7066 Obrillo Station San Juan, PR 00916	Rainfall increase 8/8/74-9/10/74	8/8/74-9/1/74	20 mi. South- east of San Juan	207	Aircraft	Pyrotechnics	AgI	2.5 to 500
75-131	North American Weather Consult- ants, Santa Barbara Municipal Airport Goleta, CA 93017	Portland General Electric Company 621 South West Adler, Portland OR 97205	Precipitation increase 12/16/74-3/30/75		Deschutes River, Oregon	7,820	Ground- Based	Propane Generators	AgI	6
75-132	Colorado Inter- national Co. P.O. Box 3007 Boulder, CO 80303	Teton Village Resort Assoc. Teton Village, WY 83025	Snow Augmentation 12/5/74-12/23/74	12/5/74-11/12/74	Jackson Hole Ski Area, WY	16	Ground- Based Aircraft	Flares on Mast Flare (Very Gun)	AgI	275 275
75-134 (Con. of 74-058)	Executive Air Corp. P.O. Box 19187 Spokane, WA 99187	Northwest Orient Airlines Spokane Inter- national Airport Spokane, WA 99219	Warm/Cold fog dispersal 10/15/74-4/15/75		Spokane Airport Runway, WA	4.5	Aircraft	Dispensing Hopper	CO ₂ , Poly- electro- lyte	136 kg/hr, 54 kg/hr

Senator PEARSON. We would be pleased to have that.

Dr. WHITE. NOAA is the central weather agency of the Federal Government. As such, it carries out broad programs of research and development on atmospheric phenomena pertinent to our ability to modify the weather by artificial means.

Our weather and climatological services are deeply concerned with the problem of drought. We keep abreast of all weather conditions throughout the United States, and issue forecasts of expected monthly and seasonal changes in the weather in addition to our daily weather forecasts.

Let me turn then to the question of drought and the possibilities of its alleviation through modification of weather processes.

First, we need to recognize that drought is brought about by weather phenomena that occur on a continental or a global scale. In order to break a drought, it would be necessary to modify weather conditions on a scale so large as to be beyond any present scientific or technical capability. We must therefore acknowledge that anything that we might do through the application of present weather modification techniques can only offer hope of modest amelioration.

Droughts are desperate situations. They inevitably evoke last-ditch measures, and given the present status of science and technology, weather modification must be regarded as a last-ditch measure.

I am not saying that such last-ditch measures should not be used. This is a decision that must be taken in the light of the actual drought situation in which we find ourselves.

However, whatever we do, should be done in full recognition of the present capabilities of weather modification science and technology. We must not generate expectations which cannot be met.

Having said this, let me address the three bills before us. First, let us consider the proposal for a Commission outlined in S. 2705. I am sympathetic to the idea that we ought to take a broad view of how this Nation should proceed to organize and support its efforts in weather modification.

I must, however, ask the question as to whether there have not been enough studies of what the Nation should do in this field. Such studies go back more than 20 years. Recent reviews of what the Nation should do in weather modification have been conducted by the National Academy of Sciences, the National Advisory Committee on Oceans and Atmosphere, and by the Government Accounting Office.

A Domestic Council subcommittee of which I was chairman has recently completed a comprehensive review of the status of weather modification and has examined the role of the Federal Government in this activity. This report is now being reviewed by the Domestic Council and the Office of Management and Budget.

I believe that we have had more than enough studies. I believe that serious consideration needs to be given as to whether another study is required at this time.

S. 2706 suggests some interesting and promising approaches. It seems to address many of the recommendations that have been made both by the National Academy of Sciences and by the National Advisory Committee on Oceans and Atmosphere.

It proposes a long-term and sustained experimental effort to define conditions under which drought alleviation is possible. It recognizes that this is not an easy task and one that should not be undertaken lightly.

If we are ever to place weather modification on a sound basis, as a management option for use in drought situations, the only way we can get there from here is a recognition of a need for a sustained experimental effort. Such an experimental effort, designed in accordance with our best scientific knowledge, monitored and evaluated so that we know the true consequences of our action, is both feasible and desirable, considering the benefits that would accrue if successful.

My views on S. 2707 are based on my assessment of our present operational weather modification capabilities. What do we know about our ability to increase rainfall by weather modification?

Precipitation enhancement has been a subject of much research in the last 30 years. We have demonstrated that clouds can be modified by seeding.

In some wintertime situations, especially over mountains, local increases in precipitation have been proven. Summertime conditions have been less amenable to conclusive studies.

In any event, it is known that cloud seeding can both increase and decrease precipitation under certain conditions. But clouds must be present to use existing techniques.

In fact, cloud seeding will work best when some rain or snow is occurring naturally. Thus, droughts are not the most suitable times for rainmaking.

There is evidence that precipitation might be enhanced on some days by a factor of two or three. For a whole season most estimates of potential augmented precipitation fall in the 5 to 15 percent range.

However, there is very little research or experience in cloud seeding during droughts. Based on hard facts available, we know we cannot end the droughts in this way.

We also recognize that we cannot give positive assurance that there would not be less rain resulting from seeding. Still, on balance, the results so far appear to favor the odds that rain increases are more likely than decreases.

The thrust of S. 2707 is to provide financial grants to States for carrying out operational weather modification programs to alleviate drought. Provided that its limited potential and uncertainty in attempting to alleviate drought by operational cloud seeding are fully understood, I could regard a decision by a State to engage in operational weather modification as a rational policy in a period of enormous stress and pressure.

I would urge, however, that a State decision to engage in seeding operations to alleviate a drought should be determined principally by the technical and scientific feasibility in a given situation and not by the availability of Federal funds.

It should be noted that the granting provisions in this bill would be contrary to the position of the administration on the establishment of Federal categorical grant programs.

The administration cannot support enactment of any of the bills now before this committee, partly because of the reservations I have expressed and also because it has under consideration some of

the issues involved. Meanwhile, the ongoing programs within the Department of the Interior, the Department of Commerce, and the National Science Foundation in weather modification can go a long way toward achieving the objectives of these bills.

Let me close by indicating that I attach great importance to the development of our understanding of the extent to which weather modification techniques can assist us in dealing with weather-related disasters.

We have an opportunity and we should do something about it. I believe, however, it should be done in a way that is scientifically sound, and offers the best hope of achieving lasting and useful results.

Thank you.

Senator PEARSON. Dr. White, I agree with you to the extent that we have got so many studies and Commissions here, and most of the reports are gathering dust on some shelf.

But, let me ask you this, and you can respond in writing at a later date as to particularity. But do we now have studies that give us the answer at this point as to the need for regulation of weather modification?

Do we have studies that tell us the extent of coordination among the agencies and where the responsibility lies?

Do we have information as to the status of the current state-of-the-art or the technology, because as I understand the Senator's bill, that is what he is trying to find out through the creation of another Commission.

If we have already got it, then there is no sense in going through it again. But, respond generally.

Dr. WHITE. Such studies have been undertaken within the executive. The most recent one is the report to the Domestic Council which addressed exactly the set of questions you have just raised.

What is the need for regulations? What are the problems of management of the activities among the agencies? What is the present status of weather modification in the various fields? And this report has been completed. It has been submitted to the Domestic Council, and the basic reason I am not indicating support for any of the bills is that this set of recommendations needs to be reviewed, as it's now being reviewed by the Domestic Council, to decide what it is we should do.

Now, there is a difference between that Domestic Council subcommittee study and the proposal for the Commission, because the proposal for the Commission does have certain merit that our study does not.

Our studies were conducted by representatives of various Federal agencies. We did bring in people from the outside, from universities and from industry, to discuss the problems with us, and to the extent that we have been able to reflect their views in our report, they are there. But the Commission proposed in one of the bills before us has the property of having people principally outside the U.S. Government, sort of an independent Commission look at this thing.

But the National Advisory Committee on Oceans and Atmospheres which does constitute a group outside the Federal Government has looked at the problem very recently. So, I think there are differences between what is proposed and the Domestic Council study.

Senator PEARSON. Let me ask you this: Does NOAA or any other Federal agency control or give permission for weather modification by private or commercial groups? Or does everybody just do his own thing?

Dr. WHITE. The only Federal law is a reporting law. There are about 30 States who do have their own legislation which governs weather modification within their States.

The State legislation varies all over the lot. Some States previously prohibited weather modification activities entirely. Others have provisions for governing the activities. So, all of the legislation of a regulatory nature today is State legislation, not Federal legislation.

Senator PEARSON. Thank you.

Senator Bellmon?

Senator BELLMON. The Senator from Kansas and I represent States that are now facing a very serious drought. What will happen is that as the spring comes on and the summer weather lets up, and as the crops dry, there will be many groups in these States undertaking to do something and there will be pressure on us to come out and help.

Now, what is NOAA at this time able to do in a situation like this?

Dr. WHITE. The only thing we can do to help the situation now is to provide advice to those groups who may wish to engage in such activities.

Senator BELLMON. Do you have a basis for giving them advice?

Dr. WHITE. We would be able to advise them based on the experiences of our scientific groups and our laboratories, and to that extent, we might be able to advise them.

Senator BELLMON. So far as giving them financial assistance, there is nothing?

Dr. WHITE. There is no authority to provide financial assistance.

Senator BELLMON. Is there any agency in the Federal Government that can give that kind of assistance?

Dr. WHITE. I don't know whether I can answer that categorically. It may be that some of the provisions of the Disaster Relief Act could be construed to apply to support of weather modification activities. But I am not an expert on that.

Senator BELLMON. Let me tell you what happened back in 1970 and 1971. Before you came we heard the mayor of Altus, Okla. They were suffering a serious drought, and finally we got some money from the Office of Emergency Preparedness. The Bureau hired a private contractor and sometime after the crops had burned up in 2 consecutive years, the weather modification program finally got started.

The problem was that it was too late, and it was too small, it covered only a five-county area. The purpose behind this legislation is to try to get statutory authority available to a leading agency, whichever one it is, so that in the case of a serious drought such as we are now facing in some of our Western States, we won't have to wait until the crops are gone.

If there is any merits, as you seem to think there is, to rainfall augmentation, we could do it while there is still time to help. It seems to me that in part of your statement you were about to endorse

S. 2706. You said it was both feasible and desirable considering the benefits that would accrue; but then on your last page you withdrew your support for this approach.

Dr. WHITE. My personal assessment is that a program of research and experimentation of the kind that is described in the bill makes a great deal of sense. I think it does conform to the recommendations that have been made for an extended, well-considered, systematically operated program of field experimentation in weather modification.

So of all of the bills before us today, my personal assessment as a scientist would be that that is the option I would choose. With respect to operational weather modification in a period of drought, I have been very careful in my testimony to try to be specific about what I mean. I think I have tried to be very, very clear that operational weather modification in a period of drought is problematical, at best. I think we have to face up to that fact.

Now, in spite of being problematical, in a State in which people are desperate in a drought situation, a decision taken with a full understanding of the nature of the possible consequences and the possibility that rainfall will be decreased is a policy decision on the part of that State.

Senator BELLMON. That is the beauty of a participation between the State and the Federal. If the State wants to put up its own funds, or perhaps if the groups within the State wish to acquire funds, then they would be making that decision rather than the Office of Emergency Preparedness. So you can see some merit in this approach.

Dr. WHITE. I would emphasize the point that Mr. Eggers made just before me, that if the Congress should decide to proceed along those lines, it is extremely important that even in an operational weather modification situation, that enough data is gathered and the project is designed with the best knowledge we have and full understanding of the expectations. I think that your bill, as I read it at least, does allow for that kind of thing.

Senator BELLMON. But when the weather modification programs begin when they are too late, there is nothing gained from those. But it was our hope that we would go into it in an orderly way and that we would monitor and gather as much data as we could, and that we would know whether it was working or not. But now we don't seem to be making much progress.

Dr. WHITE. No. I am afraid the present status of the science is that we can't give you a good answer. The best answer we can give you is maybe it will and maybe it won't.

Senator BELLMON. Do you see this Government making real progress in the direction of eventually being able to answer those kinds of questions?

Dr. WHITE. I think you can make progress towards answering the question: Does it work or doesn't it work under certain conditions? You have to formulate a program; you have to design an experiment; and you have to carry it out over a long period of time, and then you can get an answer.

Senator BELLMON. But are we doing it now?

Dr. WHITE. I don't believe we are doing it in the long-term way in which I think it ought to be done.

Senator BELLMON. You would feel that some program like that described in S. 2706 may be valuable?

Dr. WHITE. Yes. I do.

Senator PEARSON. Thank you very much, Dr. White.

Dr. WHITE. Thank you.

Senator PEARSON. Our next witness is Dr. Archie Kahan. Dr. Kahan is the Chief of the Division of Atmospheric Water Resource Management of the Department of the Interior.

**STATEMENT OF DR. ARCHIE M. KAHAN, CHIEF, DIVISION OF
ATMOSPHERIC WATER RESOURCES MANAGEMENT, BUREAU OF
RECLAMATION, DENVER, COLO.**

Dr. KAHAN. Mr. Chairman, I have a rather lengthy statement which would be an imposition on you if I attempted to read it in total.

Senator PEARSON. We will incorporate your entire statement in the record, and you may proceed to summarize it, or in any manner you see fit.

Dr. KAHAN. Thank you.

Mr. Chairman, Senator Bellmon, ladies and gentlemen, my name is Archie M. Kahan. I am a meteorologist employed by the Bureau of Reclamation in Denver, Colo. I deeply appreciate this opportunity to present before this committee a synopsis of the Bureau of Reclamation's atmospheric water resources management program, known as Project Skywater.

Nearly all human activities are sensitive to weather. Adverse weather raises the cost of the food we eat, the clothes we wear, and the homes we live in. No wonder any promise of alleviating adverse weather by scientific means receives an eager hearing, even while the science is rudimentary and unperfected. Of all weather adversities, drought and its close relative, inadequate rainfall, have motivated the greatest efforts for alleviation. The frustration of watching waterladen clouds drift by without yielding rain has precipitated many efforts to milk them.

Many rainmaking experiments have followed the classic demonstration by Langmuir and Schaefer in November 1946, that cloud seeding under suitable circumstances can initiate precipitation. A few of these experiments have been clear-cut successes, but most of them have been inconclusive.

The problem of identifying the particular weather situations conducive to successful precipitation management has led researchers more and more deeply into search for fundamental understanding of precipitation processes, natural and modified. This understanding has come to be recognized as the essential foundation for every technology of weather modification irrespective of the purpose to which it may eventually be put, whether for drought alleviation, augmentation of winter snowpack, hail suppression, moderation of hurricanes and severe local storms, or even alleviation of flood menace.

The Congress put the Department of the Interior into atmospheric water resources research late in 1961, when the conference committee wrote into the public works appropriation bill the sum of \$100,000 for research on increasing rainfall by cloud seeding. Shortly, I shall describe some of the substantial milestones that have measured our progress since that modest beginning.

We have come also to realize that the search for fundamental understanding and for the skill to apply it effectively has become more complex. The promise remains undiminished; in fact, its outlines have become clearer and its details better substantiated. But the scientific and technical problems have overmatched the resources so far devoted to their solution. These problems have been described by a committee of the National Academy of Science as among the most complex and challenging facing mankind today, while the resources devoted to their solution have remained on a scale comparable to the annual gross of a typical neighborhood supermarket.

We welcome the attention that Senator Bellmon's bills directs to the opportunity for speeding the day when substantial returns may begin to flow from the investments made in precipitation management research.

With that prelude, I turned now to the milestones of progress:

Project Skywater has focused on the two precipitation situations regarded as most likely to yield early practical returns from management. These are rainfall from relatively simple summer shower situations that are of great importance to agriculture in the Great Plains, and winter snowpack in the high mountains of the Western United States that feed the headwaters of the Colorado, Missouri, and other major Western rivers.

Respecting summer convective rain, Skywater has developed a simple, logically powerful conceptual approach. Moisture flows into the Great Plains province at low levels from the Gulf of Mexico. Within the Great Plains province it is heated over the sun-warmed ground and rises, forming clouds. A relatively small proportion of the condensed moisture falls as rain, to be used by plants, reevaporated into the lower atmosphere, and later form clouds anew.

But most of the clouds do not live long enough to breed rain, and the moisture in them ascends to higher levels, reevaporates as it mixes with drier air aloft, and is carried away eastward by the prevailing high-level westerlies. In many of these clouds, seeding is capable of increasing the proportion of the water vapor that falls as rain. In these clouds, seeding initiates formation of raindrops faster, reducing the time required for formation of rain. The main building blocks of this concept are well confirmed. They have been confirmed by repeated observation and supported by mathematical modeling.

The complexity comes in dealing with the enormous variety of conditions from cloud to cloud and from moment to moment within a given cloud. It comes also from the need to intervene in the right way, at the right time, in the right place, if management is to be successful. Skywater's high plains cooperative program, now in its initial stages, represents the Nation's most ambitious effort to date to deal with these complexities in an experimental framework.

Respecting the augmentation of mountain snowpack, a similar concept has been explored. Where clouds ride up over the crest of a mountain ridge, there is a limited time available within which snowflakes may form, grow, and fall to the ground. In many such clouds the process is inefficient. Its efficiency may be increased by seeding, starting the growth of snowflakes earlier and giving them more time to grow and fall than they would have naturally.

Again, the concept has great logical strength, and its building blocks are well confirmed by observation, laboratory experimentation, and mathematical modeling. Difficulties arise from the enormous variety of natural conditions and the rapidity with which they change. To do an effective job of precipitation management under these circumstances, recognition of opportunity and delivery of treatment must be timely and precise.

Skywater's directive to do "research on increasing rainfall by cloud seeding," accompanying its first congressional appropriation, has evolved into "developing an effective and acceptable technology for management of precipitation to help meet the Nation's needs for water" through the year 2000.

Guidance has been firm in focusing on the removal of key scientific uncertainties. The Skywater objective is thus to upgrade the technology and make it available to users, assisting users in technology transfer. Skywater has not been given the role of an operating agency to carry out precipitation management applications except for limited drought-relief activities. Users include other Federal agencies such as the Bureau of Land Management, States, counties, and the private sector.

About 85 percent of project Skywater appropriations have been expended through some 60 contractors listed in table 1, including universities, private firms, State agencies, and other Federal agencies. Skywater contract support has been instrumental in the formation of many new centers of capability in weather modification, notably meteorological research departments in four western universities.

Skywater has helped create the pool of private-sector capabilities that have been called upon for emergency drought-relief programs as well as for more routine commercial precipitation stimulation and for research support to other Federal agencies.

Through June 1975, \$49,329,000 has been expended on general and applied research, field tests and associated studies for: (a) increasing rain from summer cumulus clouds to provide additional water directly on crops and pastures; (b) increasing snowfall in the mountains to augment streamflow for agricultural energy, and municipal water users, and to improve water quality; and (c) assessment of associated environmental, social, and legal impacts and agricultural and energy benefits.

From the start of Project Skywater, the Bureau has been conducting research on increasing rain from summer clouds in the Great Plains region. Early work started in 1962 with the South Dakota School of Mines and Technology, and in 1966 at Flagstaff, Ariz. Other rain cloud seeding experiments began in 1969 in northwestern North Dakota, and in 1971 with the Texas Water Development Board at San Angelo, Tex.

All of these efforts left something to be desired as experiments, but they had a common thread of pointing to the possibility and the probability of being able to increase the precipitation by seeding.

In the Sierra Nevada Mountains of California where the cloud base of the summer cumulus are near 0°C and the updraft speeds are probably in the 3- to 5-m sec^{-1} range, could base silver iodide seeding is very effective. It appears to nearly double the amount of precipitation from these clouds.

In North and South Dakota consistent precipitation enhancement from silver iodide seeding seems to come from only a narrow range of cloud conditions. Increased precipitation is associated with seeding 3- to 5-km-deep clouds for which the model predicts a 1-kilometer or more dynamic response to the heat release from freezing of cloud and precipitation water.

Apparently the increase in cloud size is sufficient to make these clouds precipitate much more effectively and produce three times as much rain on an areawide basis. This occurs for on the order of 10 percent of the precipitation potential.

The larger clouds generally have fast updrafts and no method has yet been developed for seeding them with silver iodide to produce consistently positive results. The models suggest that there is no broad-spectrum prescription for effective seeding of these larger clouds with silver iodide and that each cloud needs its special prescribed treatment.

Hygroscopic seeding to speed up the condensation coalescence precipitation mechanism has been used on three experiments. The results indicate increased efficiency in turning cloud water into precipitation. According to the models, seeding will be most effective on the clouds that have updrafts too fast to allow effective natural precipitation formation.

A sorting of the Rapid City clouds according to actual time available for precipitation formation supports their model expectation and indicates that where hygroscopic treatment should be effective the median efficiency in turning cloud water to rain goes from 15 percent for the untreated clouds to 25 percent for the treated clouds.

The overall goal of the high plains cooperative project (Hiplex) is to establish a verified, practical cloud seeding technology and a policy and management background for responsibly producing additional rain in the semiarid Plains States. This goal includes improving the current operational cloud seeding methods, transferring the techniques and results to concerned groups, and enhancing public confidence in their use.

The immediate Hiplex objectives are:

One: Resolving the crucial scientific uncertainties in seeding cumulus clouds.

Two: Increasing the certainty of confidence in producing real benefits without disturbing or harmful side effects.

We have had \$3.2 million to work so far since the work got started. The effort is being attacked very carefully with the design help of State agencies and private groups. We feel that we have a good start on understanding the program of research that will lead to under-

standing that would improve the chances of increasing the water supply.

Seeding to increase snowpack in the mountains has been done since the late 1940's. There has been success in this to keep some projects going for 5 years.

We have put quite a bit of emphasis in our program on understanding the economic and societal interactions. We have supported work that has led to evaluations of what an additional inch of water would be worth. It is a very mixed bag. It depends upon where and how the water is to be used.

The efforts to assess environmental impact have taken two forms: Understanding what additional precipitation does, and also what the seeding materials used might be. In general, the results of the research suggest that there is no pressing short-range problem. The long-term issue has not been addressed, but there does not appear to be a basis for the idea that there are short-term catastrophic possibilities.

We have been involved in a program of local assistance and technology transfer with the States. We have cooperated in many ways. The State of Kansas actually provided funds and asked us to manage the conduct of the seeding efforts. We have loaned equipment such as radar sets to State programs to improve their evaluations. An increase in our present programs of about \$1 million annually would certainly greatly enhance our abilities in this area.

Mr. Chairman, that concludes my statement, and I would be happy to answer any questions.

Senator PEARSON. Thank you very much, Doctor. You touched on the central point, and that is that the influence of weather upon human life in our society.

I think what Senator Bellmon and I are trying to find out is whether we are proceeding to do the best we can with what we know; there is no way the Senate or the Congress can engage itself in scientific inquiry. We have a very hard time making inquiries in an unscientific way.

But, is there adequate funding? Is the state of art such that the organizational structure that we have is adequate to go forward and do what we can do? The thrust of these bills is to ask and to satisfy those questions. Do you think we have reasonable funding? Are we doing all we can in encouraging scientific inquiry into this subject?

Dr. KAHAN. I don't think we are doing all we can. I think more could be done with additional funding. There is a hazard in the approach of throwing money at the problem I would say, valid perceptions of what are the right things to do ought to precede making money available. It is not difficult to spend money if it is made available, but it needs to be very carefully considered in terms of priorities and what needs to be done. We could use more money.

Senator PEARSON. Where could you use more money?

Dr. KAHAN. In the observational networks, for example. Radar sets that would give a better description of the vertical fields of motion are scarce. Doppler radars are unique items in meteorology, but the ability to detect motion reliably by radar is commonplace in air transport. We find ourselves with network problems. Just the

problem of detecting how much rainfall has occurred is a very demanding problem, completely apart from whether or not you have influenced it in some way. Nobody measures precipitation at the present time. Everybody estimates it and they estimate it by approaches that have errors of estimate built into them.

The greater the density of the network, the less chance for being led astray, but there is no way that you are going to be able to afford large dense networks. All of this costs money, but we are not talking about vast sums of additional money. We are currently funded in connection with Hiplex with \$2.3 million a year. We see another \$1 million or so as being able to go a long way to implement what it makes sense to try to do at the present time.

Senator PEARSON. In this technology we are not today concentrating on the collection of data, rather than the analysis of that data, are we?

Dr. KAHAN. Anybody that collects data without having an advance knowledge of what he is going to do with it in the way of analysis is an activity-oriented person who ought to be drummed out of the field. It is asinine to spend scarce dollars collecting numbers just in case they will be useful.

What we are trying to do is to get a clear description of how the information will be used, how it will be processed, and how it will be analyzed. It is much easier to find people who are willing to collect data than it is to find people who are willing to sit and think about analyzing it.

Senator PEARSON. Senator Bellmon?

Pardon me just a moment.

Senator Hansen has a statement that he wishes to have incorporated into the record.

[The complete statement of Senator Hansen follows:]

STATEMENT OF HON. CLIFFORD P. HANSEN, U.S. SENATOR FROM WYOMING

Mr. Chairman, I wish to compliment Senator Bellmon for introducing these bills to enhance the Federal Government's role in weather modification, and to commend this Committee for conducting this hearing. The West is facing tremendous problems in developing adequate water supplies to sustain its agricultural economy and to provide industrial and municipal water needed to develop and process its abundant supplies of energy fuels. The current drought in the plains country also is a factor which underscores the urgency of supplementing precipitation by weather modification techniques.

However, I think that it will be impossible to adequately assess Federal weather modification activities and to authorize programs to alleviate drought without the participation of the Department of the Interior, which is charged with developing water supplies for the semi-arid and arid West. To this end, I think it is desirable and appropriate that this legislation—at least that part dealing with studies of and assistance for drought alleviation—be jointly referred to the Committee on Interior and Insular Affairs.

In the past, general research in weather modification has been carried out by the National Oceanic and Atmospheric Administration in the Department of Commerce, and I have no quarrel with that, nor with this Committee's jurisdiction over this program.

However, field operations to develop water in the Reclamation West have been carried on by the Bureau of Reclamation in the Department of the Interior. This assignment not only is appropriate, in view of the mission of the Bureau of Reclamation, but it also has been highly successful. I believe that the Bureau of Reclamation today has some of the best scientific expertise in this area, as well

as the scientific and engineering backup of its world-renowned Engineering and Research Laboratory in Denver.

The Bureau has been involved in a weather modification program since 1961, when the Congress appropriated \$100,000 for research into increasing rainfall through cloud seeding, with studies supported at three universities. At the end of the first decade of this program, the Bureau of Reclamation was working on a total of 41 interrelated projects through 35 universities or colleges, private research organizations, and Federal and State agencies.

Among the contractors participating in this program, known as *Project Skywater*, were: Aerometric Research Inc., Atomic Energy Commission, California State University, Colorado State University, EG&G Inc., Montana State University, NOAA, North American Weather, North Dakota State University, Soil Conservation Service, South Dakota School of Mines, South Dakota Weather Control Commission, State of Washington, Texas Water Development Board, University of Colorado, University of Illinois, University of Oklahoma, University of Nevada, University of Wyoming, Utah State University, Weather Science, Inc., and Western Scientific Services, Inc.

The Bureau of Reclamation has published a 32 page brochure, *Project Skywater, An introduction to Rivers in the Sky*, describing the operations of this program between 1961 and 1974. I submit a copy of this brochure for the attention of this Committee.

In this brochure, the Bureau of Reclamation announced:

"At this point in the research program, it appears that summer rainfall in the Plains States can be increased by 15 to 20 per cent through a responsible application of the current technology. Seasonal snowfall increases of up to 20 per cent can be expected in winter orographic situations."

This is good news for the arid West, and I hope that the deliberations of this committee, supplemented by the interest and assistance of the Interior Committee, can succeed in enhancing this research effort and applying on a reasonable scale the technology already demonstrated and perfected.

Senator BELLMON. Thank you, Mr. Chairman.

Dr. Kahan, in your statement you say that the scientific problems overmatch the resources so far devoted to their solution.

I think you said you could use another \$1 million a year in your project Hiplex. Is that the only area you see where we need more resources?

Dr. KAHAN. No, sir.

Senator BELLMON. Could you be more specific as to what you had in mind when you made this statement?

Dr. KAHAN. We have tried to "poor boy" things in the past, using equipment that was not designed to do the job you are demanding. For example, missile-tracking radars have been adapted to cloud physics work. They are a poor substitute for radar designed to do that work. The resources have been inadequate to obtain the best technology that is really available. In the area of aircraft, it is very expensive to fly aircraft into clouds to find out what is going on. It is relatively inexpensive to fly aircraft to do seeding, but the job of finding out what has been accomplished in the cloud as a result of seeding involves both intrepid airmen, good aircraft, and good instrumentation.

We have been forced by the lack of resources to make certain assumptions about the time history of a cloud. If you can only afford one airplane, you fly that airplane through the cloud at what you hope is a most significant level. You hope that what you measure there gives you an adequate handle on the entire depth of the cloud. This forces you to the assumption that the cloud is not going to change drastically until you can turn around and come back through

it. We know that things are going on in a very dynamic way in these clouds. If you had more resources, you would want to penetrate them with aircraft at more levels. But you can go too far in this area, too.

Senator BELLMON. We have a letter from the Secretary of the Interior in which he says that Project Skywater represents an expertise in capability for weather modification activity that is devoted to investigate for advancing the effectiveness of this technology.

Apparently the Secretary thinks you have more resources at your command than you apparently have. And he says the legislation is duplicating what you are already doing. What you have done so far is really just a drop in the bucket.

Dr. KAHAN. I assure you that we are serious about weather modification.

Senator BELLMON. What is so curious about this is that when a drought hits as it did earlier this decade, if we were to get serious about weather modification and find out whether it will work, how it works best, then we could save those kinds of disaster payments. So, it seems like we are being penny wise and pound foolish here.

Dr. KAHAN. I don't want to engage in any argument with you about this. I think if you had everything that we know how to do at the present time available to address drought alleviation, you wouldn't wipe out completely the need for that \$500 million. You might have a very good impact on it. Whether you would have 10 percent or 1 percent or a minus 10 percent would depend on what kind of a hand nature dealt you during the droughts. Droughts occur in clear skies or from clouds that are almost on the verge of precipitating and don't. And you cannot with the light of present knowledge give anyone assurance that you can do something useful. You have to approach the problem by being prepared to do what you can, by having the resources available to do what you can and the authority to use them.

And in that connection the problem of the Bureau of Reclamation in Oklahoma, there wasn't any 18-month delay on the part of the Bureau. We had our team in the field, something like 21½ weeks after we received the go ahead and authorization to do it.

Senator BELLMON. But the delay came in getting you in the field. It took us that long to get the money shook loose from the agency that finally came to our rescue down there. You were ready, but we didn't have the resources.

I have no further questions.

Senator PEARSON. Thank you very much, Doctor.

[The statement follows:]

STATEMENT OF DR. ARCHIE M. KAHAN

Mr. Chairman and members of the committee. My name is Archie M. Kahan. I am a meteorologist employed by the Bureau of Reclamation in Denver, Colorado. I deeply appreciate this opportunity to present before this committee a synopsis of the Bureau of Reclamation's Atmospheric Water Resources Management Program, known as Project Skywater.

Nearly all human activities are sensitive to weather. Adverse weather raises the cost of the food we eat, the clothes we wear, and the homes we

live in. No wonder any promise of alleviating adverse weather by scientific means receives an eager hearing, even while the science is rudimentary and unperfected. Of all weather adversities, drought and its close relative, inadequate rainfall, have motivated the greatest efforts for alleviation. The frustration of watching water-laden clouds drift by without yielding rain has precipitated many efforts to milk them.

Many rainmaking experiments have followed the classic demonstration by Langmuir and Schaefer in November 1946 that cloud seeding under suitable circumstances can initiate precipitation. A few of these experiments have been clear-cut successes, but most of them have been inconclusive. The problem of identifying the particular weather situations conducive to successful precipitation management has led researchers more and more deeply into search for fundamental understanding of precipitation processes, natural and modified. This understanding has come to be recognized as the essential foundation for every technology of weather modification irrespective of the purpose to which it may eventually be put, whether for drought alleviation, augmentation of winter snowpack, hail suppression, moderation of hurricanes and severe local storms, or even alleviation of flood menace.

The Congress put the Department of the Interior into atmospheric water resources research late in 1961 when the Conference Committee wrote into the Public Works Appropriation Bill the sum of \$100,000 for research on increasing rainfall by cloud seeding. Shortly, I shall describe some of the substantial milestones that have measured our progress since that modest beginning. We have come also to realize that the search for fundamental understanding and for the skill to apply it effectively has become more complex. The promise remains undiminished; in fact, its outlines have become clearer and its details better substantiated. But the scientific and technical problems have overmatched the resources so far devoted to their solution. These problems have been described by a committee of the National Academy of Science as among the most complex and challenging facing mankind today, while the resources devoted to their solution have remained on a scale comparable to the annual gross of a typical neighborhood supermarket. We welcome the attention that Senator Bellmon's bills directs to the opportunity for seeding the day when substantial returns may begin to flow from the investments made in precipitation management research.

With that prelude, I turn now to the milestone of progress.

I. Project Skywater has focused on the two precipitation situations regarded as most likely to yield early practical returns from management. These are rainfall from relatively simple summer shower situations that are of great importance to agriculture in the Great Plains, and winter snowpack in the high mountains of the western United States that feed the headwaters of the Colorado, Missouri, and other major western rivers.

Respecting summer convective rain, Skywater has developed a simple, logically powerful conceptual approach. Moisture flows into the Great Plains province at low levels from the Gulf of Mexico. Within the Great Plains province it is heated over the sun-warmed ground and rises, forming clouds. A relatively small proportion of the condensed moisture falls as rain, to be used by plants, re-evaporated into the lower atmosphere, and later form clouds anew. But most of the clouds do not live long enough to breed rain, and the moisture in theme ascends to higher levels, re-evaporates as it mixes with drier air aloft, and is carried away eastward by the prevailing high-level westerlies. In many of these clouds, seeding is capable of increasing the proportion of the water vapor that falls as rain. In these clouds, seeding initiates formation of raindrops faster, reducing the time required for formation of rain. The main building blocks of this concept are well confirmed. They have been confirmed by repeated observation and supported by mathematical modeling. The complexity comes in dealing with the enormous variety of conditions from cloud to cloud and from moment to moment within a given cloud. It comes also from the need to intervene in the right way, at the right time, in the right place, if management is to be successful. Skywater's High Plains Cooperative Program, now in its initial stages, represents the Nation's most ambitious effort to date to deal with these complexities in an experimental framework.

Respecting the augmentation of mountain snowpack, a similar concept has been explored. Where clouds ride up over the crest of a mountain ridge, there

is a limited time available within which snowflakes may form, grow, and fall to the ground. In many such clouds, the process is inefficient. Its efficiency may be increased by seeding, starting the growth of snowflakes earlier and giving them more time to grow and fall than they would have naturally. Again, the concept has great logical strength, and its building blocks are well confirmed by observation, laboratory experimentation, and mathematical modeling. Difficulties arise from the enormous variety of natural conditions and the rapidity with which they change. To do an effective job of precipitation management under these circumstances, recognition of opportunity and delivery of treatment must be timely and precise.

II. SKYWATER MISSION OBJECTIVES AND FUNDING

Skywater's directive to do "research on increasing rainfall by cloud seeding," accompanying its first congressional appropriation, has evolved into "developing an effective and acceptable technology for management of precipitation to help meet the Nation's needs for water" through the year 2000. Guidance has been firm in focusing on the removal to upgrade scientific uncertainties. The Skywater objective is thus to upgrade the technology and make it available to users, assisting users in technology transfer. Skywater has not been given the role of an operating agency to carry out precipitation management applications except for limited drought-relief activities. Users include other Federal agencies such as the Bureau of Land Management, States, counties, and the private sector. About 85 percent of Project Skywater appropriations have been expended through 60 contractors listed in Table 1, including universities, private firms, State agencies, and other Federal agencies. Skywater contract support has been instrumental in the formation of many new centers of capability in weather modification, notably meteorological research departments in four western universities. Skywater has helped create the pool of private-sector capabilities that have been called upon for emergency drought-relief programs as well as for more routine commercial precipitation stimulation and for research support to other Federal agencies.

TABLE 1.—PRINCIPAL CONTRACTORS AND RESEARCH COOPERATORS—PROJECT SKYWATER

University of Arizona.	Amos Eddy, Inc.	U.S. Air Force.
University of California.	Aerometric Research, Inc.	U.S. Army.
University of California at Los Angeles.	Convergence Systems, Inc.	California Department of Transportation.
University of Colorado.	E. Bollay Associates.	California Highway Patrol.
Colorado State University.	EG&G, Inc.	Colorado Department of Natural Resources.
University of Denver.	Electronic Techniques, Inc.	Forest Service.
Fresno State College.	Enterprise Electronics, Inc.	Geological Survey.
Howard University.	Environmental Research and Technology, Inc.	Illinois State Water Survey.
University of Michigan.	MBAssociates, Inc.	Kansas Water Resources Board.
Montana State University	Meteorology Research, Inc.	Montana Department of Natural Resources and Conservation.
University of Nevada.	North American Weather Consultants.	National Oceanic and Atmospheric Administration.
New Mexico State University.	Stanford Research, Inc.	National Science Foundation.
New York University.	T. G. Owe Berg, Inc.	Navy Weapons Center.
University of North Dakota.	Travelers Research Inc.	Navy Weather Research Facility.
North Dakota State University.	Weather Science, Inc.	Nebraska Department of Agriculture.
University of Oklahoma.	Western Scientific Services, Inc.	North Dakota Weather Modification Board.
Pennsylvania State University.		Sacramento River Forecast Center.
San Diego State University.		Soil Conservation Service.
South Dakota School of Mines and Technology.		South Dakota Weather Control Commission.
South Dakota State University.		Washington Department of Ecology.
Taft College.		Texas Water Development Board.
Texas A&M Research Foundation.		
Utah State University.		
University of Washington.		
University of Wisconsin.		
University of Wyoming.		

Table 2 shows the annual funding and budgets of Skywater through completion of the tasks so far approved. The budgets carry forward the High Plains Cooperative Project and the Sierra Cooperative Pilot Project, together with supporting research to the extent now covered by approved plans. Another major undertaking, a demonstration project for the Colorado River Basin, is under consideration but not yet approved. Further funding of these and other Skywater activities will depend on continuing congressional and administration assessment of objectives and results.

Through June 1975, \$49,329,000 has been expended on general and applied research, field tests, and associated studies for: (a) increasing rain from summer cumulus clouds to provide additional water directly on crops and pastures; (b) increasing snowfall in the mountains to augment streamflow for agricultural, energy, and municipal water users and to improve water quality; and (c) assessment of associated environmental, social, and legal impacts and agricultural and energy benefits.

	Dollars	Percent
General research and associated impact studies.....	11,992,000	24
Specific summer rain experiments (including the HIPLEX program).....	13,472,000	28
Specific winter snow experiments (including the Colorado River Basin pilot project and Sierra cooperative pilot project).....	23,865,000	48

Table 2.—Annual funding and budgets—Project Skywater

Fiscal year:		Fiscal year—Continued	
1962.....	\$100,000	1975.....	4,000,000
1963.....	100,000	1976.....	4,649,000
1964.....	175,000	Transitional quarter.....	1,632,000
1965.....	1,100,000	1977.....	² 4,650,000
1966.....	¹ 2,980,000	1978.....	³ 6,200,000
1967.....	¹ 3,750,000	1979.....	³ 6,420,000
1968.....	¹ 5,118,000	1980.....	³ 6,350,000
1969.....	4,265,000	1981.....	³ 3,900,000
1970.....	4,805,700	1982.....	³ 3,077,000
1971.....	6,514,500	1983.....	³ 1,000,000
1972.....	6,559,000		
1973.....	6,624,500	Project Skywater	
1974.....	\$3,900,000	total.....	87,500,000

¹ Includes underfinancing and withholding.

² Budget.

³ Planned.

Drought relief and other related cloud seeding activities

In the summer of 1971, governors of many western states requested emergency drought relief, including cloud seeding to alleviate the drought. The President's Office of Emergency Preparedness directed Skywater to conduct emergency precipitation stimulation operations in Texas, Arizona, and Oklahoma. In 1972 and 1973, Skywater personnel furnished the scientific expertise for a program of forest fire suppression conducted by the Bureau of Land Management in Alaska. Skywater has provided scientific consulting services for rain augmentation programs in Lebanon, Brazil, India, Tasmania, and Jamaica.

III. SUMMER RAIN AUGMENTATION RESEARCH

From the start of Project Skywater, the Bureau has been conducting research on increasing rain from summer clouds in the Great Plains region. Early work started in 1962 with the South Dakota School of Mines and Technology and in 1966 at Flagstaff, Arizona. Other rain cloud seeding experiments began in 1969 in northwestern North Dakota and in 1971 with the Texas Water Development Board at San Angelo, Texas.

A summary of some of the most important results that are indicated thus far are listed below.

In the Sierra Nevada Mountains of California where the cloud base of the summer cumulus are near 0°C and the updraft speeds are probably in the 3- to 5-m sec⁻¹ range, cloud base silver iodide seeding is very effective. It appears to nearly double the amount of precipitation from these clouds.

In North and South Dakota consistent precipitation enhancement from silver iodide seeding seems to come from only a narrow range of cloud conditions. Increased precipitation is associated with seeding 3- to 5-km-deep clouds

for which the model predicts a 1 km or more dynamic response to the heat release from freezing of cloud and precipitation clouds precipitate much more effectively and produce three times as much rain on an area-wide basis. This occurs for on the order of 10 percent of the precipitation potential. The larger clouds generally have fast updrafts (10 m sec^{-1} or faster) and no method has yet been developed for seeding them with silver iodide to produce consistently positive results. The models suggest that there is no broad-spectrum prescription for effective seeding of these larger clouds with silver iodide and that each cloud needs its special prescribed treatment.

Hygroscopic seeding to speed up the condensation coalescence precipitation mechanism has been used on three experiments. The results indicate increased efficiency in turning cloud water into precipitation. According to the models, seeding will be most effective on the clouds that have updrafts too fast to allow effective natural precipitation formation. A sorting of the Rapid City clouds according to actual time available for precipitation formation supports their model expectation and indicates that where hygroscopic treatment should be effective the median efficiency in turning cloud water to rain goes from 15 percent for the untreated clouds to 25 percent for the treated clouds.

Against this background of previous experimentation, the High Plains Cooperative Project (HIPLEX) was assigned to Skywater in 1973.

The overall goal of HIPLEX is to establish a verified, practical cloud seeding technology and a policy and management background for responsibility producing additional rain in the semiarid Plains States. This goal includes improving the current operational cloud seeding methods, transferring the techniques and results to concerned groups, and enhancing public confidence in their use (Conceptual Plan, May 1973).

Although HIPLEX is primarily a Skywater activity, it includes the integrated research and supporting efforts of State agencies, local groups, and other Federal agencies. Most of the field research and analyses are performed through contracts with universities and private firms. The project is closely coordinated with the National Hail Research Experiment and other National Science Foundation and National Oceanic and Atmospheric Administration research.

The immediate HIPLEX objectives are:

1. Resolving the crucial scientific uncertainties in seeding cumulus clouds.
2. Increasing the certainty of confidence in producing real benefits without disturbing or harmful side effects.

To develop the optimum water augmentation potential from summer clouds, the States and local organizations in the High Plains have joined with the Bureau in planning and implementing a broad research program to:

1. Develop and test more productive seeding methods and evaluate results.
2. Resolve the remaining cloud dynamics and precipitation physics uncertainties on seeding effects.
3. Help prepare public weather modification backgrounds and local expertise and establish working relations between concerned non-Federal entities.
4. Assess the actual economic value of cloud seeding and the possible social and ecological impacts.

A 5- to 7-year cooperative program of field experiments and study is now underway at three sites in the High Plains. Although the final reports on activities now underway are scheduled for 1982, earlier technology transfer reports will provide the practical information on cloud seeding effectiveness and latest techniques to local farmer and water user groups. In general, a step-by-step progress from (a) seeding single cumulus clouds to (b) wide-area seeding groups of cumulus clouds to (c) seeding other broad scale rain-producing weather systems is planned with solid understanding to be reached at each step before advancing to the more complex clouds. The tentative overall schedule is:

1973—Preliminary planning.

1974-1975—Design studies, equipment procurement, and field preparations.

1976-1979—Single cumulus cloud seeding experiments.

1978-1981—Area-wide cumulus cloud seeding experiments.

1982—Final analyses and reports on cumulus seeding.

1980-1983—Broad scale rain-producing system seeding experiments (possible HIPLEX extension).

Program Progress and Status

The High Plains Cooperative Program has been successfully initiated with:

1. Field facilities and research teams established at the three field sites: Miles City, Montana; Goodland, Kansas; and Big Spring, Texas.

2. Active participation and cost-sharing functioning with the States.

3. Major equipment systems installed and tested.

4. Agricultural, economic, and environmental assessment studies underway in all three areas.

5. Experimental designs and data processing and analysis procedures developed.

Preliminary field studies have been completed although no actual cloud seeding has been done. Initiation milestones and actual completion schedules are:

Conceptual Plan—May 1973.

Skywater Conference—June 1973.

Site Selection—May 1974.

Preparation and Test of Existing Systems—May 1974.

Initial Assessment Studies—July 1974.

Other Associated Studies—October 1974.

Equipment Specifications—February 1975.

Equipment Contracts—May 1975.

Field Site Contracts—May 1975.

Integration of Field Systems—August 1975.

Initial Designs and Analyses—December 1975.

Draft Environmental Impact Statement—March 1976.

Start of Major Research Activity—May 1976.

Final Environmental Impact Statement—November 1976 (est).

Start of Seeding Experiment—May 1977.

Major equipment presently procured for HIPLEX at the three sites are:

1. Radars—2 SWR-75 (5 cm), 1 modified M-33 (3 cm and 10 cm), 1 WR-100-5 (5 cm).

Data from all radars is recorded on tape for processing and analysis by computers.

2. Aircraft—2 twin-engine fully instrumented cloud physics aircraft, 2 single-engine cloud base observation aircraft, 1 aerosol and nuclei measuring aircraft.

3. Raingages—160 recording raingages, 450 (approx) nonrecording raingages, 70 telemetered raingages.

4. Four RD-65 manual tracing rawinsonde units.

5. Ice nuclei and cloud condensation nuclei counters.

6. Computer terminals and communications to the Bureau's CDC-Cyber 74

There are about 60 scientists, pilots, and technicians from universities, private firms, and State agencies and 15 Federal employees performing the HIPLEX field research work, analyses, and assessment studies.

Budget and contract summary

Actual funding for the High Plains Cooperative Program through June 30 1975, from combined Federal and State sources was \$3,202,000. This funding compares with the initially proposed budget of \$3.2 million for the first 2 years.

Cooperative agreements with the States for cost-sharing and support of field research are:

Field site	States	Date signed
Miles City, Mont.	Montana	Aug. 25, 1974.
Goodland, Kans.	Kansas, Colorado, Nebraska	May 29, 1974 (tri-State).
Big Spring, Tex.	Texas	Oct. 30, 1974.

FUNDS OR RESOURCES MADE AVAILABLE

	Federal	States	Total
Fiscal year 1974.....	\$1,250,000	\$6,000	\$1,256,000
Fiscal year 1975.....	1,821,000	125,000	1,946,000
Total.....	3,071,000	131,000	3,202,000
Initial proposed budget (1st 2 yr).....	3,000,000	200,000	3,200,000

This anticipated overall value of State cooperation and cost-sharing throughout the program is \$3 million. The budget request for the Federal portion of the project is \$20 million. Thus, the cooperating States are expected to contribute 10 to 15 percent of the total research budget.

	Federal	States	Total
Fiscal year 1976 and transitional quarter funds.....	\$3,290,000	¹ \$175,000	\$3,465,000
Fiscal year 1977 budget.....	2,500,000	250,000	2,750,000

¹ Pending legislature approvals.

Bureau of Reclamation has contracts or cooperative agreements with the following groups for HIPLEX research:

- Amos Eddy, Inc.—measurement system design.
 - Colorado Department of Natural Resources—State cooperation.
 - Colorado State University—ecological study, satellite support.
 - Convergence Systems, Inc.—cloud physics aircraft.
 - Electronic Techniques, Inc.—satellite communication modifications.
 - Enterprise Electronics, Inc.—SWR-75 radars.
 - Environmental Research and Technology, Inc.—Kansas field site research.
 - Illinois State Water Survey—comprehensive experimental design.
 - Kansas Water Resources Board—State cooperation, agricultural economic studies.
 - Mee Industries, Inc.—hygroscopic seeding system research.
 - Montana Department of Natural Resources and Conservation—State cooperation, environmental field studies, Montana field site research.
 - Meteorology Research, Inc.—cloud physics aircraft, radar modification.
 - National Science Foundation—ice nuclei measurement.
 - National Oceanic and Atmospheric Administration—cloud modification modeling.
 - Nebraska Department of Agriculture—State cooperation.
 - University of North Dakota—downwind effects research, radar and computer support.
 - South Dakota School of Mines and Technology—cloud modification modeling.
 - Texas Water Development Board—State cooperation, Texas field site research.
 - United States Air Force—rawinsonde observations.
 - University of Washington—cloud physics and nuclei aircraft.
 - Weather Modification, Inc.—radar site surveys.
 - Western Scientific Services, Inc.—field research support, EROS raingages.
- Principal Bureau subcontractors and other major groups participating directly in HIPLEX programs through contracts with States or other agencies are:
- Colorado River Municipal Water District—Texas field measurement.
 - Environmental Data Services, Inc.—Kansas field research support.
 - Kansas State University—agricultural impact studies.
 - Kansas University—radar and satellite cloud studies.
 - National Center for Atmospheric Research—ice nuclei measurement and raingage support.
 - Texas Tech—satellite cloud observation research.
 - Texas A&M—mesometeorological cloud studies.

IV. SNOWPACK AUGMENTATION ON WESTERN MOUNTAIN RANGES

Seeding to increase snowpack in mountains has been done experimentally and operationally since the late 1940's. There has been sufficient success in this to have kept some operational projects going for 25 years. There are still a great many basic questions, however, about how, why, and where cloud seeding works. It does not seem to work everywhere, and there are indications that sometimes seeding produces decreases in snowpack. The Bureau's research program is making progress in clarifying just what the conditions are under which seeding can increase snowfall. This requires knowing more and more about the conditions of natural cloud formation, how the natural precipitation mechanism works, the condition under which it is deficient, and the condition under which seeding can be effective.

Skywater winter seeding projects have been conducted to find the strands of commonality of the physics that exist across differences in geographic location, terrain features, and types of storms. Concepts of how precipitation management works in winter mountains have developed substantially since the times when these experiments were performed.

The theoretical background and development of winter orographic seeding techniques have shown that the amount of water present in a cloud, the concentration of ice crystals in the cloud and the trajectories of snow and ice crystals relative to a mountain barrier are the most important factors needed to produce additional precipitation when artificial cloud seeding techniques are utilized. Because of their importance, there is a requirement that measurable parameters be identified which reflect these factors.

Results of various cloud seeding projects have reinforced the theoretical concepts through the comparison of precipitation in seeded situations and non-seeded situations with the measured ranges of the physical parameters. The Climax experiments conducted in central Colorado under National Science Foundation sponsorship showed a 10 to 20 percent overall increase in precipitation due to seeding. Larger positive seeding effects (or increases in precipitation) were observed in a relatively warm range of estimated cloud-top temperatures with decreases for colder cloud-top temperatures.

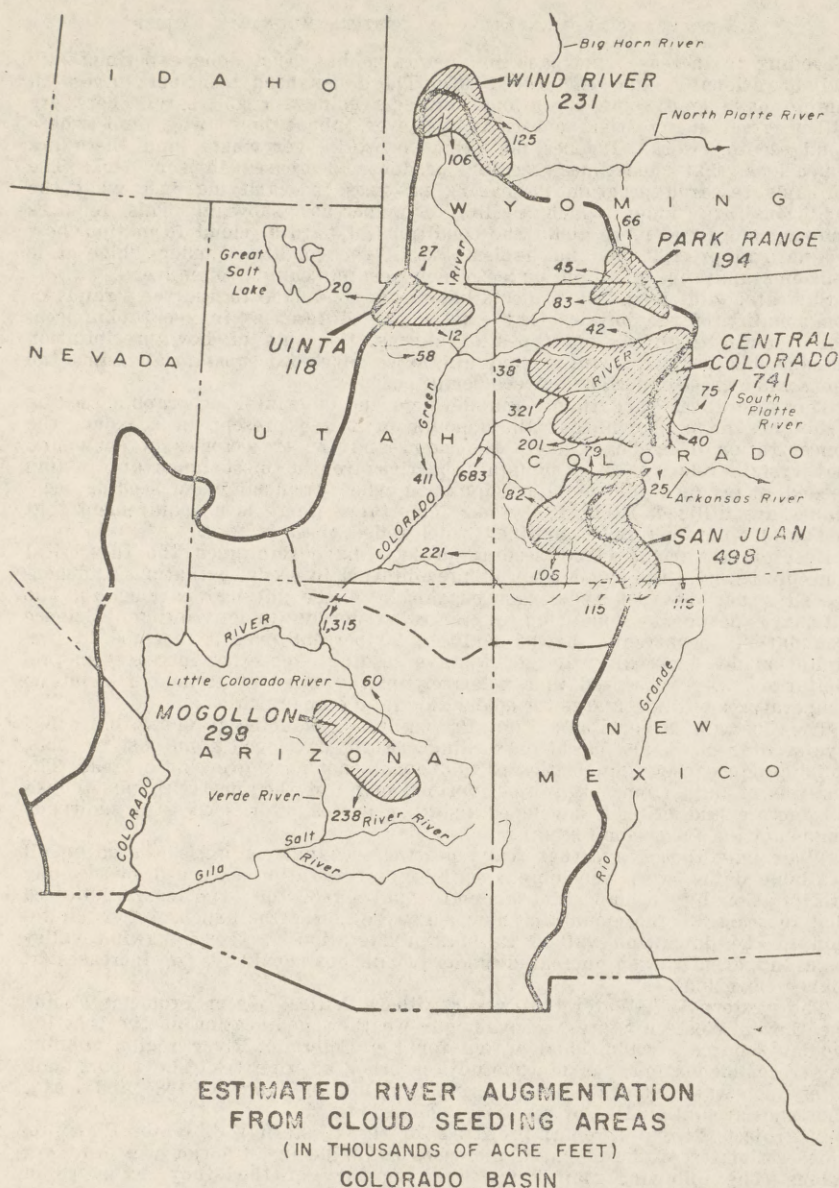
The Colorado River Basin Pilot Project was conducted to show that selective seeding of clouds, based on seeding criteria developed from past projects, could produce useful quantities of additional snowpack over large areas. The analysis of data from this project verified many of the theoretical and physical factors and criteria developed in other projects for successful snowpack augmentation from cloud seeding.

When only those days that truly met the seedability criteria (based on all available data) were considered, seed-day precipitation exceeded no-seed-day precipitation by an important amount. Analysis of the experiment indicated that increases in the mountain snowpack were not at the expense of precipitation in the downwind valley. Rather, precipitation at the downwind valley gages apparently was increased under conditions conducive to increases at higher elevations.

The western U.S. Water Plan report titled "Critical Water Problems Facing the Eleven Western States" recommends weather modification as the best immediate source of additional water for the Colorado River region. Behind this recommendation was much study of other alternatives. The report indicates spot water shortages can be expected in the Basin by 1985 and major shortages are anticipated by the 1990-1995 period.

A Project Skywater report prepared for the Western U.S. Water Plan provides estimates of the potential increases available in 12 major western river basins. The following map includes a summary of the study estimates of annual water increases for the Colorado Basin and bordering areas.

A meeting on the future of weather modification research in the Colorado River Basin with representatives of the governors of the basin states was held in Denver in December 1975. The importance of the Bureau continuing and expanding its research role was emphasized by those present. There was recognition that the actual increases still had to be confirmed and important questions in downwind effects, environmental impacts and identification of benefits to be resolved before major permanent commitments to operational cloud seeding could be made. Since the additional electrical generation by the



cloud seeding water could produce an increase in power sales that could finance a large part of the Federal research costs, the possibility of including a research or "demonstration" project as an Upper Basin Participating Project was suggested. For this to be done, the States would share by committing parts of the Upper Basin fund.

In response to locally perceived requirements for additional water in the northern Sierra Nevadas of California, a cooperative winter orographic cloud seeding experiment is now being planned and designed. Cooperation in the planning phase on social, environmental, hydrologic, and meteorologic studies has involved State agencies such as the Department of Water Resources, Department of Transportation, and the Highway Patrol, as well as the U.S. Forest Service and the Sacramento River Forecast Center.

The Bureau cosponsored an American Meteorological Society meeting in San Francisco in November 1975 to obtain the scientific community's input to the proposed program. It was concluded that a carefully designed, measured, controlled precipitation augmentation experiment in the Sierras is the most logical next step for a major effort in weather modification for both scientific and practical reasons.

V. ECONOMIC AND SOCIETAL INTERACTIONS

Increasing recognition of the responsibility for assessing the economic and societal implications of technology led to inclusion in the Skywater program of studies of economic impact and utility of weather modification and of societal institutions and attitudes affecting and affected by its implementation.

Impacts on the agricultural industry and regional economic wellbeing are of particular concern in the High Plains States. Research to date in Montana, North Dakota, South Dakota, Wyoming, Oklahoma, and in the midwest in Illinois, indicates many potential benefits from weather modification programs. Benefits from augmentation of growing-season precipitation in these areas include increased crop production, increased range production, more efficient livestock growth, increased food and cover for game animals, and increased direct agricultural income with consequent increases in secondary income in the region.

Improvements in annual water budgets can also be forecast as a result of a successful growing-season program of rain stimulation. These year-round benefits would include increased reservoir supply, improvements in ground water inventory, enhanced streamflow, and streambank storage and an important carryover effect to the following growing season. The carryover effect can be especially beneficial in dry years when atmospheric conditions fail to produce clouds that are appropriate for seeding.

Two particular questions guide the research in each State, region, or river basin: (a) will operational precipitation enhancement be desirable in this area, and (b) is it scientifically feasible on a meaningful scale?

The quest for scientifically sound answers to these questions has produced a stimulating variety of approaches in the investigation of plant-animal-human-weather relationships. Research activities range from collection of historic data on weather, range and crop yield, animal growth, soil and range studies, price indexes, and population movement to development of new computer models whose problemsolving design incorporates heretofore unused combinations of variable factors.

Oklahoma studies provided a measure of increased crop yield and income per acre (shown in Table 3) as the result of incremental increases in precipitation. The 1976 average increase was 2¼ percent in direct farm income for each inch of precipitation. The multiplier for generated indirect income was 1.40.

The Montana Agricultural Experiment Station at Montana State University predicted at the conclusion of its study additional new revenue attributable to increased rainfall ranged from \$10 million to \$43 million depending primarily upon the rainfall augmentation model used. A 10-percent increase in rainfall during the March to August period with a low estimate of range productivity resulted in a new addition of \$10,211,000 while an optimistic increase model with a higher estimate of range production resulted in a new additional revenue of \$43,000,000.

TABLE 3
[In thousands of dollars]

Crop	Average income 1967-71	Increment for 1 in of added rain
Peanuts.....	2,952	18
Soybeans.....	1,532	13
Wheat.....	1,466	80
Cotton.....	657	118
Pasture.....	8,076	129
Range.....	9,215	195
Total.....	23,898	553

Therefore, we expect that weather modification activities producing at least 10 percent more growing season rainfall will result in an increase in net farm revenue of at least \$10 million.

Research activities funded by the Bureau in several States have included investigations of public attitudes toward weather modification as an alternative for supplementing future water supply. The positive and negative attitudes expressed by people in the various areas are reflected in the decision-making process leading to operational program decisions. Results include formation of local committees endowed with veto authority over seeding operations when local conditions become unfavorable. The surveys also inform researchers of those areas in which additional knowledge must be provided before an operational program will become acceptable in each locale. These concerns lead to additional research in areas of downwind effects, flooding potential, impact of seeding agents, and general environmental impacts.

Further background was added by a comprehensive report on the legal implications of precipitation management, prepared at the College of Law, University of Arizona.

VI. ENVIRONMENTAL IMPACT

The Division is assessing the environmental impact of its experimental and pilot projects and of possible widespread or prolonged application of precipitation management technologies expected to flow from Skywater. The assessment embraces the direct impact of cloud seeding on precipitation, the possible impact of managed precipitation on other components of the natural and human environment, the possible impact of cloud seeding agents on ecological systems, and the impact of field installations and activities incidental to the program.

A special commission of the National Science Foundation reported in 1966 that "the present state of knowledge places uncomfortable limits on the prediction of the biological consequences of modifying the weather" (NSF Report No. 66-3). Speculations as to possible disbenefits were put forward by a working group of the Ecological Society of America and by various other contributors.

The Division commissioned a comprehensive problem analysis of the ecological effects of weather modification, followed by major field researchers into ecological impacts of increased snowpack in the San Juan Mountains of Colorado and the Medicine Bow Mountains of Wyoming. Planning studies for further research studies in support of the Sierra Cooperative Pilot Project and in the High Plains Cooperative Program have been made. The results of this work and of a comprehensive literature review have been assembled into a Draft Environmental Impact Statement which is now in the final stages of review and publication.

A small number of specifically identifiable impacts were found. Prolonged snowpack increases will cause some gradual changes in natural vegetative cover, for example, shifting natural aspen stands somewhat downslope and causing existing natural aspen stands to be invaded by fir. It would somewhat limit the winter range of elk and might lead to expansion of measures now being taken for artificial winter feeding to elk herds.

When snowpack augmentation results in very deep and persistent snowcover, this will reduce the population of small mammals (generally considered as undesirable vermin) though these populations tend to recover fast and to undergo as yet mysterious large fluctuations. For the most part, however, the environmental effects of added snowpack are either entirely absent or so confused with changes from other causes as to be not identifiable. For example, erosion may be increased at the immediate margins of permanent snowbanks but decreased in larger areas where the added meltwater enriches the vegetative cover. Silver iodide, once the subject of speculations about environmental damage, has not been found to cause any adverse environmental effects even at dosages many times greater than would accumulate from prolonged use of cloud seeding.

In the Great Plains area, environmental impacts are most likely to be those already known to be associated with natural periods of slightly above-normal rainfall. For the most part, these impacts are regarded as beneficial. Possible increases in insect pests and diseases appear to be more than offset by increased vigor, productivity, and variety of the biosphere.

Skywater studies directed at possible effects on precipitation far downwind of intended areas of effect have yielded strong evidence of precipitation in-

creases at distances up to about 300 miles. The largest increases, exceeding 200 percent, occurred in valley areas of naturally very scanty rainfall and were not environmentally significant. These results suggest that seeding programs in the future might be designed to take advantage of far-downwind effects.

The Draft Environmental Impact Statement includes an assessment of alternatives to precipitation management. These alternatives range from putting up with water shortage and devoting public resources to other beneficial uses, through expanded application of conventional dam-and-canal water management, to other means of securing "new water" such as desalination.

VII. ADDITIONAL REQUIRED RESEARCH

Although accomplishing the currently approved program will provide the Nation with initial weather modification technologies, additional research is required to fully demonstrate and aid transfer of methods and findings to the public. Future research should also be programmed on broader scale weather systems where larger impacts may be possible. The Bureau suggests three additions to Project Skywater:

A. The Colorado River Basin demonstration project.—A 10-year \$30 million cooperative program has been considered by the Bureau and discussed with the basin States, to increase the flow in the Colorado River Region by approximately 1.3 million acre-feet annually and to fully assess the actual benefits. This program has high priority in the Department of the Interior but has not as yet been included in the Administration's budget.

B. HIPLEX extension for synoptic scale research.—Upon completion of the areawide cumulus research in 1981, begin a 5-year extension for broad-scale modification research.

C. Full local assistance and technology transfer.—Present local assistance to the States of North and South Dakota and Utah is less than \$100,000. To better evaluate State projects and permit fuller use of present techniques, more instrumentation and analysis efforts are required. An increase to the present Bureau programs of about \$1 million annually would provide this assistance.

Mr. Chairman, that concludes our statement, and we would be happy to answer any questions that the committee might have.

Senator PEARSON. We have a vote. We are going to come back in 5 or 10 minutes, and we will go right on with the witnesses.

[Recess.]

Senator PEARSON. Gentlemen, we will start again.

Dr. Battan and Professor Fleagle and Professor Taubenfeld.

I left it to your discretion as to how you should proceed and who should proceed. Why don't you identify yourselves?

STATEMENTS OF DR. LOUIS J. BATTAN, INSTITUTE OF ATMOSPHERIC PHYSICS, UNIVERSITY OF ARIZONA; PROF. HOWARD J. TAUBENFELD, SCHOOL OF LAW, SOUTHERN METHODIST UNIVERSITY; AND PROF. ROBERT G. FLEAGLE, DEPARTMENT OF ATMOSPHERIC SCIENCES, UNIVERSITY OF WASHINGTON

Dr. BATTAN. My name is Louis Battan. I am from the University of Arizona. This is Dr. Fleagle from the Department of Atmospheric Sciences, University of Washington; and this is Prof. Taubenfeld from the Southern Methodist University, Dallas, Tex.

Senator PEARSON. Dr. Battan?

Dr. BATTAN. Contrary to the impression given by the last three speakers, my general view is that the field of weather modification is suffering from lack of nutrition. I think there has been a serious neglect on the part of the Federal Government, and as a consequence,

the progress has been very slow. This is spelled out in the formal statement I have submitted to the committee.

It started out with some early experiments that have been alluded to by a number of people which show that there is no question whatsoever that certain clouds can be modified by means of cloud seeding.

The big question that has still not been resolved satisfactorily is: Can you cause enough snow or rainfall that would not have fallen naturally, that its value exceeds the costs of producing it?

The results of these experiments have been examined by a number of committees in the Government and elsewhere over the last 10 years or more. The gist of the conclusions as I interpret them is that sometimes, given the right circumstances, you can produce more precipitation; other times, less rain or snow; and other times, nothing appears to happen.

The big trick, as I see it, is to learn how to identify those clouds which if seeded in a particular way will give whatever you like. More precipitation or less precipitation.

Senator, you asked: Has there been any progress made with the level of funding that we have had? I think there has been. I think we have learned much more than we used to know about clouds. We have learned much more than we used to know about how to deliver nuclei. I think 15 years ago there was great pessimism about the efficacy of cloud seeding. And 15 years ago there was general pessimism that it could ever work.

However, as a result of a series of analyses made over the last 10 years, the attitude has changed, and I think now it's fair to say that there is a degree of optimism not only among the people who are in the cloud-seeding business, but among the meteorological community as a whole.

There is a feeling that more research will lead to a technology where we can produce more results.

The history of funding shows not level funding but over the last few years diminished funding. The table presented earlier by Dr. Eggers gives a series of figures on funding for weather modification research in NSF, NOAA, and Interior in 1972, 1973, 1974, 1975, and 1976. If the figures are added horizontally you would find for 1973, \$16.4 million; 1974, \$11.9 million; and 1975, \$10.9 million. That is \$16.1 down to \$10.9 million over a 3-year period, and that's not level funding.

The program has been and in my judgment continues to be very, very poorly funded. It is underfunded in order to assure some progress toward a technology whose potential is of great value not only to agriculture but to society as a whole.

Let me then make a few remarks about the specific bills before us. I agree with Bob White that we have had many committees and commissions which have looked at the scientific status of weather modification and spelled out what we need to do. They end up by saying we need more research.

The problem has been that nobody is listening. Nobody is listening in Washington when these reports come out. We wonder why not. The feeling is that perhaps we are talking to ourselves.

I see a need for a Commission as spelled out in S. 2705 made up not of cloud physicists but of a cross section of people whose judgments are respected. They should come from business, Government, and universities and the individuals who can take an objective, unbiased view without any self-interest and say to the Federal Government. This is what should be done or that's what should not be done.

I think that it would be wise if such a Commission was not in an agency which already has a big stake in weather modification such as the Department of Commerce. The results would have greater impact if it was in an agency such as the Office of Technology Assessment.

I support S. 2706. I think we need a large program of weather modification and research in this country. I think it's essential that we have a principal agency. Right now the program is fragmented among the agencies.

When I say there should be an agency with principal responsibility, I don't mean that as sole responsibility. For example, the National Science Foundation, which plays the crucial role of supporting research in the universities should have programs which are larger than they have today.

There are some meteorological circumstances where I feel that weather modification involves a risk that there will be decreased rain or snow. I think it's premature to adopt a bill such as S. 2707, which calls for cloud seeding operations.

Thank you.

Senator PEARSON. Thank you.

Which agency do you think ought to have the leadership? I understand you don't want to centralize it so much that there isn't any conflict of opinion.

Dr. BATTAN. I think the problems are meteorological in nature. I think we have to learn about the physics of clouds and we have to learn the physics of the systems and therefore I think the principal agency should be NOAA because they are in the business. That's what they are told to do. There should be more research going on in this country and in the universities. The university programs have been diminished in recent years because the Federal support has been cut. For example, the Bureau of Reclamation budget was cut in half a couple of years ago and it was supporting schools like the University of Washington, the University of Wyoming and the University of Nevada. Their programs have been cut way back. I think the Federal agencies have some excellent research going on.

Senator PEARSON. Thank you very much.

Senator Bellmon?

Senator BELLMON. You have mentioned that in your opinion the proper lead agency should be NOAA. We have a letter here from the Secretary of Interior, who seems to be somewhat cool toward weather modification.

At the present time I would have to agree that the Bureau of Reclamation is the lead agency. You're suggesting that we move it from the Bureau of Reclamation to NOAA?

Dr. BATTAN. The Bureau of Reclamation has had an aggressive program in cloud seeding over the last 10 or so years. The Commerce program in weather modification up until about 10 years ago was very modest. They have tried to build it up. Some years ago they had a very ambitious plan. They were going to carry out the Hiplex project. They were doing research on the seeding of snowstorms over the Great Lakes. They were doing research in all of these areas and then their budget was cut and their programs were reduced. My understanding is that this was at the instruction of a group of officials at OMB.

Senator BELLMON. If you have this table before you and you were here where we are, how much money would you put in each of those categories?

Dr. BATTAN. Let me say this, in 1966 and 1973 the Academy of Sciences published reports in which it asked for substantial increases in support for weather modification research. In 1966 a special committee set up by ICAS, called for a program in the order of \$90 million by the year 1970. The budget is now down to \$15 million. On the basis of what was happening, what was being done 2 or 3 years ago, I think this program could absorb \$40 million and use the money wisely.

Senator BELLMON. Use \$40 million?

Dr. BATTAN. Yes.

Senator BELLMON. Where would you put it?

Dr. BATTAN. I'm not prepared to say how it would be divided. I think the Bureau of Reclamation program at the level of \$6 or \$7 million in 1973 was used wisely. I think the NSF budget is sadly deficient. I think the university talents in this country are grossly under-used both in terms of research and other purposes.

I think the university program is far from adequate. How I would divide the \$40 million isn't clear. But what I am saying is that 3 or 4 years ago \$20 million was not enough and if you want me to send you a statement on how I would use the \$40 million, I would be happy to do it.

Senator BELLMON. I would appreciate that.

[The statement follows:]

STATEMENT OF DR. LOUIS J. BATTAN

INTRODUCTORY REMARKS

My name is Louis J. Battan and my current position is Director of the Institute of Atmospheric Physics and Head of the Department of Atmospheric Sciences at the University of Arizona in Tucson, Arizona. I have had experience in many aspects of meteorological service and research since World War II when I was a weather officer in the Army Air Corps. During and following graduate work, during the early fifties, at the University of Chicago, I have been involved in various cloud physics and weather modification research programs.

CLOUD SEEDING AND PRECIPITATION AUGMENTATION

Although the earliest cloud seeding experiments in the forties gave promise that snow or rain might be increased by means of ice nuclei of supercooled clouds, it has been difficult to establish the full potentialities of cloud seeding and develop a reliable technology. We still do not understand well enough, the natural mechanisms governing the formation of clouds, rain, snow and hail. The inadequate understanding, coupled with insufficiently detailed ob-

servations of the state of the atmosphere, make it impossible at present to predict accurately the quantity of precipitation which can fall from a cloud system.

The great variability of precipitation, in time and space, particularly during periods of convective storms, makes evaluation of any weather modification procedure a difficult task. In order to know whether or not the seeding has had any effect, it is necessary to know what would have happened had there been no seeding. If you cannot accurately predict the amount (to better than perhaps 10 percent) on physical grounds, and I do not believe that anyone can do so, it is necessary to use the best available physical models and statistical techniques to ascertain whether or not cloud seeding is effective.

The scientific literature going back about 20 years includes discussions of statistical techniques for cloud seeding evaluation.¹ The fact that there still are disputes over the efficacy of cloud seeding is evidence enough that the problem is a very complex one. A review of the literature and attendance at conferences on weather modification convinces most unbiased observers that we still have a great deal to learn about the effectiveness of cloud seeding.

My own views are similar to those expressed in the 1973 report of the National Academy of Science.¹ This is to be expected in view of the fact that I played a role in the preparation of that report. One of its major conclusions as it relates to precipitation modification reads as follows:

"The Panel now concludes on the basis of statistical analysis of well-designed field experiments that ice-nuclei seeding can sometimes lead to more precipitation, can sometimes lead to less precipitation, and at other times the nuclei have no effect, depending on the meteorological conditions. Recent evidence has suggested that it is possible to specify those microphysical and mesophysical properties of some cloud systems that determine their behavior following artificial nucleation. A related problem that has come into sharper focus is to ascertain if, and under what conditions, the seeding of clouds in one area will modify precipitation amounts in another area."

In planning any cloud seeding program it is essential to bear in mind that in most places and times, we still cannot rule out the possibility that the seeding may decrease rainfall rather than increase it. In a carefully designed seeding experiment conducted over a period of seven summers in Arizona, we failed to show that seeding could increase rainfall. In fact, the rainfall was less on the seeded days, but the difference between seeded and not-seeded rainfall probably occurred by chance. In a five-year program of seeding of summer clouds in Missouri, University of Chicago scientists observed less rainfall on seeded days. On the other hand, in Israel, in Florida, in the Ukraine and in South Dakota, some summer clouds yielded more rainfall following cloud seeding than was expected to fall. The point is that the results of seeding of summer convective clouds still are unpredictable. It cannot be assumed that rainfall can be increased by means of cloud seeding. Sometimes just the opposite might occur. In some circumstances, it appears to be possible to identify those clouds which will produce more rain if they are seeded but this does not mean that we have a reliable procedure guaranteed to cause rainfall increases over watersheds or farmlands. A comprehensive program, using advanced ideas on the seeding of convective clouds was conducted from 1970 to 1973 by NOAA scientists to test if rainfall over a target area in Florida could be increased. The results were disappointing in my judgment. Nevertheless, other evidence from experiments cited above indicates that it should be possible, in some circumstances, to increase summer rain.

Two extensive programs to investigate the effects of ice-nuclei seeding on snowfall in Colorado were carried out by scientists at Colorado State University during the period 1960 to 1970. These tests known as Climax I and Climax II lead to the conclusion that clouds having certain definable physical

¹ The following are a few of the major survey reports: "Final Report of the Advisory Committee on Weather Control," vol. II, H. T. Orville, chairman, December 1957. "Weather and Climate Modification: Problems and Prospects," National Academy of Sciences, vol. II, Publ. 1350, 1966. "Weather and Climate Modification," Report of Special Commission on Weather Modification, National Science Foundation, NSF 66-3, 1966. "Weather and Climate Modification: Problems and Prospects," National Academy of Science, 1973. "Weather Modification," First Annual Report, National Advisory Committee on Oceans and Atmosphere, June 1972.

properties were made to yield increased snowfalls when they were seeded by means of ground-based silver iodide generators. It was concluded that by seeding clouds with summit temperatures warmer than -20°C snowfall could be increased; seeding of clouds colder than -27°C would decrease snowfall.

The techniques developed in the Climax Projects were tested in the Colorado River Basin Pilot Project, often called the San Juan Project, which was run under the sponsorship of the Bureau of Reclamation during five seasons ending in 1975. The plan involved seeding, by means of ground-based generators, only those clouds with summit temperatures warmer than -27°C . Analyses completed to date indicate that precipitation on the target area on seeded and not seeded days were not discernably different. Further analyses of available data show that forecasting difficulties resulted in excessively cold clouds being seeded on some occasions. It also has been concluded that in the San Juan area, the silver iodide released at the ground sometimes was not carried into clouds over the target area at the appropriate time period.

Analyses of snowfalls in and outside the original target area led Project analysts to conclude that the silver iodide nuclei caused some additional precipitation from some clouds which were seeded inadvertently.

The results of the San Juan Project, coupled with the Climax results offer grounds for optimism that snow can be increased from orographically induced winter clouds. It is essential to conduct additional research to prove convincingly, if possible, that cloud seeding can cause economically important increases in snowfall.

On the basis of comments made in the press, I believe that some people may be of the mistaken impression that cloud seeding can effectively bring an end to drought conditions. A drought comes into being when abnormalities in the general air currents over a region cause an abnormal degree of air subsidence, at times and places where rising air, clouds and precipitation should be occurring. The sinking air inhibits clouds, and without clouds of a suitable type, there will be no precipitation with or without seeding. Seeding cannot produce rain clouds and cannot change the general air patterns which cause them.

It is true that when clouds do occur during a period of drought, cloud seeding conceivably could cause more rain or snow to fall. Such a result could help alleviate drought conditions. It must be recognized, however, that in some instances, cloud seeding might conceivably lead to less rainfall and an aggravation of an existing drought. At this time, we need more research and development rather than operations based on wishful thinking and inadequate knowledge.

In my judgment it is too early to establish an operational program of cloud seeding operations for the purpose of drought relief. On the other hand, I believe it is vitally important that there be greatly enlarged research efforts directed towards the development of a proven, reliable, effective cloud seeding technology for precipitation augmentation. I support the view that one of the national goals of the atmospheric sciences should be the following:

"The identification over the next decade of the conditions under which precipitation can be increased, decreased and redistributed in various climatological areas through the addition of artificial ice and condensation nuclei."

This is a slightly revised statement of one of the major recommendations of the already cited report of the National Academy of Science. This goal can only be attained if weather modification research is given an appropriately high priority by the Federal Government. From fiscal 1973 to 1974, government support for weather modification research decreased from about \$20 to \$15 million and is no higher today, notwithstanding the recommendation of the 1973 Academy of Science Report that there be an increase. At the current levels of effort, progress in weather modification will move ahead at a snail's pace. This is a sorry state of affairs in view of the enormous potential value of weather modification techniques for augmenting water supplies and mitigating the hazards of severe storms.

In consideration of weather modification activities emphasis is usually focused on the results of investigations involving the test of a specific seeding procedure. It is essential to recognize that one of the chief reasons the effectiveness of cloud seeding is still subject to sharp disagreement is that we do not know enough about the physics of clouds and precipitation. We need to learn much more than you do about such basic points as cloud

droplet growth of ice nucleation processes, ice crystal growth, and the interaction of a cloud and its environment. It is crucial that the scale of research in the fundamental physics of cloud systems be escalated, not only because they are important in their own right, but because they will hasten the development of a weather modification technology.

INSTITUTIONAL ARRANGEMENTS

It has been proposed by various groups in and out of government, that progress in weather modification would be greater if a single agency were assigned principal administrative responsibility for a national program in weather modification. In view of the fact that this is still a problem requiring expertise in the atmospheric sciences, I believe that the National Oceanic and Atmospheric Administration is best equipped to handle the assignment. At the same time, I wish to make it clear that, in my view principal responsibility does not mean sole responsibility. If we are to make rapid progress, those agencies which have had successful programs should be encouraged to enlarge their activities as it relates to their appropriate functions. As important examples I can mention the programs in the National Science Foundation and the Bureau of Reclamation. More is said about this later in the statement.

COMMENTS ON S. 2705

Having made these brief introductory remarks about my views on the status of development of cloud seeding techniques for increasing precipitation, I wish to say a few words about the specific bills under consideration at this hearing.

I support the concept of a National Weather Modification Commission but have some reservations about the details of the proposal they made in S. 2705. Over the last decade, there have been a number of reports by prestigious scientific groups calling for a major research effort in weather modification but they have fallen on deaf ears in Washington. Perhaps a presidentially appointed Commission composed of prominent individuals from the scientific and non-scientific community can cast new light on the subject. Hopefully, the Commission's recommendation to the Federal Government will lead to more positive actions than have resulted from reports by the National Academy of Sciences, the National Advisory Committee on Oceans and Atmosphere and other such groups.

It seems to me that the Commission should review the status of knowledge, what needs to be done, how much it might cost, how long it will take, who should manage the effort and who should do the work. This being the case, I do not believe the Commission should be established within the Department of Commerce which already has a major involvement in weather modification. The Commission's findings are likely to have wider support if they came from a governmental base independent of the various agencies currently having a major stake in weather modification. Perhaps the Office of Technology Assessment would be such a place.

In appointing the Commission, political party affiliations should not be relevant. Fortunately, policy questions in meteorology have managed to avoid partisan colorations in the United States. Dr. Robert White, the Administrator of NOAA, has served with distinction under four presidents, two from each party. Before him, the highly esteemed Dr. F. W. Reichelderfer served for some 25 years. Members of the Commission should be individuals who have had distinguished success and whose judgments will be respected. Among these should be some scientists who have had experience in meteorology or related sciences.

COMMENTS ON S. 2706

I strongly support the proposal that the Department of Commerce carry out a program of research to determine the feasibility of and the most effective methods for drought prevention and alleviation by means of weather modification techniques. In order to make any headway in answering the many questions about the efficacy of cloud seeding, we need an agency that has principal responsibility for advancing knowledge in this field and is adequately funded over a sufficient number of years to do the job. The agency must be prepared to make use of the limited available talent in government, universities and the private sector.

Because the weather modification problem is mostly a meteorological one, the National Oceanic and Atmospheric Administration is the logical agency to be given principal agency responsibility, but as I noted earlier, the term principal should not be taken to mean sole responsibility.

Agencies such as the Department of the Interior and Department of Agriculture should be encouraged to pursue those areas of weather modification research which bear on their mission responsibilities. I believe it would be a serious mistake to restrict all research to one agency. A certain degree of overlapping efforts are essential to increase the advance of knowledge and to serve as cross checks on the validity of claims.

It is vital that the creative talents in the universities of this country be brought to bear on the weather modification problem. Several years ago the Bureau of Reclamation, through its support to universities, developed a number of strong university programs in cloud physics and weather modification. When the Bureau's weather modification budget was cut in half a few years ago, many university programs had to be reduced drastically. Research and educational activities were seriously damaged.

The level of support for weather modification research in the National Science Foundation, the main source of university support, has been fairing poorly over the last few years. It was about \$4 million in fiscal year 1974 down from \$5.4 million two years earlier.

A review of the scientific literature shows that university scientists make a major share of the contributions, particularly in the area of basic research on the choice of clouds and precipitation. In addition, universities produce the scientists of the future. If we are to make significant advances in the atmospheric sciences, and in weather modification in particular, it is essential that university scientists be an integral part of the scientific planning and decision making apparatus and be adequately funded to carry out research.

In the past, NOAA's contributions to university research and educational activities have been disappointing when compare to the size of its internal programs. If NOAA is to be given principal responsibility in weather modification, it should also be given major responsibilities in assuring the vitality of university programs of research and education.

COMMENTS ON S. 2707

In view of the uncertainties about the effects of cloud seeding, and the recognition that, in some instances, cloud seeding may decrease precipitation, I believe it is premature to engage in operational cloud seeding for the purpose of drought alleviation. For this reason, I cannot support S. 2707.

Senator PEARSON. Professor Fleagle?

Professor FLEAGLE. Mr. Chairman, I am Robert G. Fleagle, professor and chairman, department of atmospheric sciences, University of Washington. I have been active in the study of Government policy relating to weather modification for more than 10 years. A report of some of this work was published in 1974 under the title "Weather Modification in the Public Interest." This book was distributed by the American Meteorological Society to all Members of Congress and should be in the files of this committee.

The long history of weather modification shows that a real national program does not exist. There is no national policy within which agency programs can be developed. Despite the importance of weather modification to national policies relating to food, energy problems, and natural hazards, there is no lead agency responsible to the Congress and the President for coordination and leadership, although the critical need for such a lead agency has been identified by the National Academy of Science's Committee on Atmospheric Sciences, by the General Accounting Office, and by others over the years.

As a natural consequence budget decisions of the individual agencies are responsive primarily to their individual missions. When budgets are squeezed, as we have already heard, weather modification programs often have been sacrificed.

For example, when, in early 1973 political decisions led to extensive budget impoundments, weather modification research received a blow from which it has never recovered. Five of seven national projects at that time were interrupted or terminated. Among these were the High Plains project, the Great Lakes project, Project Stormfury, all of the Department of Commerce, each one, a project of considerable promise.

A lead agency is important to programs of weather modification because the fundamental problems require extensive field programs. For example, learning how to increase precipitation in a target area, we must also learn what the possible effects downwind may be, otherwise the benefits in one region could be canceled out by losses in another. Progress on this problem has been slow and I believe this is related to the fact that research programs have been submarginal in scope, in support, and in quality. A lead agency is needed to be responsible for drawing up objectives and plans, providing stable support, and insuring the necessary high quality science.

My views on the three bills follow in large part from what I have already said. I support S. 2706 concerning experimental research programs on the feasibility of drought prevention. This program might help greatly to cure the chronic illness which has afflicted weather modification. It would establish the Department of Commerce as the lead agency responsible for leadership. As the agency responsible for prediction of weather, the Department of Commerce has the necessary broad expertise and understanding of the atmosphere. I am especially glad to see the provision for an annual report to the Congress and to the President. This would help to insure the necessary high quality science and would emphasize the importance of agency responsibility.

I oppose S. 2707, which authorizes grants to States. This bill reflects some of the same misconceptions which have been responsible for failures in the past. I will leave to my written statement the evidence on this point.

S. 2705 establishing a national commission would be useful in reviewing agency funding and interagency coordination. However, it seems to me that a national commission would be more effective if it had a considerable broader mandate. A study carried out by highly qualified and respected individuals with a broad knowledge and vision should be addressed to the Nation's capacity to meet problems of inadvertent weather modification, air quality, and climate changes, as well as problems of deliberate weather modification.

I believe such a commission might be more effective than one addressed solely to deliberate weather modification, a field which has been studied many times, as we have heard this afternoon.

I emphasize this because the environmental problems I have listed are closely related scientifically, and consequently it seems to me a consistent policy should be adopted for them.

This concludes my statement.

Senator PEARSON. I confess in the day-by-day routine you don't think about weather modification until you have a drought in western Kansas. But what are the areas in the country that are or should be very concerned about weather modification?

Professor FLEAGLE. Virtually every area has a stake in and stands to benefit from possible improvements in weather modification technology. One of the problems is that the various regions of the country suffer from very different kinds of weather.

And this, I think, in part has led to the fragmentation, or at least it has encouraged the fragmentation which we have experienced, with one agency responsible for research on lightning to suppress forest fires, for example, and another agency, hurricanes, and so on.

Senator PEARSON. Senator Bellmon?

Senator BELLMON. You said we need a lead agency. And I believe Dr. Batton chose NOAA as that agency.

Would you agree?

Professor FLEAGLE. Yes. I pointed out in my statement that because NOAA has the responsibility and the expertise in observing and predicting the atmosphere, it seems to me NOAA has the logical base on which to develop a comprehensive high quality program.

Senator BELLMON. Now, if we're going to have a lead agency, the only way that agency will be effective is for it to have control of the money. You have seen this chart that was attached to Dr. Eggers' statement, in which it shows a breakdown of the agencies.

Would you channel most of those funds to NOAA or to the Department of Commerce if you were to make them the lead agency?

Professor FLEAGLE. I think the benefits of diversity should not be overlooked. And by naming NOAA as the lead agency, I would not want to have that imply that all funds should be channeled through NOAA.

I do think that the bulk of an enhanced weather modification program should have the major funding in NOAA, because as I see it, the central needs are for major programs involving large expenditures.

Senator BELLMON. Dr. Battan mentioned the figure of \$40 million. Does that seem like a realistic level of funding for weather modification to you?

Professor FLEAGLE. It sounds about right.

However, I think it would be irresponsible not to make one other point, and that is that in listing the various ills that weather modification has suffered under for the past 20 years, I put leadership and coordination higher than lack of funding.

I would like to see that problem solved first.

Senator BELLMON. Do you feel these bills solve that problem?

Professor FLEAGLE. S. 2706, the bill establishing a research program, it seems to me, goes a long way toward solving that problem.

Senator BELLMON. And you mentioned that you would like to see the Commission have a broader charter. Do you think the makeup should be about the same? Representing the Government and States and the private sector and the universities?

Professor FLEAGLE. I am somewhat uncomfortable with the designation of the makeup. It suggests that the members of the Commission are to be representatives of constituencies, and it seems to me that that is not a desirable type of commission. Rather, I prefer a commission made up of objective, wise, experienced statesmen of policy, science, and business, without specific regard to their constituencies.

Senator BELLMON. You would leave it to the President to choose the members?

Professor FLEAGLE. Yes. I think it's clear that a broad representation has to be achieved, but to designate them on a one-by-one basis to certain constituencies seems to me undesirable.

Senator BELLMON. Do you think that present language is too narrow? Could you look that over and give us your recommendation as to how you would restructure the Commission, not now, but for the record?

Professor FLEAGLE. Yes, I would be glad to.

[The statement follows:]

STATEMENT OF ROBERT G. FLEAGLE

Senator Pearson, and members of the Committee, I am Robert G. Fleagle, Professor and Chairman, Department of Atmospheric Sciences, University of Washington. I have been active in the study of weather modification and in particular in government policies relating to weather modification for more than ten years. A report of some of this work was published in 1974 under the title, "Weather Modification in the Public Interest."¹ This book was distributed by the American Meteorological Society to all members of Congress, and should be in the files of this Committee.

I believe I can be most useful to this Committee by speaking to certain policy problems which have helped to make weather modification a controversial subject among scientists, government administrators, commercial operators, and the general public for more than 30 years. Let me recall to you that a joint university-government research program showed in 1953 that winter snowfall over mountains could be increased by about 15 per cent. For more than 20 years this conclusion has stood without substantial revision, despite innumerable efforts to prove the effectiveness of seeding techniques. Seeding to increase precipitation from other types of clouds, to suppress hail, or to modify hurricanes has not yet produced proof of positive results, although there remains evidence for optimism. It is necessary to ask what has constrained advances in weather modification and what must be done to rescue this potentially valuable technology from endless frustration.

To answer this question one must recognize that research in the physics of clouds is inherently extremely difficult, and that therefore the best in scientific talent and facilities is required. But progress over the past 25 years has been constrained by the administrative weather and climate which has determined national policies for weather modification. It is unnecessary to review the history which leads to this conclusion because reports of many studies are available which enable us to identify the major policy deficiencies which have made it difficult if not impossible to develop a research program of the needed quality and scale.

However, the following list of policy actions taken by Congress over the past 23 years may be helpful in providing perspective to the problem.

1953 P.L. 83-256 established President's Advisory Committee on Weather Control.

1958 P.L. 85-510 Assigned lead agency responsibility to NSF.

1967 S. 2916, assigning lead agency responsibility to Department of Commerce, passed by Senate, but did not become law.

¹ R. G. Fleagle, J. A. Crutchfield, R. W. Johnson, M. F. Abdo, 1974: "Weather Modification in the Public Interest," Univ. Washington Press, 88+ pp.

1968 P.L. 90-407 removed NSF mandate as lead agency.

1969 P.L. 91-190 (National Environment Policy Act) required impact statements.

1971 P.L. 92-205 required filing of reports of nonfederal weather modification activities with Department of Commerce.

1973 OMB impoundment reduced fiscal year 1973 weather modification budget from \$25.4 million to \$20.2 million.

This sequence of actions reflects the fact that, despite frequent references to the contrary, a National Program in weather modification does not exist. Development of capabilities to increase water supplies by seeding or to modify hurricanes are not treated as national policy issues by the Executive Branch or by Congress, even though successful efforts clearly would heavily impact national policies relating to food, energy, and natural hazard. There is no lead agency for weather modification research, although reports of the National Academy of Science Committee on Atmospheric Sciences,² the General Accounting Office,³ and others have identified this as a critical need. As a natural consequence, budget decisions are responsive at best to individual agency perceptions of the national interest. When, in early 1973 political considerations led to extensive budget impoundments by OMB, five of seven weather modification research programs which had been identified by the Federal Council on Science and Technology as National Projects were arbitrarily terminated or suspended. The total federal budget for weather modification was reduced from \$25 million to \$20 million, and it was subsequently reduced still further to \$15 million with consequent interruption of much promising research. The lack of stability which this example illustrates has been typical of the field of weather modification.

The atmosphere does not give up its secrets easily. To develop reliable methods for increasing precipitation, or to discover whether hurricanes can be modified beneficially requires the following elements: excellent science, stable support, and effective inter-agency coordination and leadership.

I will turn next to the three bills which are before you. S. 2705, establishing a National Weather Modification Commission, could be a useful step especially in reviewing agency funding and interagency coordination. I should like to suggest that the Commission should be composed of highly qualified and respected individuals of broad, objective knowledge and vision, not of representatives of constituencies as proposed in Section 3. I am concerned, also, that in specifying that not more than five members be of the same political party, the bill places the Commission in the political arena.

However, I should like to suggest that such a National Commission could be more effective if it had a considerably broader mandate. There is an array of related environmental problems badly needing the kind of attention a National Commission could provide. I suggest that a broad study addressed to the nation's capacity to meet problems of inadvertent weather modifications, air quality, and climate change, as well as deliberate weather modification, might be more effective than a commission limited to a field which has been studied many times. I emphasize this because these problems are closely related scientifically; consequently a consistent policy should be adopted for these environmental fields.

With respect to S. 2706, concerning an experimental research program to determine the feasibility for drought prevention and alleviation. I believe this program might go far to care the chronic illness which has afflicted weather modification. In effect, it would place responsibility for leadership for this important part of weather modification in the Department of Commerce where I believe it should be. The stated objective is important and reasonable, and the proposed ten year program provides a realistic time base. I am especially glad to see the provision for an annual report to the Congress and the President which I believe would help to insure the necessary high quality science and would emphasize the importance of agency responsibility.

² NAS-NRC Committee on Atmospheric Sciences, 1971. The Atmospheric Sciences and Man's Needs: Priorities for the Future, Washington, D.C.

³ NAS-NRC Committee on Atmospheric Sciences, 1973: Weather and Climate Modification: Problems and Progress, Washington D.C.

⁴ General Accounting Office, 1974: Need for a National Weather Modification Program, Report to the Congress.

I do not have the same high opinion of S. 2707 as I have of S. 2706. This last of three bills authorizes grants to states for the purpose of preventing or alleviating drought by weather modification. I believe this to reflect several misconceptions regarding the field of weather modification, misconceptions which have been in large part responsible for the frustrations the nation has experienced in this field. First, the greatest need in weather modification is for high quality research; our knowledge and capabilities are not adequate to justify drought prevention programs. Second, we need major, well managed programs; this bill would be likely to dissipate resources in submarginal efforts. Third, drought typically occurs on a scale larger than a single state. Fourth, and finally, passage of the bill would encourage states and private citizens to place more faith in weather modification than can be justified. For these reasons, I do not believe S. 2707 is in the national interest.

To summarize, I support S. 2706, I believe the Commission established under S. 2705 could be helpful, but a broader mandate should be considered, and I believe S. 2707 should not be approved.

Senator PEARSON. Professor Taubenfeld?

Professor TAUBENFELD. I am Howard Taubenfeld, and I come to this committee with a couple of different backgrounds or hats.

I have been the director of a study on the legal implications of international weather modification published in 1970 under the title, "Controlling The Weather, A Study Of Law And Regulatory Processes," which was translated into the more interesting title of, "Controlling the Weather." We were in fact concerned with controlling those who were trying to control it.

I am presently the director, and we are writing our final report, of the NSF-funded Study Group on Societal Implications of Intentional Weather Modification. I have made available to you the outline of the final report. That study involves some 20 or 25 individual studies. Those are available at the NSF.

Also, I am a nonphysical scientist. I am a lawyer and a political scientist. I may be the only one on this side of the table today.

I am also chairman of the Advisory Committee on Weather Modification to the Texas Water Development Board, which gives me a somewhat different perspective, too. I was once introduced in your State of Oklahoma as the next speaker after a man who described the hot air which blows in from Oklahoma to Texas; then they introduced me. I moved on from that point.

We have already experienced a number of the problems you raised earlier. We actually, in Texas, by number, license more weather modification operations which are designed to affect Oklahoma than are designed to affect Texas. We license seven or eight of Dr. Krick's projects annually located in the northern areas of Texas.

I must tell you that when I raised the question with our staff as to whether they could certify to us that these do not affect Texas, their answer was that, since they couldn't affect anything, anywhere, it was OK for us to license them.

But the actual issue remains. I am not as convinced as staff that we're not licensing operations which have an effect in Oklahoma.

I have also furnished to you some testimony delivered to the Subcommittee on Climate Change of the Domestic Council last spring, which I want to summarize in just five or six words, because we suggested there, from the preliminary findings of our study group, that, as many of my colleagues have suggested, weather modification

has been treated by the Federal Government, which is the only substantial funder, as a very real backburner operation.

It has suffered from inadequate funding. But in dealing with this inherently very complex subject of the atmosphere, it has been not only inadequate in numbers, but, and I think that's part of the thing we haven't come to grips with, the nature of the Federal funding effort has insisted not merely on low numbers, but on short-term funding.

I notice with approval that the current bill suggests a 10-year program for precipitation augmentation. It is entirely possible that a definitive program to establish any of these facets of weather modification might very well be a 10- to 20-year program, and we don't seem to know how to do such programs, except perhaps in nuclear energy.

We were, in our study group, asked initially to deal with ICAS 15-A, which was a definition of responsibilities among the agencies, in a particular document.

That plan did have in it, for example, the establishment of NOAA as the entity that would do the large precipitation augmentation program. While we were looking at that as one of the interesting notions of how the Federal effort might be channeled, the OMB came along and said: No, NOAA is out of that. The Bureau of Reclamation will do it with only a fifth of the budget. That affects the level of funding if you shift programs around without the agencies themselves being responsible for making the changes.

Also, there have been interagency rivalries which have led to fragmentation.

There are two other major points that have gone into Federal projects so far. One of the difficulties which we have insisted on calling to the attention of agencies is that these programs have been designed initially by atmospheric scientists who have assumed that the basic problems were inherently science or meteorology. They are not.

Very real problems are these: Suppose you know something more about the atmosphere and can do something. Should you? How do you compensate the "losers"? In no case has any of these programs contained the input, in the designing of the scientific programs, so that it would reflect all the answers you wanted, of lawyers, social scientists, and others.

Some of them have had social scientist components, but they have not been designed initially to yield all the answers, and that increases the complexity. None of them has built in any liability component.

If, as Dr. Eggers told us earlier, one of the true findings of the hail suppression program is that, in fact, during the program, hail was increased, what do those who suffered through the program in silence now do, particularly if they have clever lawyers in the community?

There are very serious problems and I would be opposed to a bill like that proposing a Federal funding for precipitation augmentation during drought without at least two additional major components.

One, that even though there is a drought, at least half of the area is reserved for nonseeding operations. In other words, that this be conducted as a scientific experiment.

And second, if you tell me that this will cause problems which you could have alleviated, then I tell you that you should build into the program recompense for those who lose.

Thus far, in weather modification, the Congress and the agencies have been content to shift those costs on to those on whom the research has been done. When you are looking at these issues, these social costs can be shifted, perhaps to foreigners, but they cannot be eliminated. The hail program's impact statement talks about northern Colorado as a sparsely populated area. So is western Kansas, where part of the effects may have been felt. So is western Nebraska, but the people living there don't feel as if they are living in a nonhuman area.

I suppose that I should stop. You probably have some questions, but I do want to suggest one alternative to the Commission's study approach.

If there is to be a Commission, I think a strong case can be made for the Commission being a Presidential committee or another form that does not involve a particular operational agency. That does something to the credibility of the performance, no matter what else happens.

I want to suggest an alternative which we do suggest very briefly in this Study Group testimony if weather modification is to be something other than a backburner operation, if, because there is an increasing need for food and fiber, and if, for example, in the Great Plains augmentation you are not just relieving a little drought—if you can get a little more water incrementally, you increase the value of large areas of land a small amount, not just the areas of immediate impact, but each area that grows down from that.

Particularly in the Midwest the value of land is highly weather dependent. We propose that at least one might explore the notion of a national center for research into this kind of alteration of the environment, a national center to conduct the modification research which would be well funded and well endowed, and staffed by social as well as physical scientists who could assess implications and develop the information base needed to assess the implications ultimately when any technology was being tested and became operational.

Thank you.

Senator PEARSON. Professor, in looking at the various agencies, did you perceive a recognition of some of the elements you have been talking about, the legal and social implications?

Do you think they are recognized by the Government agencies?

Professor TAUBENFELD. That there are implications is recognized by the agencies in the field, as Dr. Kahan pointed out. His agency has funded studies of the legal implications of Snowpack and of weather modification.

Our effort of societal implications has been funded by NSF. And NOAA, a little bit less than some of the others, has funded studies, too. But these have generally been taken as add-ons to the scientific programs. They have been done simultaneously or after the event.

They have not, typically, in history, been components of the decision to do a program or of the design of the program.

Senator PEARSON. Then they do not inhibit the agencies?

Professor TAUBENFELD. These are not designed as inhibitors, but as expanders of the basic research design. In the hail program, the initial hail research program did not take into effect downwind effects. This is a scientific problem, which is debatable. But from our point of view or from my point of view, if that program had gone in accordance with the so-called Russian model, and if it had determined that in that area where you were attempting to suppress, you had suppressed, you still wouldn't know whether you should do the work or not, because it could be that 50 miles downwind you were causing twice as much hail or no rainfall.

Simply shifting, for example, the notion of reducing large hail to small hail, is not necessarily a victory. If you increase the wind speed, you may create more devastating hail. One doesn't know.

So my argument here is that the initial research design should be designed to furnish all the information that economists, lawyers, and others will need, so that they can answer the question ultimately. If the technology succeeds, is it worth doing! Is it appropriate?

Let me also say that some of the dilemmas become enhanced internationally. We have now a very brief treaty with Canada about weather modification. There has been a very serious crimp placed in the potential of moving the hurricane suppression work to the Pacific, because the Japanese and the Chinese Governments have said it's risky.

When one asks about whether there have been conflicts, there is no conflict in that last case; we're just not doing it. And I think that's something you need to take into account. And part of the reason is that the program was not developed in a way that led to an understanding or might have led to an understanding of all the factors involved.

I don't know that you could ever get the Chinese to agree to anything. That's a different problem.

Senator PEARSON. Senator Bellmon?

Senator BELLMON. Professor, it seems to me that the thrust of your testimony is that we need to be considerate of the full ramifications of weather modification and that is one of the purposes of these bills. We want to have a well-monitored program to be sure we know what we are doing when we get into this. I don't know that the Federal Government would ever want to impose its will on an area unless the people in the area indicated some willingness to participate in these kinds of experiments. Don't you think that the local people should be involved in a decision as to whether the weather in their area will be modified.

Professor TAUBENFELD. I think you do need to be very considerate that way. If you do not accept even at the Federal or State level the notion of responsibility if damages do occur, you find or will find, as we have at the State level, that the answer is a political action and the answer by the people affected is to drop out of the programs entirely. Since I believe that there are on balance far more good things that modification research might lead to than potential harms, I hate to see that happening.

We are already experiencing it in Texas. When a group of parties who felt that their water was diminished by private hail suppression

programs lost in an attempt to get an injunction, a well-fought suit, they moved to the legislature, and now we have a change in the law permitting that an election be held to determine whether weather modification can be done.

My point is that you do move to political actions.

I am supportive of the notion of trying to achieve agreement. I would protest the notion in the 10-year program of suspending the Federal program when a State Governor says, "There is an emergency, and we want to get involved in a direction action," as if he is saying, "We know what we are doing, so you hold off."

Senator BELLMON. It is anticipated under this bill that if there is a Federal program there will be areas treated and areas left untreated. It may be difficult of a Governor to say to a group of people: "You cannot benefit by weather modification."

Professor TAUBENFELD. But then you are back to the original notion that if it happens in the third year, then all bets are off and you come back and start the research all over again.

Senator BELLMON. The program hopefully would continue once the emergency was passed.

Professor TAUBENFELD. I have problems with that.

Senator PEARSON. Thank you very much.

Dr. Booker?

Dr. BOOKER. I have a formal statement which I think I have given you. I would rather not read from it.

Senator PEARSON. We will put the entire statement in the record and you summarize it and treat it as you wish.

**STATEMENT OF DR. D. RAY BOOKER, AEROMET, INC.,
NORMAN, OKLA.**

Dr. BOOKER. Fine.

Weather modification is 30 years old now, this spring.

I have been involved in it about half that time. I came into weather modification as one of those who doubted that it would ever amount to anything. However, I was funded to do some research in that area and continue to do research today. I found that in flying through some 3,000 storms with a light aircraft, making measurements, a number of things became very clear.

First, I found that storms are extremely complex. When I take an airplane and fly into a storm and attempt to see that thing with a few grams of material, it is a very humbling experience. There are many unknowns in the realm of weather modification. And any man who tells you we understand it all is overstating the problem.

But I can't say that we have learned nothing. I can't say that even though there are many things yet to be learned that we should not be doing operational weather modifications.

To me the problem in weather modification can be illustrated by a corporation. I have experience in operating a corporation. I have operated a manufacturing corporation. Manufacturing companies are made up of different departments. You have a marketing department whose job it is to know what the market needs. A company also is made up of an R. & D. department. An engineering department whose

job it is to develop the products according to what the market needs as the users express it. A company is also made up of a production department whose job it is to produce in the most efficient possible manner those products once they have been developed. There are other departments. Let's just stop there and look at these.

In weather modification we have corollaries to these departments in a corporation. The problem, as I see it in weather modification, is that there is no plan calling for these departments to work together. The R. & D. department, made up by the Federal Government, is our R. & D. department. The private operators in the States who operate weather modification programs are the production department. We have a credibility problem between these two departments.

The scenario that prevails is that when a drought occurs, the city's lake is dry of water and the State's crops are going to waste. People become alarmed and hire a cloudseeder. Or the Government comes in with a hurryup program of some sort called an emergency drought relief effort. The scientists knowing the problems say these operations are not well thought out and should not go on. The operation should wait until we have finished our research.

The operators say: "It costs 3 to 5 cents an acre. To do a weather modification program."

I think it is unfair for the scientific community to say that these operations should not go on. Much of the funding that occurred in weather modification in the late 1960's and early 1970's resulted from a review of data from operational projects.

It is very, very difficult to look at the results where commercial cloud seeding has gone on for 26 years and each year the mounting evidence becomes more and more certain of an 8-percent increase in the snowpack worth millions of dollars and costing very little. It is so certain that no one can contest the validity of those results.

This was not a research program. It was simply an operations program. My point is that weather modification is divided into several segments. The basic problem surrounding weather modification is credibility between these segments.

S. 2705 is right in its time and it is right in its content. The main thing that is good about S. 2705 is that it calls for a Commission made up of representatives of constituencies, representatives of the departments of weather modification, if you will.

It is because of this that I believe this is the most important group, which will have looked at weather modification for many years.

Senator PEARSON. Have we had other commissions?

Dr. BOOKER. Yes.

Senator PEARSON. What did they tell us?

Dr. BOOKER. What they told us was that in examining the facts of weather modification there are few things we know but there are many things we don't know. And because of these things we don't know and because of their potential to be applied we should invest more money in research.

But my problem with those committees is that their representation did not include the different constituencies who are concerned about weather modification. And because it did not represent the interest of these people they lack credibility.

And if I were on that side of the table, I think I would also doubt—

Senator PEARSON. Do you think the Government agencies have attitudes that range somewhere between pessimism and being timid about the jobs in weather modification?

Dr. BOOKER. That is fair. I am not sure the Federal agencies are in tune with the needs.

Senator PEARSON. You seem to be saying that people outside the Government are very optimistic about their capabilities.

Dr. BOOKER. We are saying we don't know nothing. We know some things. And we should apply what we know. It is important to put the emphasis in research where the potential payoff is. I am uncomfortable with spending money on rain enhancement programs overseas. I would like to see that money spent in Oklahoma and Kansas and South Dakota in those areas where grain is raised that feed the cattle that support our tables.

If we look at your State and my State north to Minnesota and Montana, we find that most of the rainfall occurs at night. Many of us recognize this. The commercial operators are required to see around the clock 7 days a week.

The operational projects are uncomfortable with seeding at night because there has been no research done on nighttime storms. I think the basic reason is that our R. & D. department does not recognize that nighttime is when the most potential shower clouds occur. We don't even have a good radar climatology for nighttime storms. We don't even leave the radars on at night. I think we should have our scientists up at 3 o'clock in the morning to research on those nocturnal storms.

Senator PEARSON. You obviously operate in several States. Does one particular jurisdiction, to your mind, represent a more enlightened approach so far as the legislation that covers it and the rules and regulations?

Dr. BOOKER. I think perhaps yes and no. I think the development of the State programs, although they have been criticized, is good. This development of State programs has been led by South Dakota and by North Dakota. Other States are developing rather good programs now.

The thing that has happened is that the era of the cloud seeder who comes into an area and passes a hat for a few volunteers to pay for a rather temporary weather modification operations is being replaced by more deliberate and well-planned operations funded at the State level and protected by State laws.

And interstate agreements. And I think the area in the Northern Great Plains from North Dakota to Texas is the area where the greatest progress is being made at the State level. The people in that area probably are leaders in the development of operational programs. They are, however, pleading for research to be superimposed on operational projects in their areas.

Senator PEARSON. Well, we have quack doctors and shyster lawyers. Would there be fly-by-nights in this industry? Who are they and are they detectable? What about the fraud and corruption in this field?

Dr. BOOKER. I got in a lot of trouble a few years ago naming names, so I won't name names today. But yes; they do exist.

As Dr. White pointed out today, droughts are caused by weather phenomena on a continental scale.

Senator PEARSON. Have the States corrected those situations?

Dr. BOOKER. It is being corrected. It is slow, but it is being corrected. The field is maturing, I believe.

Senator PEARSON. Thank you very much, Doctor. We are going to leave the hearing record open for 2 weeks.

I think during the course of these hearings we have asked several people to answer our inquiries in writing.

[The statement follows:]

STATEMENT OF DR. D. RAY BOOKER

BACKGROUND

Those of us who live in the middle west have personal and intimate experiences with the severe droughts of the 50's and early 70's. We remember the economic disaster caused by losses of crops which led to shortage of feed for animals and ultimately to scarce and high priced food for our tables. The drought years have directly influenced many other important aspects of our national economy, particularly including the national balance of payments.

In other countries, droughts have been even more devastating. In Africa, several years of drought wiped out most crops and decimated livestock herds, to the point that decades may be required to recover. Widespread malnutrition and even starvation have been a direct result of years of drought. The effects of damaging storms has also been felt, but to a smaller degree.

It is most important to recognize that weather modification can not eliminate drought or damage from severe storms. However, the impact can be dramatically decreased by a viable weather modification technology. Studies by North Dakota State University have estimated that one inch of additional rainfall during the growing season would add three hundred million dollars to the gross state product. The benefit to the nation, with widespread application, should be several billion dollars with similar increases in rainfall on dry years.

The cost of operational weather modification projects is extremely small compared to the other costs in agricultural production. In South Dakota, where a farmer typically invests sixty to one hundred dollars per acre in his crop, a weather modification project for increasing rainfall and decreasing hail has cost less than four cents per acre per growing season.

If weather modification is so attractive, why have we not developed a generally applied weather modification technology during the last thirty years? I believe the greatest reason is that we do not have a national weather modification policy. We do not have a plan which identifies the greatest needs and directs our research resources to solving problems identified by the users of weather modification.

A NATIONAL WEATHER MODIFICATION POLICY

The major reason for slow progress is that we do not have a plan for developing and implementing weather modification. There have been numerous studies of weather modification by high level and knowledgeable panels. Each has recommended a substantial increase in our national effort to develop this science because of a recognition that the enormous potential benefits are worth the investment of substantial research funds. Yet, these recommendations have led to nothing.

Weather modification is a science with severe sectors, each having little dialog with the others. There is the research community which has been almost entirely supported by federal funds. Federal employees and university researchers make up most of this group. There is an operational sector which has been made up of private operators. Several states have developed state funded, large scale operational programs and have formed an association known as the North American Interstate Weather Modification Council. The states can be counted as another sector. The end users, primarily represented by farmers, power

companies, municipalities and others who buy weather modification services are a fourth sector. Other interests are concerned with social, legal and environmental implications.

The problem with previous high level studies of weather modification is that they did not include active leaders of the several interested sectors.

S. 2705 suggests a National Weather Modification Commission which would be made up of representatives of the several interested sectors. The commission would conduct an intensive one year study leading to a draft of a national weather modification policy. This policy is vital to the future usefulness, or perhaps the survival of weather modification. The report of the commission would likely have the largest possible body of support because it would present a balanced view and recommendations which would truly be in the national interest.

I believe S. 2707 is the most important piece of legislation concerning weather modification which has ever come before the congress. It is right because it proposes to develop a plan. With this plan, we can develop and implement weather modification in the public interest. Without it, we can only look forward to continual inefficiencies and controversy and possible the demise of this science.

I urgently recommend the passage of S. 2705 as it is written at the earliest date possible.

WEATHER MODIFICATION RESEARCH

The \$17 million to \$18 million this country invests annually in weather modification seems small in view of the potential benefits to be derived from an operational weather modification technology. The full truth, however, is only available if we look at what this money is spent for. A great deal of it goes for very expensive airplanes and in-house federal staffs. Most of the money is spent on research for which there is no plan for implementation. Very little of it is spent on developing methods of mitigating the effects of drought.

A study by the North Dakota State University indicates the gross state product of North Dakota would be increased by at least \$300 million through the addition of one inch of additional rainfall during the growing season. This benefit would undoubtedly be several billion dollars if the same increase were spread over several states. Disaster relief payments could be substantially reduced if an inch of rainfall were available in dry years.

The spectre of drought is now creeping across the middle West and Western states. Substantial damage has already been done to crops in many states. If the drought continues into summer, we must expect a clamor for emergency drought relief programs like the hasty and ineffective ones we saw in 1971-1973. As our agriculture capacity becomes more strained, we can only expect this clamor to increase in future drought years.

We do not have a research program to cope with the impending need for answers. Our paltry investment in drought relief research can not provide much support for even the existing operational programs and can not hope to cope with future demands.

For these reasons, and more, I support S. 2706. This bill is right in its purpose, its scope and its time. The only reservation I find is that the research program suggested will not find the fullest possible support if it is placed in any one federal agency. I suggest the project be funded by a federal agency and be run by a non-profit corporation which is formed especially for and dedicated to this research project, and which would cease to exist at the end of the research project. Such a corporation can be formed by a cooperative of states with interests in weather modification and can be partially funded by those states.

OPERATIONAL WEATHER MODIFICATION

Several states now have state-funded large scale operational weather modification programs, primarily for agriculture users. The benefits to be derived from the success of those programs belong as much to the federal government as to the individual states. The U.S. has a vital interest in our national agricultural productivity, the extra business it generates, the balance of payments, disaster-relief payments and even the tax revenues to be derived.

It is therefore logical and reasonable to me for the federal government to help with the cost of operational programs in the manner proposed by S. 2707. I support this bill as it is written.

SUMMARY

Weather modification deserves to have a focused federal program, if only to make more efficient use of our present investment. It is therefore vital that we create a policy which can be supported by all the interested sectors. This can only be done by a congressionally authorized, Presidentially appointed and representative commission such as is suggested by S. 2705. I urge passage of the bill.

Our national interest is best served by investing research dollars where the greatest potential benefit is. It is clear to me this is in drought alleviation. Therefore S. 2707 proposes a project which may be one of the most cost effective investments which can be made by our congress.

Operational weather modification is the means of recovering our research investment. The federal government should protect its interest by assisting the states in paying for scientifically viable operational programs. I therefore support S. 2707.

Senator PEARSON. I think Senator Bellmon wants to submit some questions to be answered in writing.

We thank you all very much for participating.

[Whereupon, at 6 p.m., the hearing was adjourned.]

ADDITIONAL ARTICLES, LETTERS, AND STATEMENTS

UNITED STATES SENATE,
COMMITTEE ON AGRICULTURE AND FORESTRY,
Washington, D.C., February 23, 1976.

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

DEAR MR. CHAIRMAN: I am enclosing a statement from Vern Butler, Secretary of the South Dakota Department of Human Resources and Chairman of the Weather Modification Council concerning S. 2705, 2706 and 2707 on which your Committee held meetings last week.

I would appreciate insertion of this statement into the Hearings record.

With every good wish, I am

Sincerely,

Enclosure.

GEORGE MCGOVERN.

NORTH AMERICAN INTERSTATE COUNCIL,
Las Cruces, N.M., February 19, 1976.

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

DEAR CHAIRMAN MAGNUSON: As Chairman of the North American Interstate Weather Modification Council (NAIWMC), I would appreciate having this letter and the attached position papers entered into the hearing record on S. 2705, S. 2706 and S. 2707.

Having received information on Friday, February 13, 1976 that a public hearing on the above weather modification bills was scheduled for the following Tuesday, I was unable to arrange my schedule to appear before the Committee. Therefore, if additional hearings are to be held, I would appreciate notification in order to speak for the NAIWMC members.

The NAIWMC is a relatively new organization having been organized at a meeting held in Denver, Colorado on January 16-17, 1975. At this time representatives of fifteen states, three Canadian Provinces and Mexico met to discuss weather modification needs, problems and opportunities. See attachment A for a summary of that meeting.

On January 15-16, 1976 the Council again met in Kansas City, Missouri to review the past years activities and outline a program of activity for the current year. Dues formember states were purposely held high to foster interest and concern in the organization.

Eleven states, Alberta, Canada and Mexico had official delegates to the Conference and some 60 people were in attendance. Two additional types of memberships were created: "temporary regular" for those states or provinces unable to raise the \$1500 membership fees initially and "affiliate" for political subdivisions, national agencies, professional organizations or scientific societies.

I provide this background information in order for the Committee to understand our concern and interest in S. 2705, S. 2706 and S. 2707. Basically the Council is a State and local organization of responsible officials interested in the use, benefits and appropriate regulation of this new technology, weather modification.

I believe our Executive Secretary, Dr. Conrad G. Keyes, Jr. has provided the Council's position papers regarding these three bills to the Committee members,

but I have attached a copy hereto. I believe these position papers are self-explanatory and I will not comment further.

The NAIWMC is most interested in working with the Committee on Legislation affecting weather modification activities and would be most willing to make our services available and answer any questions from the Committee.

Very truly yours,

VERN W. BUTLER, *Chairman.*

Enclosure.

[Press Release]

NAIWMC ORGANIZED

On January 16-17, 1975, representatives of 15 states, 3 Canadian Provinces, and Mexico met in Denver, Colorado, for the purpose of organizing the North American Interstate Weather Modification Council (NAIWMC).

The purpose of NAIWMC, as outlined in the adopted by-laws is: (1) To assist organizations in the planning, design, implementation, coordination, and assessment of weather modification operations and encourage interstate and international cooperative operational programs. (2) To assist organizations in weather modification research and development and provide a forum for the exchange of experience, data, and information about weather modification. (3) To serve as a spokesman for the needs and views of members and develop information programs. (4) To assist national, state, or provincial governments in the preparation, review, and alteration of proposed of existing legislation affecting weather modification. (5) To assist regulatory agencies in maintaining a high level of integrity and professional competency in the weather modification field.

An earlier conference held in Sioux Falls, South Dakota, had brought out the needs and concerns of the various states regarding the use of weather modification technology and the potential for interstate cooperation and assistance. The inclusion of Canadian Provinces and Mexico gives a broader spectrum to the Council and allows for consideration of weather modification activities across the whole continent.

In addition to adopting a set of by-laws, the members elected an executive committee composed of a chairman, vice-chairman, and secretary-treasurer and a 10-member board of directors. Vern W. Butler, Secretary of the Department of Natural Resource Development, South Dakota, was elected Chairman; Gordon Sterling, Chairman Interim Weather Modification Board, Alberta, Canada, Vice-Chairman; and Paul Gillette, Division of Water Resources, Utah, Secretary-Treasurer. Directors were selected by geographic areas throughout the United States, Canada, and Mexico.

The Council anticipates holding at least an annual conference each year. The theme of the Denver conference was weather modification—a useable technology. Additional information on the NAIWMC can be provided by writing to the chairman or secretary-treasurer.

VERN W. BUTLER.

POSITION STATEMENT NO. 76-1, JANUARY 16, 1976

ESTABLISHMENT OF A NATIONAL WEATHER MODIFICATION COMMISSION

The purpose of S. 2705, introduced by Senator Bellmon in the first session of the 94th Congress, is to establish a National Weather Modification Commission to investigate and study the need for regulation of weather modification activities, the status of current technologies, the extent of coordination and the appropriate responsibility for operations in the field of weather modification, and for other purposes.

The North American Interstate Weather Modification Council (NAIWMC) has adopted the position to strongly support the purpose of S. 2705 and pledges to work with such a Commission if established.

Furthermore, the NAIWMC recommends that the life of the established Commission be one year plus a six month period for preparation of the final report.

For this Commission to be effective, the NAIWMC also recommends that the National Weather Modification Commission be an independent body reporting directly to the President and the Congress of the United States.

Adopted January 16, 1976.

VERN W. BUTLER, *Chairman.*

POSITION STATEMENT No. 76-2, JANUARY 16, 1976

DROUGHT PREVENTION PROGRAMS

The purpose of S. 2706 is to authorize and direct the Secretary of Commerce to plan and carry out an experimental research program over a ten year period.

The purpose of S. 2707 is to provide matching funds to States and their political subdivisions to implement operational weather modification to provide immediate and long term relief from drought. Both bills have been introduced by Senator Bellmon in the first session of the 94th Congress.

The North American Interstate Weather Modification Council (NAIWMC) has elected to adopt no position on these two bills, pending action on S. 2705 establishing a National Weather Modification Commission and the recommendations therefrom. However, the NAIWMC reserves the right to adopt a position on either or both bills at some later date.

Adopted January 16, 1976.

VERN W. BUTLER, *Chairman.*

POSITION STATEMENT No. 76-3, JANUARY 16, 1976

WEATHER MODIFICATION RESEARCH, DEVELOPMENT, AND CONTROL ACT OF 1975

The purpose of H.R. 10039, introduced by Representative Evans of Colorado and others in the first session of the 94th Congress, is to provide for research and development in weather modification and to institute a comprehensive data-gathering system which will assist in the development, administration, and supervision of weather modification in a safe and scientific manner.

The North American Interstate Weather Modification Council (NAIWMC) has adopted the position of opposition to H.R. 10039.

The NAIWMC suggests that H.R. 10039 is premature until such time that a National Weather Modification Commission can indicate the direction which a long range national program weather modification should take.

Furthermore, the NAIWMC strongly suggests that any future regulatory function on the part of the Federal Government should be closely coordinated with the regulatory functions of the various states.

Adopted January 16, 1976.

VERN W. BUTLER, *Chairman.*

AMERICAN METEOROLOGICAL SOCIETY,
Boston, Mass., January 27, 1976.

HON. HENRY L. BELLMON,
*U.S. Senate, Russell Senate Office Building,
Washington, D.C.*

DEAR SENATOR BELLMON: On behalf of the American Meteorological Society, I am writing in support of Senate Bill S. 2705 providing for the establishment of a National Weather Modification Commission to assess the state of weather modification, the needs for further research, the appropriate distribution of governmental responsibility, and the requirements for regulation.

Repeatedly over more than two decades a variety of distinguished committees and panels have reviewed the status of weather modification and have expressed optimism concerning its promise for contributing to the benefit of mankind through the enhancement of water resources for agriculture and energy, and the mitigation of the hazards of severe storms. While recent research and operational activities around the globe have supported these optimistic appraisals in a few cases, by and large the anticipated benefits have not yet been realized.

I believe it is fair to say that the bulk of the experts in the field remain optimistic about the ultimate economic and social benefits of weather modification. We have also become deeply concerned about the deleterious effects on weather and climate of inadvertent weather modification due to industrialization, power plants, surface vehicles, aircraft, hydrocarbons, and even fertilizers. But we also seem to be unable to attack these problems in a rational, carefully planned, and integrated fashion.

The sources of our difficulties to make headway either in realizing the full benefits of intentional weather modification are manifold. They reside in part in the absence of any well defined set of national goals, the inadequate and fraction-

ated research programs, and the premature emphasis on applications rather than basic research in some areas. Many of us also believe that progress has been impeded in part by the absence of clear leadership upon the part of any one agency and the inadequate coordination among the variety of agencies now involved in weather modification. The need for an in-depth analysis of the problems and recommendations for their solution is therefore manifest.

With respect to the specific components of your bill, we note an important gap in its failure to make explicit mention of inadvertent weather modification. As indicated above, inadvertent effects may be profound and far reaching. Thus the Commission's charge should explicitly include the study of inadvertent weather modification.

We also respectfully suggest the following changes:

1. That the Commission be composed of highly qualified and respected individuals of broad, objective knowledge and vision, and not of representatives of various constituencies as now proposed.

2. Political affiliation should play no part in the selection of members; only expertise and objective integrity should be of concern.

3. The effective implementation of the recommendations of the Commission would be better assured if it reported directly to the President and not to the Secretary of Commerce.

While we hope that you will give consideration to these changes, the American Meteorological Society strongly supports the basic intent of this legislation. We also stand ready to provide background information and testimony should you find that helpful.

Sincerely,

DAVID ATLAS,
Immediate Past President.

NORTH AMERICAN INTERSTATE COUNCIL,
Las Cruces, N. Mex., February 10, 1976.

Hon. WARREN G. MAGNUSON,
*Commerce Committee, U.S. Senate, Dirksen Office Building,
Washington, D.C.*

DEAR SIR: The purpose of the North American Interstate Weather Modification Council, as outlined in its adopted by-laws is: (1) To assist organizations in planning, design, implementation, coordination, and assessment of any weather modification operations and will encourage international and interstate cooperative operational programs. (2) To assist organizations in the development of research and shall provide a forum for the exchange of experience, data, and information about weather modification. (3) It shall serve as spokesman for the needs and views of state members and shall develop information programs. (4) It shall assist national and state or provincial governments in preparation, review, and alternation of proposed or existing legislation affecting weather modification. (5) It shall assist regulatory agencies in maintaining a high level of integrity and professional competency among weather modifiers.

The Council, at its last meeting in Kansas City, MO on January 16, 1976, elected to take position statements on S. 2705, S. 2706, S. 2707 and H.R. 10039. These position statements are enclosed. The Council strongly recommends that these positions be adopted by the Congress at this time. Your support of these statements would be appreciated.

If additional information can be provided to you or the committee, please do not hesitate to contact us.

Very truly yours,

CONRAD G. KEYES, Jr., Sc. D.

DEPARTMENT OF ATMOSPHERIC SCIENCES,
UNIVERSITY OF WASHINGTON,
Seattle, Wash., February 24, 1976.

Senator JAMES B. PEARSON,
*Senate Office Building,
Washington, D.C.*

DEAR SENATOR PEARSON: I am glad to respond to Senator Bellmon's request at the weather modification hearings on February 17, 1976, for a written statement of my views respecting the National Commission proposed under S. 2705.

The greatest value of such a Commission, I believe, would be to bring to bear on the problems of organization, funding, and agency leadership a searching inquiry by highly respected and qualified individuals. As the hearings emphasized, in recent years many groups have produced reports on weather modification. One of the reasons that these reports have not been more successful in advancing the field has been that the reports have tended to isolate the problems of weather modification from closely related environmental problems. It seems to me beyond question that in the next decade the U.S. government must improve the organization of its resources and capabilities for increasing water supplies, managing the quality of its air, avoiding damage to the ozone shield, reducing damage due to storms, and minimizing losses and maximizing gains resulting from long term changes in weather and climate. The problems are closely related scientifically; in many cases two or more of these problems may be worked on by a single group or individual, and progress on one problem can be expected to contribute to progress on others. I believe that a study addressed to the problem of organizing the national effort in these related fields would be likely to be much more effective than a study addressed to weather modification alone. For this reason, I urge that consideration be given to a broad mandate for the National Commission.

Another reason that reports on weather modification have been relatively ineffective is that, because they have represented the views of persons active in the field, they have to some extent been vulnerable to the charge of self-interest. For this reason, I believe the Commission should be composed of knowledgeable individuals of recognized judgment and integrity. I contrast this with the Commission proposed in S. 2705 which would be composed of representatives of various constituencies and points of view.

Of course, a broadly based, highly qualified Commission will include persons who have been active in the fields being investigated and in that sense will be broadly representative. However, it would be better if this were a secondary matter. Qualifications for membership on the Commission might be stated as follows: "The Commission shall be composed of nine members to be appointed by the President. The Commission as a whole shall include broad training and experience in the atmospheric sciences, in federal administration of science programs, in national environmental policy formulation, in environmental law and economics, and in industrial research and development. Each should be distinguished in his or her particular field of endeavor. The President shall designate one of the members of the Commission as Chairman. Two members of the House of Representatives and two members of the Senate shall serve as Observers and shall participate in all Commission meetings."

As a model of the type of Commission that is needed I suggest the Stratton Commission on Marine Science, Engineering, and Resources, whose recommendations were instrumental in the creation of NOAA.

I hope that the hearings which you have held will result in creation of an effective weather modification program, and I shall be glad to help in any way I can.

Sincerely yours,

ROBERT G. FLEAGLE, *Chairman.*

THE EVALUATION OF POSSIBLE HAIL SUPPRESSION IN KANSAS

(By Donald Christy, Scott City, Kan.)

The goal of Weather Modification was bushels of wheat—wheat being the major crop of Western Kansas. The intent was to produce more rain, since rainfall is the major limiting factor of wheat production in Western Kansas.

The method of rain enhancement was based on the observation that when an extremely small amount of AgI was released between 10:00 A.M. and 12:00 noon into a gentle up-slope wind (SE) when there was a rain haze showing around the sun or a few small feathery cumulus had started to develop, at about 4:00 P.M., a rainstorm often developed approximately 75 miles northwest of the initial seeding location. The storm appeared to move in a general easterly direction. These results seemed to require the seeding to be done about 15–20 miles south of the desired rainfall location.

It was further noted that as long as AgI seeding was being used, these clouds would appear for days after the seeding stopped. This indicated that the AgI persisted and remained in the area.

During 1956, the author developed the concept that continuous seeding of small amounts of AgI was a means of starting an early convergence close enough to the Kansas-Colorado border for the rains to continue into Kansas. Those that started just west of the Kansas border were the ones that supplied much of the Kansas summer rainfall. It had been noted that the extremely short vectors of the windroses of Western Kansas were of about equal length in each direction, indicating little net air movement into or out of the area during the summer. If these assumptions are true, then AgI releases in the area should permeate the area between rainstorms so that upslope winds would carry them to a desirable location where energy releases would start the convergence process.

The map (Fig. 1) showing the morning upslope wind direction and the storm's easterly movement illustrates the concept. Since the rainstorms form in the area every few days, and each storm results in a convergence, the convergence would concentrate the AgI and it would be washed out of the air on a regular basis. This would indicate the need for continuous reseeding.

The nine year Weather Modification attempt was initiated in 1957. The idea was to use an eleven year trial, one sunspot phase. The experiment was terminated after nine years due to the Federal requirements of record keeping. It was noted that hail loss north and east of Scott City seemed to be low during the seeding period. Crop Hail Actuarial Association Insurance of Chicago was contacted as to available data. They supplied a crop-hail computer print out of the hail low-risk ratio for the years 1924-1972 inclusive. This included not only a township by township, but county by county, and finally a state, year by year summary.

The search for the area of influence, if any, was initiated. The procedure for determining changes in yields and changes in rainfall had already been worked out. The same general procedure of analysis was used to determine the effect of such seeding on hail losses. The procedure was to determine the normal hail loss risk for each county for the period of record. This was plotted on a Kansas map. Then a similar map was made by subtracting the period of record from the period of study. Hence, if the results were positive, there was an increase in hail loss compared to risks taken. Since the anticipated effects were widely variable and small, compared to other factors, the 4-county average, moved progressively, tended to clarify the locations of change in losses. When the hail loss results are plotted on a map, the lines of equal loss drawn, the resulting map (Fig. 2) indicates a reduction of hail loss about 80 per cent in the affected areas. The data was plotted on the map (Fig. 2) then lines A-A, B-B, etc. were analyzed. The cross sections representing A-A, B-B, etc. (Fig. 3) indicates a broadening comparable to the original estimated divergence of the storm paths. The divergence results in a broadening of the area affected until it is almost as wide as the state is broad with indicated hail loss reductions equal to about 30%.

There are two other comparisons that might be possible. The counties just north and south of the affected area can be compared to the area affected as indicated by Fig. 3. The hail loss of the area itself can be compared to the years in which seeding was not being done.

In the first instance the normal hail loss for all the years are compared to see whether there is substantial difference of hail loss for the period during which seeding was practiced would give some bias on the conservative side. Compare column 4, Table I, the seeded area with column 2 of the unseeded area. Note the 7.39 loss of the unseeded years of the seeded area compared to 7.47 of the unseeded area. To be conservative the 6.13 : 9.43 ratio of 65.01 would be corrected by multiplying it by $7.47 : 7.15 \times 6.13 : 9.43$ by 100 = 67.91 per cent of normal loss, a 32 percent reduction in hail loss.

The other, compares the nine seeded years with the unseeded years for the same counties divides the hail loss during the seeded years by the hail loss during the unseeded years, Table I, Col. 3 divided by Col. 4— $6.13 : 7.39 \times 100 = 82.95$ or a 17.05 per cent reduction.

One of the problems of this analysis is that a seeding comparison between the hail losses during one phase of the sunspot magnetic polarization could seriously bias the result if it were compared to an unseeded period of the opposite polarity. Using Kansas as an example, if the years of seeding had been in

the south sunspot phase of 1951-1960 and the comparison was the straddling years of 1941-1950 inc. plus 1961-1970 the results would have been $3.74 : 4.73 \pm 1.98 : 154 \times 100 = 79.07$ or an apparent 21 per cent reduction. For the total period of 1924-1972 the reduction would have apparently been $2.69 : 4.73 \times 100 = 46.33$ or 54 per cent reduction.

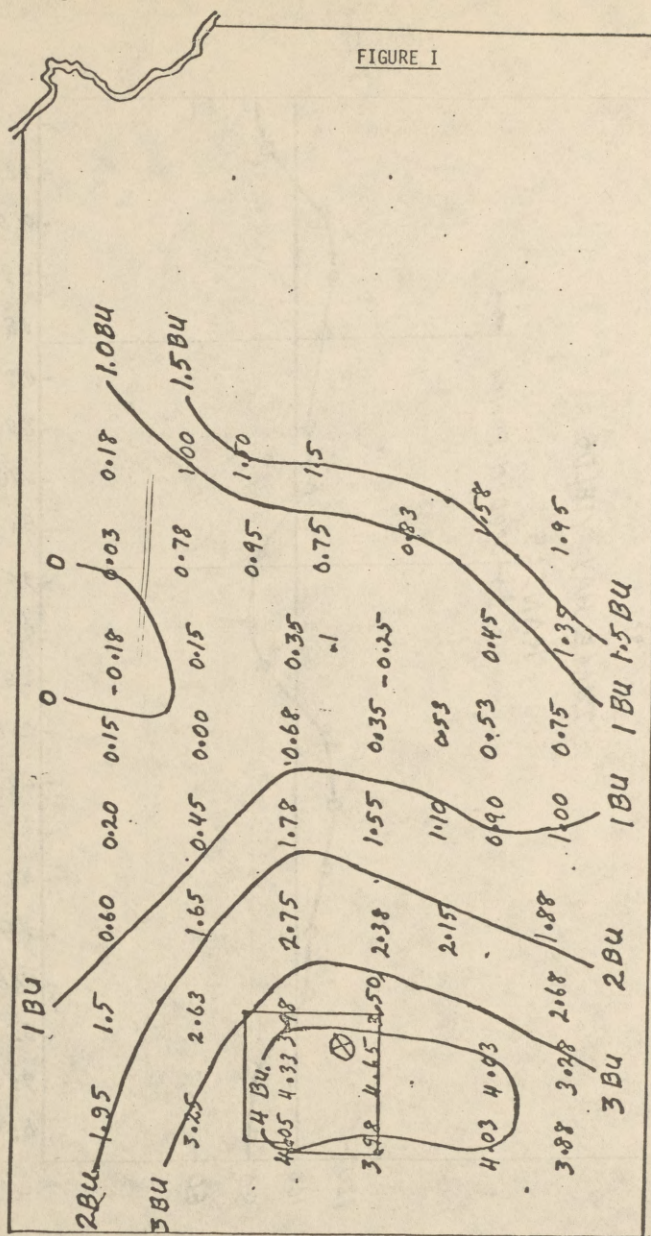
In this particular instance the number of years selected accidentally straddled the change from south to north phases with 4 years in the south mode of the sun spot cycle and 4 years in the north mode of the cycle (Fig. 5). In other words the seeding period covered the last part of the ensuing wet phase of the sun's polarity.

It should be noted that the sunspot phase does not affect precipitation on the same time table in all parts of the world.

There does not seem to be correlation between the sunspots and the precipitation in the Columbia River Basin. Further, there are places like the northeastern United States where the effect of the sunspots are the reverse of that of the mid-continent U.S. Hence, there is a need to analyze the sunspot effect for the area in question.

Eleven counties of southwestern Kansas engaged in an all-out attempt at weather modification in 1975. It started April 15 for both rain enhancement and hail suppression. The rain enhancement stopped during most of June to the first week of July, the wheat harvest period. The program is to terminate in mid-September. The initial attempt to evaluate is shown in Fig. 6 and Fig. 7, which shows the rainfall and the evaluation available at the time of preparation of this presentation.

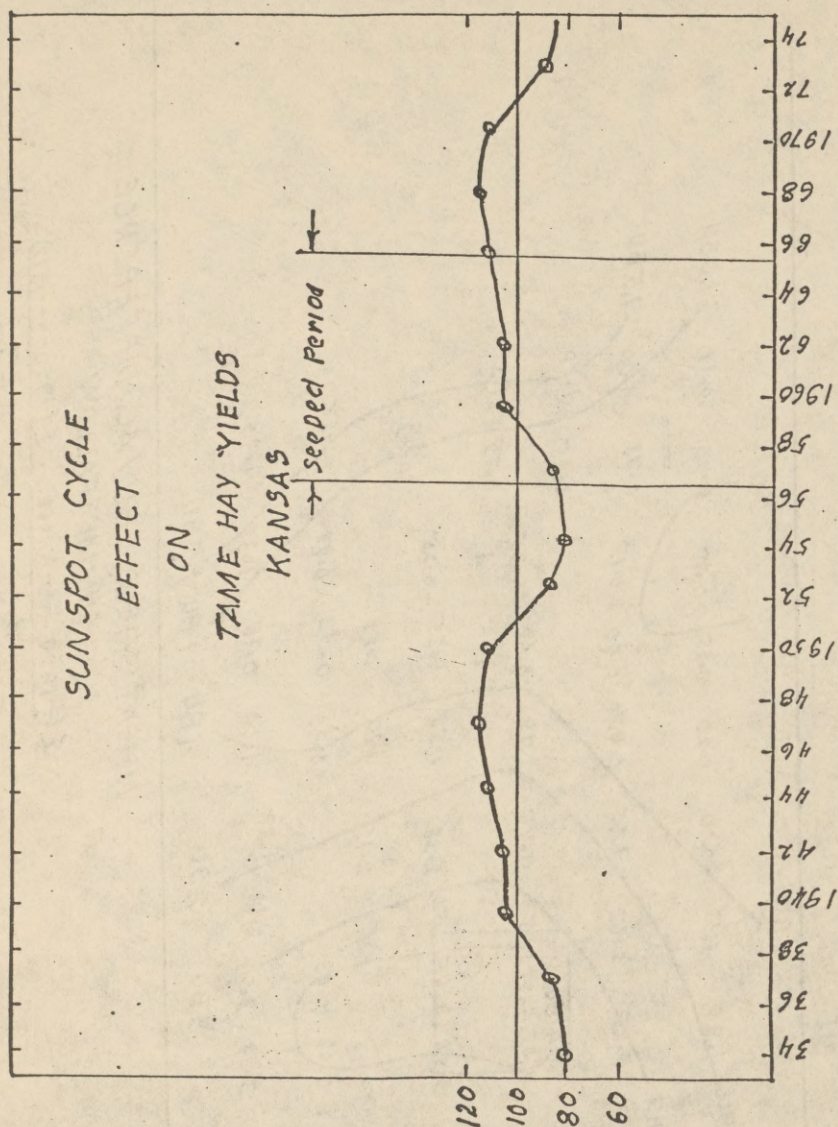
FIGURE I

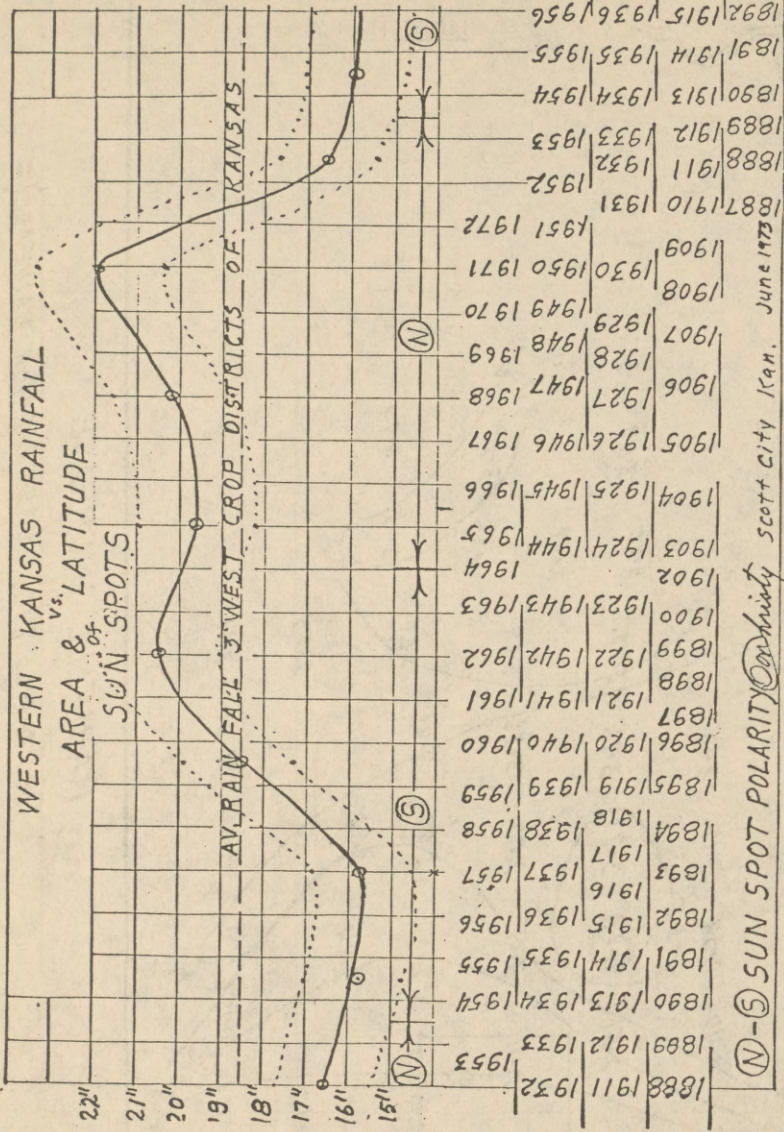


WHEAT YIELD BU./AC. DIFFERENCE
SUMMERFALLOW

$$\frac{\sum(\frac{1}{2}1957 \dots \frac{1}{2}1966)}{9} - \frac{\sum(1950 \dots 1972)}{23} =$$

FIGURE II

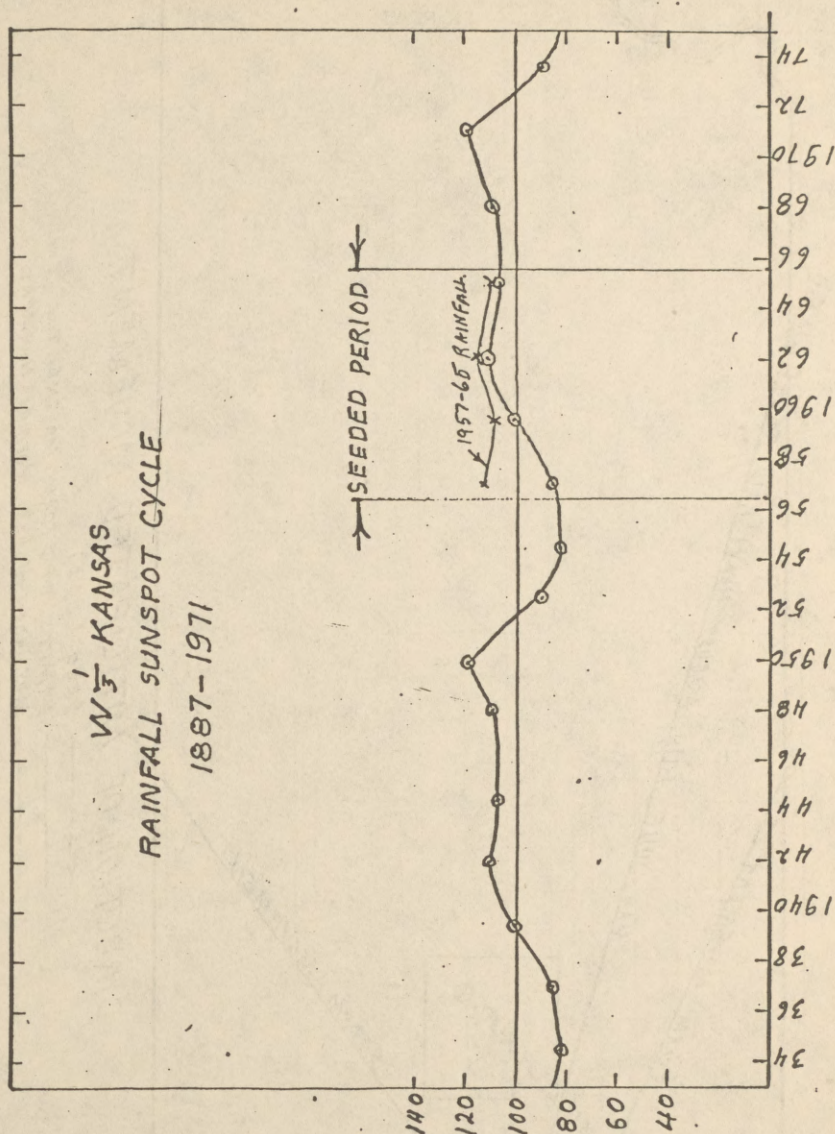




(N) - (S) SUN SPOT POLARITY

FILE IV

FIGURE V



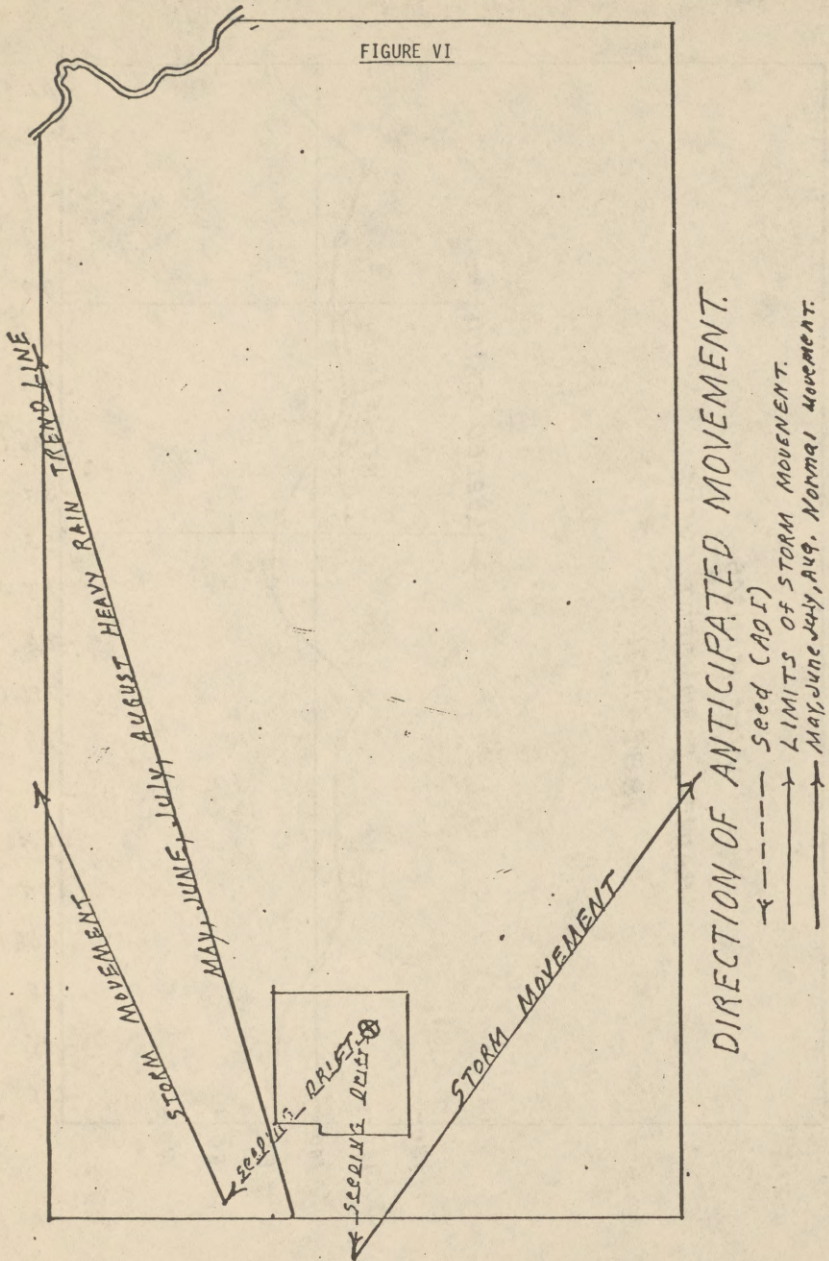
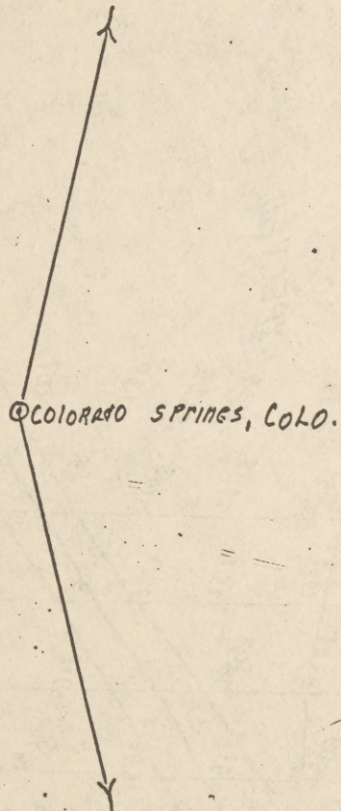


FIGURE VII

ATOMIC ENERGY FALLOUT PATTERN.
AS SKETCHED BY ONE OF STAFF.

FIGURE VIII

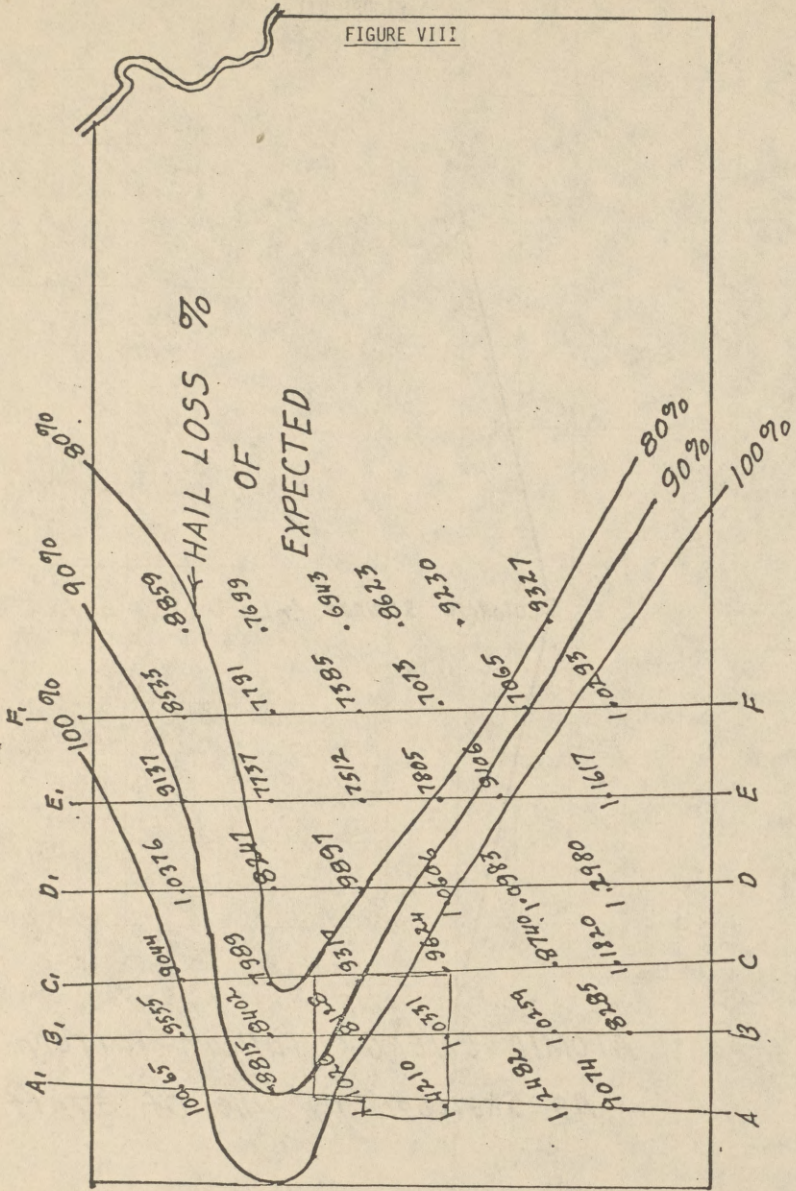
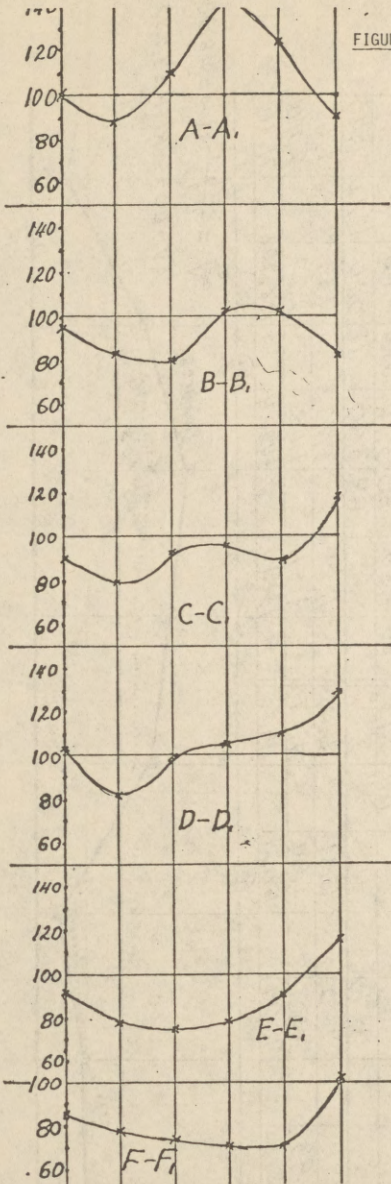


FIGURE IX



CO'S	NO YRS DATA.	1924 TO 1972	1957 TO 1965	UN- SEEDER YRS.
WALLACE	47	8.10	7.76	8.18
THOMAS	49	6.08	3.59	6.64
LOGAN	45	9.28	8.08	9.58
SCOTT	48	7.86	5.67	8.37
SHERIDAN	49	6.54	4.98	6.89
GOVE	48	7.69	7.48	7.74
LANE	48	6.48	7.53	6.24
GRAHAM	49	5.74	3.67	6.21
TREGO	48	7.21	6.67	7.33
NESS	48	6.53	5.87	6.68
	AV.	7.15	6.13	7.49
	±	1.08	1.65	1.22
VARIANCE	90	15.16	26.99	16.30
CHEYENNE	49	11.22	14.89	
RAWLINS	49	6.98	6.99	
DECATUR	49	4.96	6.27	
NORTON	49	4.56	7.23	
GREELEY	46	9.45	16.40	
WICHITA	46	9.96	8.43	
KEARNY	47	9.84	15.36	
FINNEY	48	8.04	8.07	
GRAY	47	5.08	5.21	
FORD	48	4.62	5.48	
	AV	7.47	9.43	
	±	2.56	4.35	
VARIANCE	90	34.26	46.15	

$$\frac{7.47}{7.15} \times \frac{6.13}{9.43} \times 100 = 67.91$$

32 % REDUCTION

OR

$$\frac{6.13}{7.49} \times 100 = 81.84 \text{ OR } 18.16\%$$

FIGURE XI

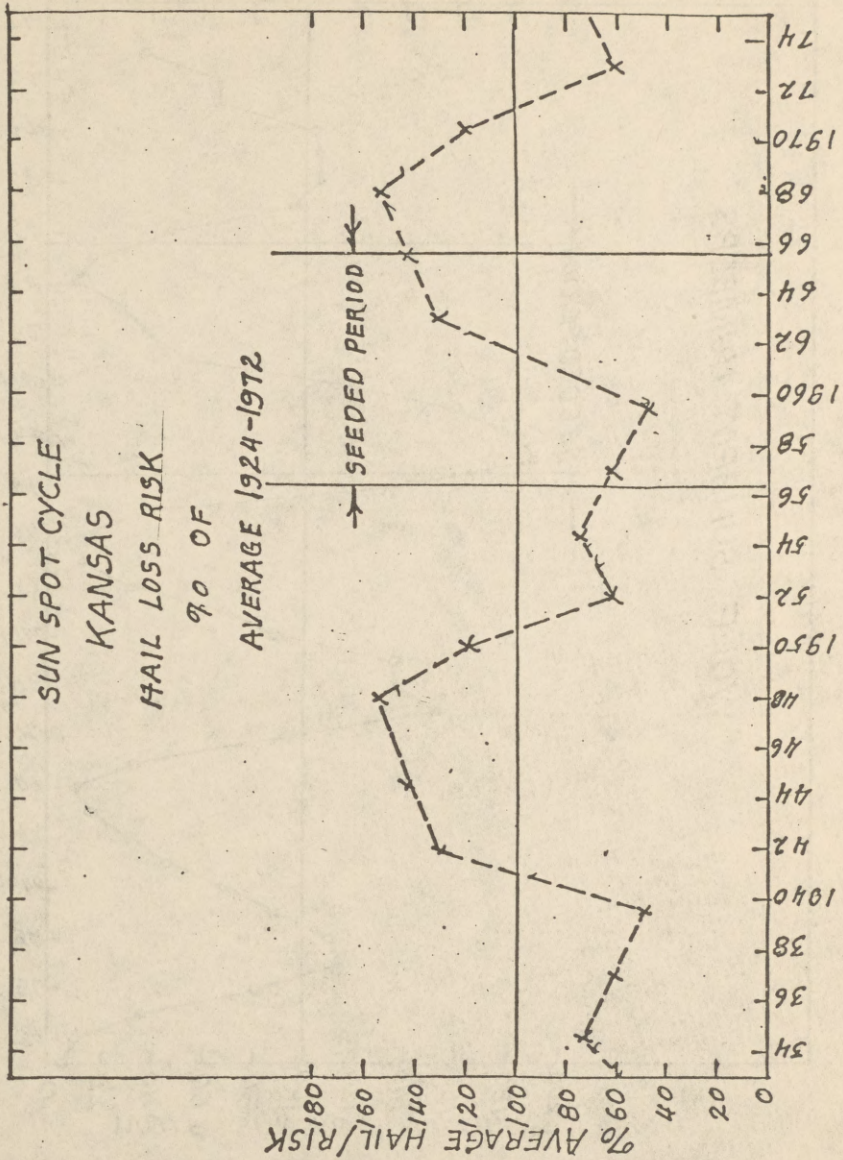


FIGURE XII

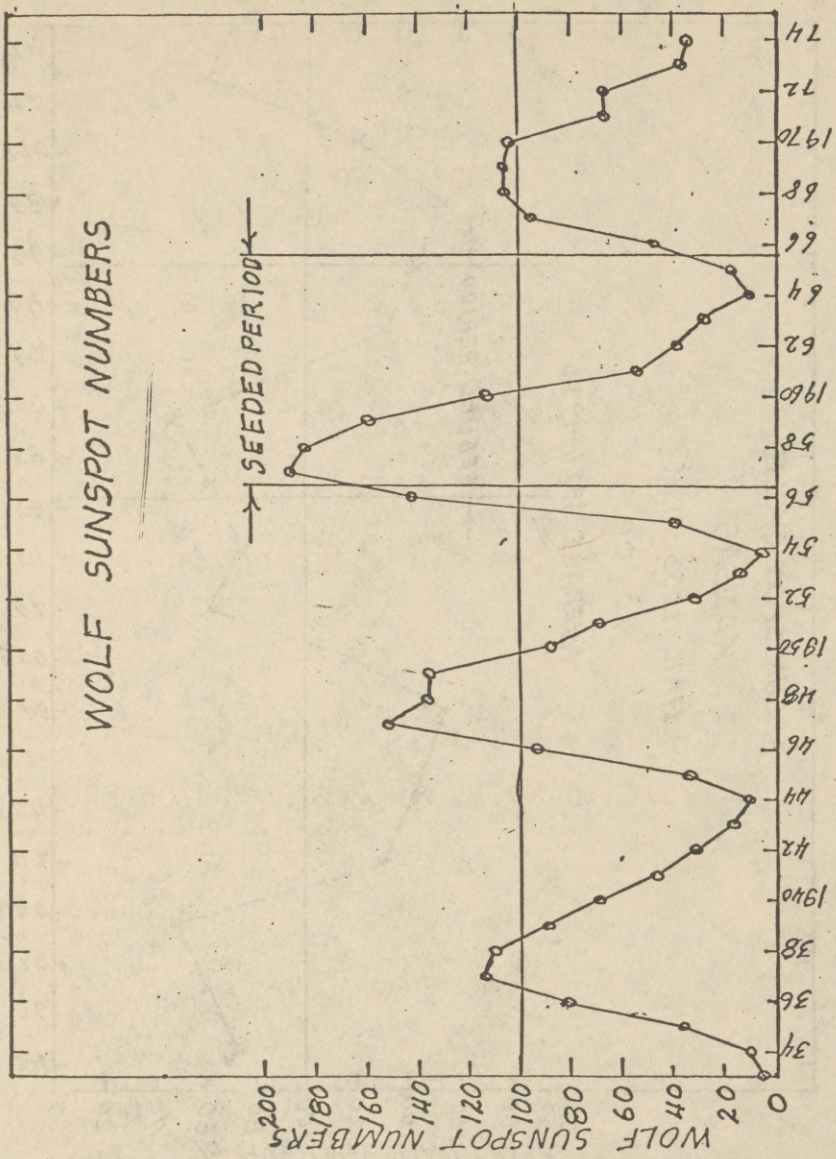
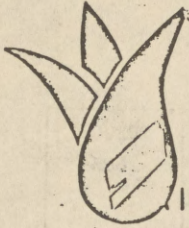


FIGURE XIII

RESULTS OF
MUDDY ROAD I
15 APRIL TO 1 SEPTEMBER

SOIL REDUCED BY 32% IN TARGET AREA

463,473.00 ACRE FEET OF ADDITIONAL
WATER (EST.)

COST PER ACRE FOOT - 17¢

COST OF PROGRAM - \$80,000.00

NORTH DAKOTA

50% COST SHARING

SOUTH DAKOTA

\$75,000.00 FROM
STATE AND 75% COST
SHARING

FIGURE XIV

INSURED TO LOSS PERCENTAGE

15 APRIL - 7 JULY

CHEYENNE 40%	WALLACE 100%	LOGAN 90%	GOVE 30%	TREGO 68%
	19%			
KIOWA 55%	GREELEY 33%	WICHITA 15%	SCOTT 32%	LANE 51%
PROWERS 31%	HAMILTON 40%	KEARNY 49%	FINNEY 24%	HODGEMAN 6%
	5/2		GRAY 31%	FORD 59%
BACA 68%	STANTON 12%	GRANT 75%	HASKELL 30%	
	MORTON 49%	STEVENS 50%	SEWARD 29%	MEADE 35%
				CLARK 50%

32% REDUCTION IN CLAIMS FILED
IN TARGET AREA

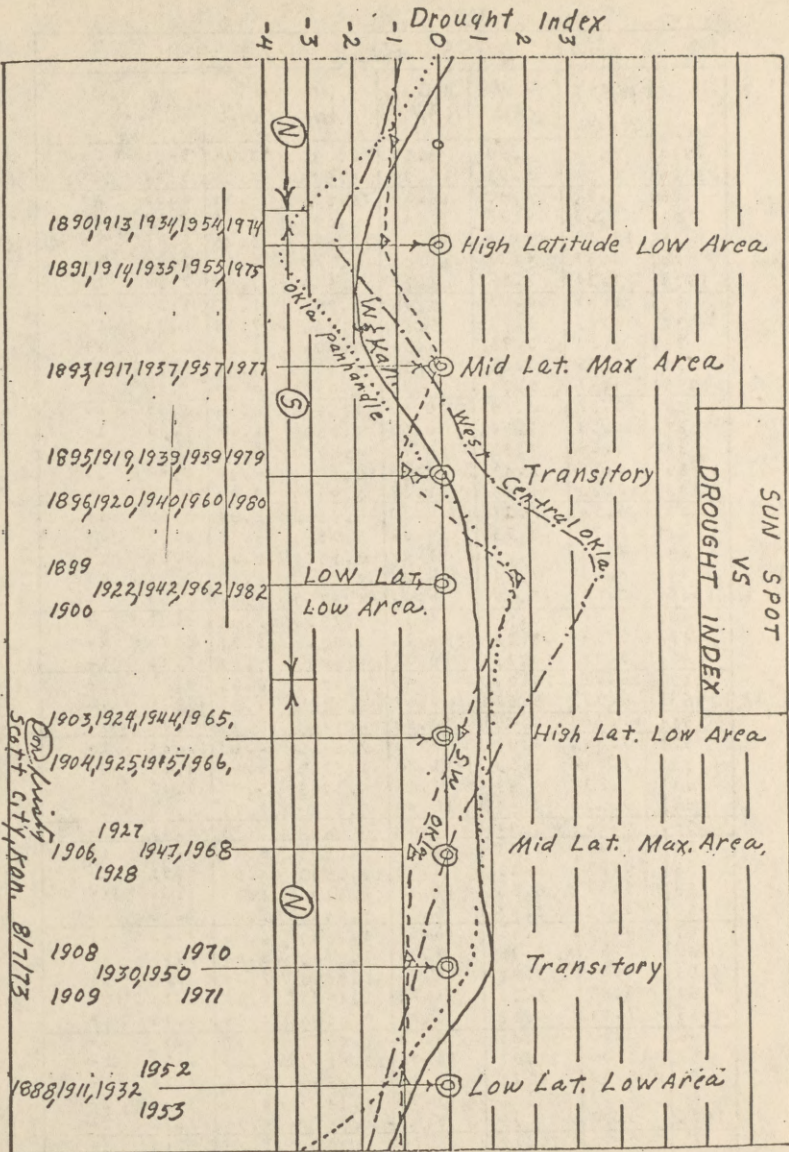


TABLE 2

HAIL LOSS - RISK RATIO							
	WEST KAN.	N.W KAN.	WC KAN.	S.W KAN.	45 CO.'S	KAN.	
1924	6.43	8.90	3.50	7.0300	3.45	5.35	Σ+
1925	6.53	5.04	4.31	9.5400	4.02	5.44	Σ+
26	9.27	4.96	16.33	6.8300	5.11	4.55	Σ+
27	9.05	9.38	7.43	9.5200	5.46	6.12	Σ+
28	17.15	9.37	15.53	22.6700	5.25	7.91	Σ+
29	8.87	4.33	11.03	10.0400	2.57	2.81	Σ+
1930	4.97	1.57	3.72	7.5500	1.63	2.38	Σ+
31	1.35	0.93	2.30	2.0600	1.32	1.57	Σ+
32	6.22	1.23	6.39	8.3000	2.45	1.74	Σ+
33	0.12	0.33	0.00	0.0000	0.30	0.52	Σ+
34	5.53	10.26	6.53	4.1000	4.35	1.51	Σ+
1935	0.37	0.37		1.0500	0.82	1.25	Σ+
36	0.34	0.30	0.97	1.0900	0.58	0.55	Σ+
37	1.35	1.54	0.53	3.0800	1.24	1.64	Σ+
38	5.65	7.33	8.72	4.8200	5.35	4.20	Σ+
39	8.52	5.41	12.13	10.8000	6.35	4.47	Σ+
1940	2.20	1.33	1.77	2.9100	0.62	0.25	Σ+
41	4.34	7.37	6.30	6.3100	3.94	3.62	Σ+
42	9.13	3.73	14.92	5.7500	6.05	6.33	Σ+
43	7.64	4.24	11.42	7.1500	5.20	5.09	Σ+
44	3.53	7.44	2.23	2.1400	2.55	2.34	Σ+
1945	0.65	15.92	8.04	4.9300	7.95	7.23	Σ+
45	3.57	6.51	3.12	2.7900	2.31	3.51	Σ+
47	5.14	3.25	4.74	3.6000	5.71	5.70	Σ+
48	8.32	13.33	10.91	1.4200	5.01	5.44	Σ+
49	13.01	23.26	9.40	9.4700	4.65	5.76	Σ+
1950	6.39	5.57	9.17	6.4100	3.33	2.51	Σ+
51	11.77	8.45	10.93	14.1700	10.25	7.73	Σ+
52	5.53	6.07	2.75	2.6900	4.10	2.55	Σ+
53	2.53	5.50	1.37	1.5700	3.52	3.12	Σ+
54	7.73	3.83	3.14	6.3200	5.93	3.47	Σ+
55	9.50	5.92	16.44	5.5600	7.21	5.40	Σ+
56	6.25	3.77	2.53	6.5400	1.33	1.63	Σ+
57	12.35	6.63	15.29	15.0600	6.43	4.04	Σ+
58	10.23	3.61	6.50	13.5800	4.53	5.51	Σ+
59	2.33	6.50	1.51	1.5100	1.69	1.56	Σ+
1960	3.30	3.37	6.39	1.9300	2.07	2.53	Σ+
61	10.75	14.45	16.53	4.3800	4.70	4.40	Σ+
62	7.88	9.38	7.91	7.9100	5.81	5.53	Σ+
63	6.34	3.92	4.59	8.8400	2.44	3.02	Σ+
64	5.05	7.13	8.71	1.4300	4.14	3.13	Σ+
1965	7.51	6.12	5.76	9.4400	4.35	3.75	Σ+
65	5.00	7.05	5.13	2.4600	6.37	4.55	Σ+
67	13.00	11.37	13.00	13.6100	6.10	6.53	Σ+
68	5.30	4.73	10.33	4.2500	4.50	3.74	Σ+
69	4.13	3.81	3.37	4.4900	4.45	3.60	Σ+
1970	3.32	5.25	5.09	4.0500	5.25	4.75	Σ+
71	6.55	10.17	6.76	3.3000	11.28	5.10	Σ+
72	3.74	4.54	3.41	3.5200	1.31	1.45	Σ+
NOVARS	49.00	49.00	43.00	49.0000	49.00	49.00	0
AK	3.57	4.53	4.63	4.4300	2.43	2.02	0
	6.53	7.00	7.39	6.0800	4.34	3.90	0
VARI- ANCE	54.22	55.4157	63.3057	72.8671	56.03	51.57	0

NATIONAL WILDLIFE FEDERATION,
Washington, D.C., March 1, 1976.

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

DEAR MR. CHAIRMAN: We appreciate this invitation to express our views on three bills dealing with weather modification, S. 2705, S. 2706, and S. 2707. It is requested that the comments contained below be made a part of the official public record on the bills.

General: The National Wildlife Federation (NWF) is already on record, both in the form of a national resolution adopted in March, 1975 and a statement made last May before the Subcommittee on Climate Change, Environmental Resources Committee of the President's Domestic Council, as expressing concern about the environmental effects of weather modification and acknowledging the need for the Federal Government to vigorously support adequately-funded, well-coordinated research in weather modification, especially as it relates to inadvertent ecological changes. Copies of the MWF national resolution and the May, 1975 statement are enclosed for your information and use.

S. 2705: The Federation does not object to the establishment of a National Weather Modification Commission, but we seriously question its need in view of the studies already made by the National Academy of Science and the President's Domestic Council, as well as the on-going efforts of the National Science Foundation and the Interdepartmental Committee on Atmospheric Sciences (ICAS). Should the Congress decide to establish a commission, however, NWF urges that: (1) it be chartered independently to insure that the commission is allowed maximum latitude in its deliberations and that its recommendations are not unduly biased by mission-oriented agencies; (2) the commission's charter be broadened to insure that such related subjects as inadvertent weather modification and climate change are addressed adequately; and (3) the composition of the commission be revised to include equitable professional representation from the environmental/conservation community.

S. 2706: NWF supports the principles contained in this bill. In our judgment, the National Oceanic and Atmospheric Administration (NOAA)—through the Secretary of Commerce—is the most logical federal agency to assign overall responsibility for planning and carrying out an experimental research program to determine the feasibility of, and the most effective methods for, drought prevention and alleviation by weather modification. Assigning NOAA such a lead role should not denigrate the work of the Bureau of Reclamation, the National Science Foundation, the Department of Agriculture, and the Military Departments but it should insure better coordination of federal efforts. Hopefully, it will result in a savings of manpower, equipment, and money. With respect to the Advisory Board established by Section 2(b) of S. 2706, the Federation recommends that the board's membership include professional representation from the environmental/conservation community.

S. 2707: NWF is opposed to the passage of this bill aimed at providing cost-sharing grants to states to carry out a program of assistance in preventing and alleviating drought emergencies. Our opposition is based on the supposition, supported by many scientists, that droughts are cyclic in nature and that weather modification—much as cloud seeding—is unlikely to eliminate the meteorological abnormalities associated by such cyclic weather phenomena. Therefore, it would be premature, at least at this state-of-the-art, for the Federal Government to get involved in operational cloud seeding. As already stated, federal funding should be channeled into a more aggressive, better coordinated weather modification research and experimentation program as proposed in S. 2706.

Thank you for this opportunity to express our views.

Sincerely yours,

THOMAS L. KIMBALL,
Executive Vice President.

Enclosures.

STATEMENT OF COL. KENNETH R. HAMPTON, USA (RET.) ON BEHALF OF THE
NATIONAL WILDLIFE FEDERATION, MAY 16, 1975

Mr. Chairman, I am Col. Kenneth R. Hampton, U.S. Army (Ret.), Assistant Conservation Director for the National Wildlife Federation which has its national headquarters at 1412 Sixteenth Street, N.W., here in Washington, D.C.

I am a professional conservationist with degrees in Forest Management and Meteorology.

Ours is a private organization which seeks to attain conservation goals through educational means. Affiliates of the National Wildlife Federation are located in all 53 states, Puerto Rico, Guam, and the Virgin Islands. These affiliates, in turn, are made up of local groups and individuals who, when combined with associate members and other supporters of the National Wildlife Federation (NWF), number an estimated $3\frac{1}{2}$ million persons.

I welcome the invitation to speak on the subject of the federal role in weather modification. But before I do, please permit me to lay a little foundation for my remarks. As you know, I appear before this subcommittee today wearing two hats—the first as a representative of NWF and the second as Chairman of the National Resources Council of America (NRCA) weather Modification Liaison Committee.

Wearing the first hat, I can express, with confidence, the NWF position on weather modification. In that regard, I have attached to my statement a copy of an NWF Resolution adopted at our most recent annual meeting held this past March.

As chairman of NRCA's Weather Modification Liaison Committee, however, I can only reflect in broad, general terms what I believe to be the principal concern of the private conservation organizations which belong to NRCA. The reason I cannot be more specific is that the NRCA does not attempt to develop positions on individuals issues. It serves mainly to a "clearing house" for information. To give you a better understanding and appreciation of this important council, I have attached a page extracted from the 1975 issue of the annual Conservation Directory published by NWF. You will note that 43 national organizations are represented on the council including the Wildlife Society, a counterpart of the American Meteorological Society.

One of my responsibilities as chairman of the NRCA Weather Modification Liaison Committee is to keep NRCA advised, insofar as I can, of what is going on in the field of weather modification. In all candor I must admit that, because of conflicting demands on my time, I am not able to do this to my satisfaction. However, I am at least providing NRCA members with a written annual summary report on weather modification which, hopefully, is useful. A copy of last year's—and the first—report is attached also for your information.

With that background, I hope that you have a better understanding of my role in your hearings. Now let's talk for a few minutes about weather modification and the part played by the Federal Government in such activities.

First, I will address what I believe to be the overriding concern of conservation organizations—and probably with many other citizens not even associated with environmental groups. It should not come as any great surprise to this committee that conservationists, in general are quite concerned about the impact of weather modification on the ecology of an area. They have the uneasy feeling that man, in his understandable desire to increase precipitation in water-short areas or to suppress hail, for example, might significantly alter the interrelationships between the flora and fauna of given ecosystems or cause abnormal soil erosion or stream siltation. Recognizing that man has already inadvertently affected his natural environment in several ways, especially in industrialized, urban areas, conservationists are worried about inadvertent changes in rural or wild ecosystems stemming from adverting weather modification projects which perhaps have not been researched adequately. (I must say, candidly, that I share that concern to some extent.)

As they see it, the government has a moral and ethical responsibility to see that man is not permitted to "tweak" the atmosphere for self-serving purposes unless man has substantial evidence to indicate that his activities will not have a significant adverse effect on the environment.

Now, switching hats and speaking as an NWF representative, let me give you our thoughts on how the Federal Establishment can perhaps respond best to the concern just expressed. It seems to us that at this still-developing stage of the weather modification state-of-the-art, Uncle Sam has two principal responsibilities: first, he must vigorously support continued weather modification research, especially as it is related to inadvertent ecological changes; and second, he must keep a watchful eye on what, if anything, is happening in the environment both in the U.S. and elsewhere as the result of adverting weather modification work.

I believe my first point requires only a little expansion. MWF encourages continued research by Federal agencies, either in-house or by contract. We want that research to be unstifled and we expect the reports produced as a result of the research to be scientifically sound. Furthermore—and here is where ethics comes into the picture—we expect a report's conclusions and recommendations to be based strictly on scientific documented facts insofar as possible and not be unduly influenced or biased by agency missions. In our opinion, there is no room in the system for that form of intellectual dishonesty.

My second point, i.e., keeping a watchful eye on what, if anything, is happening in the environment as a result of advertent weather modification, needs more clarification. By keeping a watchful eye, NWF does *not* mean that the Federal Government should regulate weather modification—at least not as matters stand now. At this point in time, we believe the states are capable of keeping the situation under control as long as they are willing to coordinate on weather modification proposals impacting on regions embracing more than one state.

Keeping a watchful eye on what is happening, *does* mean—in our judgment—some sort of reporting system wherein some Federal agency has the responsibility to keep abreast of worldwide weather modification projects, insofar as practicable. We know that NOAA is already mandated to do that within the U.S. by P.L. 92-205. If it is not being done on a worldwide basis—and I suspect it's not—we would like to see some international body like the UN's World Meteorological Organization take on the task.

Besides the record keeping, we believe there is a continuing great need for close interagency coordination at the Federal level (as there is) to avoid duplication of research effort and sharing information. I want to underscore the word "research" because, in our judgment, the Federal agencies should not engage in operational type activities.

Boiled down to its essentials, Mister Chairman, the Federation generally supports a "status quo" arrangement, at least for the foreseeable future. Our position is subject to change, of course, if ongoing research indicates a need for Uncle Sam to take a tighter grip on the reins. Meanwhile, we urge the Federal Establishment to actively encourage all forms of weather modification research (with emphasis on inadvertent ecological effects) but to promote only those activities—such as fog dispersal and orchard protection—which have the greatest payoff for the public with little, if any, impact on ecosystems.

Thank you for this opportunity to express my views.

[Resolution No. 7]

WATER MODIFICATION

Whereas, the state of the art in weather modification has progressed to the point where man, in his efforts to enhance agricultural production, aid commerce and avert natural disasters, now is frequently able to modify weather to increase precipitation, suppress hail, and dissipate certain kinds of fog under favorable atmospheric conditions; and

Whereas, there is a growing body of evidence that intentional weather modification can inadvertently affect the environment by causing long-term changes in vegetative cover, by adding potentially toxic chemicals to the environment, and by otherwise upsetting complex ecological systems; and

Whereas, the long-term social implications and legal aspects of advertent weather modification present serious unresolved problems; Now, therefore, be it

Resolved, That the National Wildlife Federation, in annual convention assembled March 14-16, 1975, in Pittsburgh, Pennsylvania, hereby urges all governmental agencies and private contractors to conduct advertent weather modification activities with extreme caution and only when and where there is substantial evidence that such activities will not have significant adverse effects upon the environment.

The Federal Role In Weather Modification

**Domestic Council
Environmental Resources Committee
Subcommittee on Climate Change**

December 1975



Subcommittee on Climate Change
Environmental Resources Committee
Domestic Council

<u>Member</u>	<u>Title and Agency</u>
Dr. Robert M. White, Chairman	Administrator, National Oceanic and Atmospheric Administration Department of Commerce
Dr. Harry C. Trelogan	Administrator, Statistical Reporting Service Department of Agriculture
Dr. Edward S. Epstein	Associate Administrator for Environmental Monitoring and Prediction National Oceanic and Atmospheric Admin- istration Department of Commerce
Mr. James L. Kerr	Bureau of Reclamation Department of Interior
Mr. Christian A. Herter, Jr.	Deputy Assistant Secretary for Environmental and Population Affairs Department of State
Mr. Samuel C. Coroniti	Deputy Program Manager for CIAP Department of Transportation
Dr. Lee M. Talbot	Assistant to the Chairman for Interna- tional and Scientific Affairs Council on Environmental Quality
Dr. John E. Naugle	Deputy Associate Administrator National Aeronautics and Space Administration
Dr. Edward P. Todd	Deputy Assistant Director for Astronom- ical, Atmospheric, Earth, and Oceans Sciences National Science Foundation
Mr. Carl Hystad	Chief, Commerce Branch Office of Management and Budget
Capt. Kenneth W. Ruggles, USN Observer	Military Assistant for Environmental Sciences Office of the Director of Defense Research and Engineering Department of Defense

EXECUTIVE SUMMARY

Economic losses due to weather extremes and severe weather events have steadily increased. Increasing population and property development make it likely that this will continue. The present and growing water shortages in many areas of the Nation have also created serious problems of National concern.

Weather modification represents a potential tool for exerting a favorable influence over destructive weather events and for augmenting water supplies in some areas where additional water is needed for energy, food, and fiber production.

General Recommendation

- A policy should be adopted to develop, encourage, and maintain a comprehensive and coordinated national program in weather modification research and in the beneficial application of the technology along the lines of the recommendations embodied in this report.

Specific Findings and Recommendations

A. RESEARCH

Findings

- Present Federal strategy in research in weather modification is to develop techniques to achieve particular objectives such as augmenting water resources or diminishing the damage from hurricanes. The strategy does not view the development of a weather modification science and technology as a specific national goal whose achievement would allow many different applications as needs arise.
- This strategy, which encourages the individual agencies to conduct weather modification research in pursuit of their assigned missions, has divided the research responsibility, while budgetary limitations over the past several years have produced a situation in which many individual projects are marginally staffed, funded, and operated.
- The level of scientific and technological complexity of even modest weather modification experimentation requires a higher level of funding than has usually been available to accomplish individual project goals.
- While progress has been generally slow and uneven, some advancement has been achieved over the past two decades in several types of weather modification research under existing policies.

- More vigorous encouragement and development of the fundamental knowledge of the physics and dynamics of cloud processes are necessary to permit adequate development of the potential of this field.

Recommendations

- The Federal Government should recognize weather modification as having significant potential for ameliorating important weather-related problems and foster a broad-based effort of research and experimentation in weather modification designed to realize this potential during the next decade.
- The Federal Government should examine its institutional structure for planning and management of the national weather modification effort to carry out its responsibilities for research and experimentation. The Subcommittee identified two practical institutional options but could not achieve consensus on either. A decision should be made between the following options:
 - Option (1) Continue coordination and planning of the national weather modification effort through the Interdepartmental Committee for Atmospheric Sciences of the Federal Council for Science and Technology, with individual agencies pursuing their mission responsibilities.
 - Option (2) Establish a lead agency to foster the broad advancement of the science and technology of weather modification as recommended by the National Advisory Committee on Oceans and Atmosphere, the National Academy of Sciences, and other groups to coordinate and plan the national effort with the assistance and participation of other agencies.
- Weather modification research in general should be funded at an increased level to ensure that present marginal efforts can be transformed into significantly more productive activities.
- The Federal Government should develop and support a more vigorous program of fundamental research and experimentation in the physics and dynamics of cloud processes to advance weather modification technology and its application.
- Greater emphasis in research should be placed on the assessment of the socioeconomic and environmental impacts of weather modification.
- Greater emphasis should be placed on the development of improved methodologies to evaluate the effects of weather modification.

B. OPERATIONS

Findings

- Few operational weather modification techniques have been thoroughly proven.
- Several weather modification techniques are sufficiently close to a stage of proven effectiveness that they should be considered as management options in some situations.

Recommendations

- When and if weather modification techniques are determined feasible and desirable for a given situation, the Federal Government should reserve for itself the responsibility in the following areas:
 - Precipitation modification related to water resources benefiting several states and to projects under Federal jurisdiction.
 - Weather modification to improve conditions over airports, roads, ports, National Forests, and other lands under Federal jurisdiction.
 - Mitigation of large-scale (more than one State) developing drought, with the concurrence and cooperation of the States involved, where it is determined that the effects may be widespread or threaten the Nation's welfare.
 - Mitigation of hurricanes and other extensive storm systems, which affect more than one State and represent a major threat to life and property.
- The States and private sector should be encouraged to consider operational weather modification as a management option addressed to problems other than those specified above as being Federal responsibilities.
- Private sector capabilities should be used in the conduct of Federal weather modification operations where both feasible and desirable.

C. REGULATION

Findings

- Additional Federal regulatory legislation is not needed at this time.
- Present reporting procedures have fulfilled an important need.

- Given the significant amount of activity in the field as well as the potential for increased use of the technology, prudence dictates a continuing examination of the need for Federal laws and regulations and international treaties and agreements to govern weather modification activities.

Recommendations

- A formal procedure should be established for the periodic reassessment of regulatory needs, based on an ongoing review of operational weather modification activities.
- The design and implementation of future U.S. domestic and foreign weather modification activities should include prior assessment of the potential international implications.

TABLE OF CONTENTS

	<u>Page</u>
Executive Summary	1
Preface.	vi
The Potential Benefits of Weather Modification	1
The State of the Art	7
Fog and Stratus Cloud Dissipation	7
Precipitation Enhancement	8
Severe Storm Amelioration	10
Hail Suppression	10
Lightning Suppression.	10
Hurricane Modification	10
Tornado Suppression.	11
Inadvertent Weather and Climate Modification. . .	11
Deliberate Climate Modification	12
The Role of the Federal Government	13
Research.	13
Operations	21
Regulation.	25
Appendix A: A Lead Agency for the National Weather Modification Research Program	A-1

PREFACE

The Domestic Council's Environmental Resources Committee, at the request of the Council, formed the Subcommittee on Climate Change in August 1974. One element of the Subcommittee's charter was to examine and make recommendations on the Federal role in weather modification research, operations, and regulation.

The Subcommittee is composed of representatives drawn from the Departments of Agriculture, Commerce, Interior, State, and Transportation; the Council on Environmental Quality; the National Aeronautics and Space Administration; the National Science Foundation; and the Office of Management and Budget. The Department of Defense participated as an observer in discussions on weather modification.

In preparing its report, the Subcommittee has drawn substantially from recent documentation on the progress, status, and problems in weather modification and, through a two-day open hearing, from well-informed representatives of the scientific community, commercial sector, state governments, conservation groups, agriculturalists, and the legal field. Although inadvertent changes in the weather that may be caused by human activity are discussed briefly, the Subcommittee limited itself to deliberate weather modification in developing its conclusions and recommendations.

The Subcommittee recognized the increasing level of activity in weather modification in other countries and the role that the United States may play in those programs. Also recognized was the fact that domestic use of weather modification techniques has the potential for international impacts. However, because of time and resource limitations, the Subcommittee decided to limit the scope of this report to domestic concerns.

THE POTENTIAL BENEFITS OF WEATHER MODIFICATION

Most human activity is directly or indirectly influenced by weather. Historically, man has attempted to modify his activities to take advantage of prevailing weather and minimize the effects of adverse weather. During the last quarter century, however, he has been attempting to develop techniques by which he can manage the weather as a resource for his benefit and for the protection of life and property.

Although early interest in weather modification centered on increasing economic benefit through stimulation of local precipitation, there has been an increase in research directed toward reducing losses from adverse weather and certain weather-related disasters. Reduction of losses due to severe storms invites particular attention because losses are often large for any single event and, because of increasing urban development in vulnerable areas, average annual property losses are increasing drastically.

Property damage caused by hurricanes has been increasing in the United States since early in the Twentieth Century while loss of life has been decreasing. Improvements in the hurricane warning service and in community preparedness programs are saving lives. Expansion of cities into vulnerable areas and construction along coasts are largely responsible for the increased annual property loss, now estimated to exceed \$780 million (table 1) with large variation from year to year. Relatively few storms cause most of the damage.

Property damage from tornadoes has increased dramatically over the past three decades. Damages during 1970-1974 averaged \$360 million per year, approximately 10 times the annual average during 1940-1944. Tornado-related deaths during 1970-1974 averaged 140 per year, approximately

Table 1. Annual property damage and loss of life from weather-related disasters and hazards in the United States and FY 1975 Federal weather modification research funding

Weather Hazard	Loss of Life/ (Billions of Dollars)	Property Damage/ (Billions of Dollars)	Modification Research (Millions of Dollars)
Hurricanes	30 (1970-74 Avg.)	0.8 (1970-74 Avg.)	0.8*
Tornadoes	140 (1970-74 Avg.)	0.4 (1970-74 Avg.)	1.0**
Hail	-	0.8 (1973)	3.9
Lightning	110 (1950-72 Avg.)	0.1	0.4
Fog	1000 (Avg.)	0.5 (Avg.)	1.3
Floods	240 (1965-69 Avg.)	2.3 (1965-69 Avg.)	-
Frost (Agric.)	-	1.1 (Avg.)	-
Drought	-	0.7 (Avg.)	3.4#
Totals	1520	6.7	10.8

* These funds do not include capital investment in research aircraft and instrumentation primarily for hurricane modification, which in FY 1975 amounted to \$9.2 million.

** These funds support theoretical research on modification of extratropical cloud systems and their attendant severe storms such as thunderstorms and tornadoes.

These funds support precipitation augmentation research, much of which may not have direct application to drought alleviation.

1/ Sources: Assessment of Research on Natural Hazards, Gilbert F. White and J. Eugene Haas, The MIT Press, Cambridge, Mass., 1975, pp 68, 286, 305, 374; The Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 1976, U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), Washington, D.C., April 1975, p 9; Weatherwise, Feb. 1971, 1972, 1973, 1974, 1975, American Meteorological Society, Boston, Mass.; Summary Report on Weather Modification, Fiscal Years 1969, 1970, 1971, U.S. Department of Commerce, NOAA, Washington, D.C., May 1973, pp 72, 81; Estimating Crop Losses Due to Hail - Working Data for County Estimates, U.S. Department of Agriculture, Economic Research Service, Sept. 1974; Natural Disasters: Some Empirical and Economic Considerations, G. Thomas Sav, National Bureau of Standards, Washington, D.C., Feb. 1974, p 19; Traffic Safety Magazine, National Safety Council, Feb. 1974.

16 percent less than during 1940-1944, undoubtedly the result of improvements in the timeliness and accuracy of tornado forecasts and public response to the forecasts.

Other severe weather events that cause substantial damage in the United States for which reasonably reliable loss figures are available are hail and lightning. In 1973 the annual hail damage to crops in the United States totaled \$680 million. Damage to other property brought the U.S. 1973 hail damage figure to over \$750 million. The average annual lightning-caused forest fire damage exceeds \$100 million, not including cost impacts of the reduction in esthetic value and possible further damage due to floods from denuded watersheds.

A fifth weather hazard, fog, costs domestic airlines more than \$80 million per year due to aircraft delays, diversions, and cancellations. Fog-associated accidents on the Nation's highways and in the Nation's ports cause approximately 1000 deaths and damages in excess of \$400 million each year.

The average annual cost in the United States directly identified with selected impacts of these five hazards - hurricanes, tornadoes, hail, lightning, and fog - exceeds two billion dollars. It is more difficult to assign a precise dollar value to losses suffered as a result of other forms of adverse weather, particularly extremes in precipitation and temperature. Conservative estimates, however, place annual average losses from floods and frosts in excess of three billion dollars, with frost being primarily an agricultural problem. Weather is, in fact, the most significant variable explaining year-to-year fluctuations in the yield of most agricultural crops. It has been estimated, for example, that drought

(a period when water is deficient enough for long enough to cause serious crop damage over a sizable area) causes average annual crop losses in excess of \$700 million. There are, however, large year-to-year variations in these losses, ranging near zero in optimum growing years to billions of dollars in years with severe drought conditions. For example, loss estimates from crop damage in Nebraska alone as a result of the 1974 drought totaled approximately one billion dollars.

Weather modification is one alternative, albeit technically limited, available to decrease the risk of loss from weather hazards. Other alternatives include relocating economic and population centers to low-risk areas; constructing weather-proof facilities; or expanding hazard insurance coverage. To the extent that weather modification is economically more attractive than its alternatives, it should be employed. However, it is recognized that not all weather-related losses can be prevented. Consider hurricane losses for example. Weather modification has the potential of reducing winds and wind damage, but there are no present techniques which could reduce losses due to heavy rainfall and inland flooding. Therefore, the potential gain in practicing weather modification would not be a full recovery of the \$780 million loss as shown in table 1, but only a fraction of the loss attributed to wind damage effects. In a similar sense, weather modification to ameliorate damage from tornadoes, hail, and lightning could only be selectively practiced due to the widespread occurrence of these storms and the difficulty in predicting their occurrence. Nevertheless, even a ten percent reduction of losses from severe storms, drought, and fog would save \$300 to \$400 million annually. Present Federal investment in weather modification research, however, is

insufficient to make substantial progress toward these levels of return in the near future.

Most existing experimental weather modification techniques are inexpensive to apply compared to their potential utility. Estimated benefit-to-cost ratios of potential weather modification technologies range from about 3 to 1 for fog dissipation at airports, 30 to 1 for precipitation augmentation, and as high as 100 to 1 for hurricane moderation. In a few cases the benefits to some may be partially offset by losses to others, but there may well be sufficiently large net benefits to enable compensation programs in those instances.

For example, it has been estimated that an additional inch of rain in North Dakota during the growing season could provide \$100 million in direct benefits through increased crop production plus an additional \$200 million in indirect income within the state economy. The cost of a statewide precipitation augmentation program would be less than \$2 million per year.^{2/} While it is not proven that an additional inch of rain can be produced consistently by cloud seeding, a 2700 square mile pilot project in North Dakota has shown that such changes are within the realm of possibility.^{3/}

Such favorable benefit-cost-ratios offer inducements to make use of promising ideas as they are developed. A strong responsibility rests upon the Federal Government to develop, test, evaluate, and refine these techniques and to document ancillary consequences.

^{2/} The Effects of Added Rainfall During the Growing Season in North Dakota, North Dakota State University, June 30, 1974.

^{3/} Evaluation by Monte Carlo Tests of Effects of Cloud Seeding on Growing Season Rainfall in North Dakota, by A.S. Dennis, et al., J. Appl. Meteor. V. 14, No. 5, August 1975, p. 959-969.

Social acceptability of both research and operational weather modification has varied considerably with location in the United States and elsewhere. In Florida the fear of additional rain from a cloud seeding experiment harming tomato crops at critical stages of development caused curtailment of the seasonal duration of the program. Potential avalanche danger in the Colorado Rockies and impact on hunters have restricted experiments in snowpack augmentation. There have been attempts to halt operational programs through court injunctions and even through violence. Such problems have not been the rule and good communications and public relations have usually minimized unfavorable reactions. Nevertheless, it is clear that social, environmental, and international concerns must be fully explored to assess the potential adverse impacts of routine application of weather modification techniques.

THE STATE OF THE ART

The principal focus for weather modification concerns and activities are:

1. Fog and stratus cloud dissipation;
2. Precipitation enhancement;
3. Severe storm amelioration, including intensity reduction, redistribution of precipitation, and hail and lightning suppression;
4. Inadvertent weather and climate modification; and
5. Deliberate climate modification.

The ability to achieve a modification objective varies significantly. In some categories progress has been substantial; in others research has only begun. Few modification techniques have been scientifically proven to be completely effective and dependable. Nonetheless, some deliberate weather modification is practiced as a commercial service sold to private groups and local and Federal Government entities. Approximately 65 percent of these services are directed at precipitation enhancement. The remaining operations are divided nearly equally between fog dispersal and hail suppression.

Briefly, the state of the art in weather modification may be summarized as follows:

1. Fog and stratus cloud dissipation
 - Supercooled (water droplets at a temperature below freezing) fog and stratus can be cleared from airports. Operational systems for cold fog dispersal have been established at some U.S. Air Force bases and at some commercial airfields in the United States and in several foreign countries.

- Warm fog (at a temperature above freezing) dissipation has been demonstrated as technically feasible in certain meteorological situations. The only operationally proven technique, however, is the application of heat over airport runways to evaporate fog.

2. Precipitation enhancement

- Snowfall in certain mountainous areas of the western United States can be increased locally by 15 to 20 percent and in some instances redistributed by seeding winter orographic clouds. This capability was established to the satisfaction of much of the scientific community during the 1960's at Climax, Colo., and is being tested in other mountainous regions of the West. Private weather modifiers, however, have been conducting operational winter orographic cloud seeding to increase snowpack for power companies and water interests for over 20 years. These programs have been commercially funded and endorsed; however, they have not been designed for rigorous scientific evaluation.
- Long-term seeding experiments conducted in Southern California, Israel, and Australia to stimulate precipitation from winter convective systems have provided significant positive results. Israel recently converted to an operational seeding program supported by continuing research aimed at improving this technology. Winter convective systems usually consist of convective cells embedded in stratiform cloud decks. There is persuasive evidence of sizeable extra-area effects as a result of seeding

winter convective storms. Apparent increases in rainfall on seeded occasions have been found 80 to 150 miles downwind of seeding sites in southern California.

- Recent experiments in the Plains States, especially those in the Dakotas, and experiments in Florida involving randomized, ice-nuclei seeding of summer convective clouds strongly suggest that precipitation can be enhanced from some isolated cumulus clouds. "Seedable" clouds, as determined by simple computer cloud models, produce more precipitation when seeded than when not seeded. However, the majority of summer rainfall comes not from isolated clouds but from organized convective systems. Results from experiments in organized cloud systems over fixed target areas have not been as conclusive although recent findings of the North Dakota Pilot Project are promising.^{4/} Four years of seeding research in Florida over a target area of 4900 square miles have shown that the natural variability of convective rainfall is far greater than the additional rainfall expected from seeding, thereby making definitive proof of rain increases elusive. Despite the lack of definitive proof of success, operational application of convective cloud seeding to augment precipitation has been extensive under the sponsorship of state and county governments and primary water users, especially in agricultural regions such as North and South Dakota, Texas, and Oklahoma.

^{4/} Ibid.

3. Severe storm amelioration

- Hail suppression is a form of precipitation modification for which some success is reported. Most hail suppression operations in the United States are conducted by commercial cloud seeders under contract to state and county governments and community associations. Hail suppression operations are conducted extensively in foreign countries. However, the lack of a satisfactory system for evaluating the results of these operations leaves many important questions unanswered. Three years of field experimentation by the National Hail Research Experiment (NHRE) have not provided sufficient information and understanding to answer these questions.
- Results of field experiments to suppress lightning activity by silver iodide seeding have been ambiguous. Although the analysis is continuing, the seeding program has been terminated. In recent experiments in lightning suppression, thunderstorms were seeded from below with chaff (very fine metalized nylon fibers), and the number of lightning occurrences was observed to be about 25 percent of that observed in the control storms (based on an analysis of data from 10 seeded thunderstorms and 18 unseeded control storms). Although the experiments were not strictly randomized, statistical evaluation indicated that the observed difference between seeded and control storms was significant.
- Hurricane modification research and field experiments suggest that the maximum winds in hurricanes might be reduced by 10'

to 15 percent if the appropriate clouds of the storms are seeded with freezing nuclei. Additional experiments are needed, however, to determine if the observed reductions in maximum wind are truly results of the seeding. There is no indication that the hurricane track or associated precipitation can be modified.

- Tornado suppression is beyond the present state of the art with little hope for success in the near future. Long-term investigations have been initiated recently into the modification of cyclonic storm systems and the mitigation of their attendant severe weather.

4. Inadvertent weather and climate modification

- A major field project, the Metropolitan Meteorological Experiment (METROMEX), was established in 1971 at St. Louis, Mo., to study the effects of urbanization on various aspects of atmospheric behavior (inadvertent regional climate modification). Preliminary results show that the St. Louis urban-industrial complex influences summertime convective storm behavior, increasing the average precipitation by 20 to 30 percent and the intensity and frequency of severe weather including hail by even greater amounts in localized areas within 25 miles downwind of the city center.
- Studies are being conducted to assess the large-scale impact of man's activities on climate (inadvertent global climate modification). Thermal pollution, particulate pollution, and increased generation of such gases as CO_2 , NO_2 and chloro-fluoromethanes are being studied. For example, the Climate

Impact Assessment Program has examined the effect of high altitude aircraft. A global network of monitoring stations is being established to determine baseline values of small, variable trace constituents of the atmosphere and to determine the effect of long-term trends in these trace constituents on global weather and climate. These data will provide input for diagnostic and prognostic numerical global models being developed to predict climate changes resulting from man's activities. At this time, however, knowledge about inadvertent modification processes is insufficient to allow definitive conclusions.

5. Deliberate climate modification

- The United States Government is not giving serious attention to any proposals to intentionally modify climate over sizeable areas.

THE ROLE OF THE FEDERAL GOVERNMENT

The Subcommittee on Climate Change is charged with examining the Federal role in domestic weather modification activities. Deliberation by the Subcommittee included a two-day open hearing at which selected individuals with valid concerns and well-formed views on the Federal role in weather modification were invited to testify. Speakers included representatives from the research community, private operators, the legal sector, state governments, conservation groups, and agriculturalists.

In addressing the Federal role in weather modification, the Subcommittee limited itself to those activities identified earlier as deliberate weather modification. The Subcommittee examined separately issues in research, operational programs, and regulation and concluded that there is a need for a Federal policy covering these areas. It is recommended, therefore, that:

- *A policy be adopted to develop, encourage, and maintain a comprehensive and coordinated national program in weather modification research and in the beneficial application of the technology.*

Specific findings and recommendations which could form the basis for such a policy are presented in this section of the report.

A. Research

Weather modification encompasses many research areas. Fundamental research is conducted in cloud physics, cloud dynamics, and in natural and artificial nucleation. Equipment development includes measuring instruments and delivery and observing systems. Supporting studies include numerical and physical modeling, analysis and evaluation studies, field

experimentation, and special studies of the sociological, ecological, economical, legal, and international impacts of weather modification. Although field experimentation is the most visible part of the program, it represents only a portion of the total Federal research effort in weather modification.

An identifiable coordinated Federal research program in weather modification has been in existence at least since 1959 when the National Science Foundation, in response to Public Law 85-510, established a program to support studies, research, and evaluation in the field of weather modification. After a slow beginning, Federal funding for deliberate weather modification research increased steadily from \$3.7 million in FY 1965 to a peak of \$18.7 million in FY 1972. Support for the program decreased 34 percent to \$12.4 million in FY 1975. As shown in table 2, six Federal agencies have participated in this research program. FY 1976 planned expenditures indicate an increase of \$1.7 million with the support being increasingly concentrated in three agencies, the Departments of Commerce and Interior and the National Science Foundation.

The Subcommittee recognized that the Interdepartmental Committee for Atmospheric Sciences (ICAS) figures, which form the basis for table 2, have excluded capital investments in Department of Commerce aircraft and instrumentation used primarily for weather modification. In FY 1976 these additional funds amounted to \$5.5 million.

Table 2 also includes the FY 1976 planned expenditures for research in meteorology, as defined in the ICAS annual reports on the national atmospheric sciences program. These include research and development expenditures in such areas as physical and dynamic meteorology, observation,

description, prediction, and dissemination, and major support items such as highly instrumented research aircraft. Clearly, funding for weather modification research is a small amount embedded in a much larger program of atmospheric research. However, many facets of the larger program relate to weather modification and provide indirect benefits.

Table 2. Agency Funding for Deliberate Weather Modification Research Compared with Total FY 1976 Funding for Meteorological Research^{5/} (Millions of Dollars)

<u>Agency</u>	<u>FY 72</u>	<u>FY 73</u>	<u>FY 74</u>	<u>FY 75</u>	<u>FY 76</u>	<u>Total FY 76 Meteorology Funding</u>
Dept. of Agriculture	0.4	0.3	0.3	0.1	0.1	2.3
Dept. of Commerce	3.9	3.8	3.3	2.7	3.3	53.7
Dept. of Defense	1.8	1.2	1.2	1.3	0.5	26.1
Dept. of Interior	6.7	6.4	3.9	3.5	4.6	4.6
Dept. of Transportation	0.4	0.4	0.1	0.1	0.0	11.7
Nat'l Science Foundation	5.5	6.2	4.7	4.7	5.6	45.9
Other Federal Agencies	0.0	0.0	0.0	0.0	0.0	64.3
Totals	18.7	18.3	13.5	12.4	14.1	208.6

Virtually all research in weather modification in this country has been Federally supported. In reviewing the Federal role in this area of research, the Subcommittee noted with concern the lower level of support for conducting research programs during recent years. The Subcommittee unanimously feels that the Federal Government must recognize and fulfill its commitment to research in weather modification. Greater nonfederal participation should be encouraged. States are now contributing in some instances. For example, some state governments have made funds available to participate in the Bureau of Reclamation High Plains Cooperative Program,

^{5/} National Atmospheric Sciences Program Fiscal Year 1976, Interdepartmental Committee for Atmospheric Sciences, Washington, D.C., ICAS 19-FY76, May 1975.

and one state is participating in METROMEX. It is hoped that such state government involvement in research will continue. There appears to be little incentive for private industry to invest its own resources in research in weather modification.

The magnitude of individual experimental weather modification projects dictates Federal responsibility. In major weather modification projects, such as the hurricane modification experiments, there can be no question concerning the Federal role. Clearly, such projects must remain the responsibility of the Federal Government if for no other reason than the immensity of the undertakings, the social and international implications, and the magnitude of the required resources. Even smaller projects like NHRE and METROMEX require a concentration of resources unlikely to be made available other than through the Federal agencies.

The Federal research effort in weather modification has been subject to persistent criticism by various review groups during the past few years. The most consistent criticisms include the lack of a National policy, fragmented programs, and subcritical funding levels.^{6,7,8/} In their recent review of the administration of Federal weather modification research, for example, the General Accounting Office indicated concern for the fragmented nature of past research activities and cited the lack of

6/ A Report to the President and The Congress, National Advisory Committee on Oceans and Atmosphere, First Annual Report, June 30, 1972.

7/ Weather and Climate Modification, Problems and Progress, Committee on Atmospheric Sciences, National Academy of Sciences, Washington, D.C., 1973.

8/ Need for a National Weather Modification Research Program, Report to the Congress B-133202, August 23, 1974, Comptroller General of the U.S. General Accounting Office, Washington, D.C.

central management of the overall research effort. The Subcommittee, taking these criticisms into consideration during its deliberations, came to the following conclusions with regard to the present state of affairs:

- To the extent that a National policy on research in weather modification can be identified^{9/} it reflects the present Federal strategy of developing techniques to achieve particular objectives such as augmenting water resources or diminishing the damage from hurricanes. This strategy does not view the development of a weather modification science and technology as a national goal whose achievement would allow many different applications as needs arise.
- This strategy, which encourages the individual agencies to conduct weather modification research in pursuit of their assigned missions, has divided the research responsibility, while budgetary limitations over the past several years have produced a situation in which many individual projects are marginally staffed, funded, and operated. This divided responsibility approach lends itself to the criticism of "fragmentation" by some.^{6,7,8/}
- The level of scientific and technological complexity of even modest weather modification experimentation requires a higher level of funding than has usually been available to accomplish individual project goals. This finding is consistent with recent conclusions

^{9/} Letter from Norman E. Ross, Jr., Assistant Director, Domestic Council, to Congressman Gilbert Gude, Congressional Record - House, June 17, 1975, p. H5629.

reached by the National Academy of Sciences and the National Advisory Committee on Oceans and Atmosphere.^{6, 7/}

- While progress has been generally slow and uneven, some advancement has been achieved over the past two decades in several types of weather modification research under existing policies. This finding is in agreement with conclusions reached in the reports cited above.
- Fundamental knowledge concerning physics and dynamics of cloud processes is inadequate. This finding is consistent with the general view expressed by the recent American Meteorological Society cloud physics review.^{10/} The lack of the necessary scientific base is one of the major bottlenecks impeding development of useful, deliberate weather modification techniques. Other scientific and technical aspects of weather modification also need improvement; for example, observation systems, techniques of evaluation, and delivery systems.

In light of the economic losses and potential benefits discussed in the opening section of this report, the Subcommittee concludes that weather modification represents an important potential tool for exerting influence over destructive and disruptive weather events. Successful weather modification techniques to favorably influence weather elements would have a high benefit/cost ratio. As the population continues to grow and becomes increasingly concentrated in regions of severe weather and as the demand for water for agriculture, industry, and domestic use grows, the

^{10/} "Cloud Physics", Roscoe R. Braham, Jr., and Patrick Squires, Bulletin of the American Meteorological Society, Vol. 55, No. 6, June 1974, pp 543-586.

possibilities for effective weather modification are likely to appear even more attractive as a means for augmenting the economy and preventing disasters. There remains, however, the serious question of possible disbenefits or ancillary consequences. Only through additional research can the ultimate potential of weather modification be estimated accurately. The Subcommittee recommends, therefore, that

- *The Federal Government recognize weather modification as having significant potential for ameliorating important weather-related problems and foster a broad-based effort of research and experimentation in weather modification designed to realize this potential during the next decade.*
- *The Federal Government examine its institutional structure for planning and management of the national weather modification effort to carry out its responsibilities for research and experimentation. The Subcommittee identified two practical institutional options but could not achieve consensus on either.^{11/}*

A decision should be made between the following options:

Option (1) Continue coordination and planning of the national weather modification effort through the Interdepartmental Committee for Atmospheric Sciences of the Federal Council for Science and Technology, with individual agencies pursuing their mission responsibilities.

^{11/} Appendix A presents views submitted by those agencies wishing to comment on these options.

Option (2) Establish a lead agency to foster the broad advancement of the science and technology of weather modification as recommended by the National Advisory Committee on Oceans and Atmosphere, the National Academy of Sciences, and other groups to coordinate and plan the national effort with the assistance and participation of other agencies.

- *Weather modification research in general be funded at an increased level to ensure that present marginal efforts can be transformed into significantly more productive activities. A number of scientific bodies have looked at the level of funding needed for a comprehensive weather modification program. In 1966, the National Academy of Sciences suggested that some \$30 million in Federal support would be required by fiscal year 1970. The Federal Council for Science and Technology (Newell Report), on the basis of a much more thorough study of agency requirements, recommended a figure of about \$90 million for fiscal year 1970. The National Academy of Sciences, in its 1973 report, estimated that no less than \$50 million will be required annually to implement their recommended national program. We as a Subcommittee believe there is now a need for a new plan or assessment as to what is required, and that such a plan should be prepared by the Federal group or agency with central responsibility as determined by the previous recommendation.*

- *The Federal Government develop and support a more vigorous program of fundamental research and experimentation in the physics and dynamics of cloud processes to advance weather modification technology and its application.*
- *Greater emphasis in research be placed on the assessment of the socioeconomic and environmental impacts of weather modification.*
There are many cases where field experimentation has encountered serious difficulty because of public (social) impact or the concerns expressed by foreign governments. More important is the need to provide input for rational decisions concerning the possible application of the developed technology.
- *Greater emphasis be placed on the development of improved methodologies to evaluate the effects of weather modification.* This recommendation has been made because this is a major obstacle to efficient experimentation and to effective monitoring of weather modification operations. Current evaluation methods are not adequate to distinguish natural from man-made changes.

B. Operations

Federal weather modification programs generally have been limited thus far to research and development activities. However, depending upon the definition selected, there have been some domestic activities that could be termed operational.

Because of severe drought in 1971, emergency cloud seeding efforts for drought alleviation in Arizona, Texas, and Oklahoma were undertaken by the Bureau of Reclamation at the request of the governors of those states and at the direction of the Office of Emergency Preparedness. The National

Oceanic and Atmospheric Administration also expanded its ongoing research project in seeding tropical cumulus clouds in Florida in 1971 in response to an appeal by the Governor of Florida for drought alleviation assistance. In addition, the Department of Defense has undertaken operational weather modification to disperse fog at several of its military installations.

The Bonneville Power Administration of the Department of the Interior proposed to utilize cloud seeding operationally to help relieve a critical power shortage in the Pacific Northwest in the fall of 1973 by augmenting precipitation in the drainage basin above Hungry Horse Dam in Montana. The project was never implemented because a change in weather conditions made it unnecessary. However, there are plans to consider implementing the project should conditions again warrant such action.

There has also been limited Federal application of existing lightning suppression and precipitation enhancement seeding techniques in an attempt to decrease initiation of lightning-caused forest fires or suppress ongoing fires in Alaska. A seeding capability was tested and deployed, though not actually used, at Cape Canaveral in connection with Apollo-Soyuz and Viking launches during the summer of 1975.

Results from most Federal research projects have not yet reached a generally acceptable level of statistical significance; research in some areas of weather modification is not presently considered to have reached the experimental state (tornadoes, blizzards, and flood control), nor have anticipated economic benefits or environmental effects been fully determined. Nevertheless, many nonfederal groups, after weighing the uncertainties, have proceeded to implement operational programs.

In a report on weather modification activities in the United States covering calendar year 1974, a listing of 74 reports submitted to NOAA shows that there were 65 nonfederally sponsored operational projects conducted in 22 different states, most in the West.^{12/} The data also show that there were three principal purposes for the activities: precipitation increase, fog dispersal, and hail decrease. Sponsors of these operational activities included states, cities, counties, municipal districts, airport authorities, community associations, power companies, airlines, and others.

Although few operational weather modification techniques have been thoroughly proven, the Subcommittee finds that several techniques are sufficiently close to a stage of proven effectiveness that they should be considered as management options in some situations. For example, given the proper conditions, precipitation can be increased from cold orographic winter clouds and from individual cumulus clouds, and supercooled fogs and low stratus can be dissipated over limited areas. Although success has been claimed in other operations such as hail modification, these operational weather modification activities have not been subjected to the kind of scrutiny required for substantiating such claims.

In view of this finding and because of expected increased public pressure for Government action to cope with critical water shortages, periodic droughts, destructive storms, and other weather phenomena, the Subcommittee believes that relative roles of the Federal Government and the nonfederal sector in the operational application of weather modification should be clarified. Accordingly, the Subcommittee recommends that:

^{12/} Weather Modification Activity Reports - Calendar Year 1974, Environmental Modification Office, National Oceanic and Atmospheric Administration, Rockville, Maryland, March 1975.

- *When and if weather modification techniques are determined feasible and desirable for a given situation, the Federal Government reserve for itself the responsibility in the following areas:*
 - *Precipitation modification related to water resources benefiting several states and to projects under Federal jurisdiction.*
 - *Weather modification to improve conditions over airports, roads, ports, National Forests, and other lands under Federal jurisdiction.*
 - *Mitigation of large-scale (more than one State) developing drought, with the concurrence and cooperation of the States involved, where it is determined that the effects may be widespread or threaten the Nation's welfare.*
 - *Mitigation of hurricanes and other extensive storm systems which affect more than one state and represent a major threat to life and property. Tornadoes pose a special problem because of their local and short-term, but extremely severe, effects. Because there is no known technique for dealing with the tornado problem, the Subcommittee feels that it is inappropriate to make a recommendation with regard to relative roles at the present time.*
- *The States and private sector be encouraged to consider operational weather modification as a management option addressed to problems other than those specified above as being a Federal responsibility. A number of states have already adopted weather modification legislation and some have initiated extensive*

operational programs.

- *Private sector capabilities be used in the conduct of Federal weather modification operations where both feasible and desirable.*

C. Regulation

Currently, Federal legislation does not provide for regulation or control of weather modification activities. The only Federal legislation and rules associated with weather modification deal with the reporting of nonfederal projects to the Department of Commerce under Public Law 92-205. Federal projects are also reported to the Department of Commerce by inter-agency agreement.

The rules that implement the reporting law provide a viable mechanism for gathering information in the United States on project details as well as related environmental impact and safety considerations. The reporting program also allows State officials and project personnel to be alerted if an activity poses a possible hazard to the public, property or the environment, or interference with Federal research. Since the program was initiated in 1972, no alert notices have been issued. Although more restrictive legislation has been proposed, the reporting law remains the only applicable Federal regulation on weather modification.

On the state level, approximately thirty states have enacted legislation relating to weather modification. These statutes range from simple acknowledgement of weather modification to strict requirements for such items as licenses, permits, financial responsibility, public notices, tax levies, and penalties. The most recent state laws are more sophisticated in their coverage than earlier legislation. A few states are now considering new legislation or amendments to present laws. Thus, in the United

States, weather modification is controlled by the States, with a varying degree of regulation.

Three years ago, a detailed study^{13/} summarized and analyzed the various needs for Federal regulation in the field of weather modification. That paper concluded that all nonfederal weather modification projects should be prohibited unless a Federal permit was first obtained. The grounds for review of proposed projects would have been limited to interference with federally sponsored projects and protection of the public and of the national environment. The issuance of a Federal permit would signify merely that the Federal Government was satisfied on those two grounds.

The recommendations as contained in that paper were based upon the following findings made in 1972 that:

- A. "There is a substantial and growing amount of weather modification activity in the United States. --- Extensive operational programs are being carried out by the private sector.
- B. "The present state of the art in weather modification varies with the phenomena involved, but is advancing rapidly.
- C. "There is a real and growing concern over interference between and among weather modification programs, particularly between private operations and extensive research programs supported by Federal funds.
- D. "Projects may have significant adverse environmental effects, ranging from immediate hazards to life and property to long-term alterations in land use patterns and threats to ecological systems.

^{13/} Federal Regulation of Weather Modification, December 22, 1972, staff paper, the Council on Environmental Quality, Washington, D.C.

- E. "The purpose, scope and adequacy of (State laws) have varied widely."

Examination of current information and the Subcommittee's hearing testimony shows that the findings of three years ago require qualification.

It now appears that:

- A. A rapid growth of weather modification activity has not continued in the Federal and nonfederal sectors. Federal funding of weather modification research has decreased about 25 percent; funding for the private sector is not known, but no dramatic increase has been indicated. The number of projects, operators and States involved has shown no sustained growth. The conclusion is that weather modification activities in both the Federal and nonfederal sectors are substantial and steady. Generally, there are fewer projects in fewer states with fewer operators, but the total target area is increasing.
- B. The state of the art of weather modification has not advanced as speedily as anticipated.
- C. Interference between and among weather modification activities has not been a problem in the past three years.
- D. To the extent that environmental effects have been investigated, no short-term adverse effects have been substantiated. The question of long-term impacts remains open.
- E. State laws have tended to become more comprehensive. Major issues or problems due to State laws governing weather modification have not developed.

In view of the above the Subcommittee finds that additional Federal regulatory legislation is not needed at this time and reporting procedures have fulfilled an important need. However, given the still significant amount of activity in the field as well as the potential for increased use of the technology, prudence dictates a continuing examination of the need for Federal laws and regulations and international treaties and agreements to govern weather modification activities. This conclusion is based on the overriding considerations that weather phenomena cross state and national boundaries and improperly conducted weather modification may adversely affect public welfare.

In addition, weather modification activities may have effects outside U.S. territory and thus have an important impact on our foreign relations. An earlier concern by Canada on a proposed cloud seeding project in Washington State that could affect Canadian territory is a case in point. As a result of this and related concerns, the U.S. and Canada signed an agreement on March 16, 1975, to exchange information on weather modification activities conducted within 200 miles of the international boundary. Such considerations demand a continued Federal role in gathering information on weather modification activities in close coordination and consultation with the Department of State.

In light of the Subcommittee's evaluation concerning the need for regulation of weather modification, it is recommended that:

- *A formal procedure be established for the periodic reassessment of regulatory needs, based on an ongoing review of operational weather modification activities.*

- *The design and implementation of future U.S. domestic and foreign weather modification activities include prior assessment of the potential international implications.*

A LEAD AGENCY FOR THE NATIONAL WEATHER MODIFICATION
RESEARCH PROGRAM

The Departments of Commerce, State and Transportation and the National Aeronautics and Space Administration have examined the institutional options presented on pages 19 and 20 of the Subcommittee on Climate Change report, "The Federal Role in Weather Modification," and subscribe to option 2. This option calls for the establishment of a lead agency to foster the broad advancement of science and technology of weather modification. We strongly support the position that establishing a lead planning and coordinating agency for weather modification research and development would provide the basis for a more productive and effective national program, and we recommend that the National Oceanic and Atmospheric Administration (NOAA) be assigned this lead agency responsibility.

Various review bodies are identified in the Subcommittee report as advocating the lead agency approach. These groups have argued that a lead agency is needed to achieve the following objectives:

- To provide a central focus for the overall weather modification research and development effort.
- To overcome fragmentation and duplication in past weather modification research activities.
- To develop a national program with goals, objectives, priorities, and milestones.
- To develop a plan to allocate resources to the national program elements.

- To effectively coordinate activities of Federal departments and agencies providing support to or conducting weather modification research.
- To provide the scientific and management competence, the dedication, and the resources necessary to make the national goals in weather modification an integral part of its basic mission.

For the above reasons and because of our conviction that technologies for different modes of weather modification that one would wish to develop for different application all flow from a common font of science and experimentation, we subscribe to the view that the science could best be served by assignment of lead responsibility to an appropriate agency.

We feel that the charter for this lead responsibility should include the following:

- The lead agency would assume the leadership for planning the federal weather modification program, in concert with those other concerned agencies, universities, and the private sector.
- The lead agency would present, within the Executive Branch, a consolidated national weather modification research plan and be available to represent the national plan before the Congress.
- The lead agency would, within the framework of the joint planning effort, encourage and assist in justifying programmatic activities in other agencies that might contribute significantly to the national weather modification objectives, especially when those programs can be implemented as supplements to the agencies' ongoing mission-related activities.

- The lead agency would take on the responsibility for presenting the budgetary requirements to carry out the national plan to the Office of Management and Budget and, with due consideration of overall priorities of the agency, would seek to provide within its own budget for activities essential to the national plan and not incorporated in the budgets of the other agencies.

It is expected that other departments and agencies, because of their continuing responsibility for the application of weather modification, would provide for the necessary financial support within their individual agency budgets.

The recommendation that NOAA be designated the lead agency for weather modification research stems from its broad weather responsibilities as the principal national civil weather agency. These broad weather responsibilities give NOAA a broad range of managerial, technical, and facility capabilities suited to the role of a lead agency. It should be emphasized that, within the framework of the designation of NOAA as lead agency, it is expected that the National Science Foundation would continue to have the primary responsibility for supporting the basic science and the fundamental research at the universities and at the National Center for Atmospheric Research. Other Departments, such as Interior and Agriculture, would continue to exercise responsibilities for application of weather modification in support of their missions. The National Aeronautics and Space Administration would continue to have primary responsibility for supporting research and development in the application of space technology to problems in weather modification. The Department

of State would exercise the responsibility for assessing the impacts of weather modification activities on U.S. international relations and formulate foreign policy positions relevant to such activities.

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY,
Socorro, N. Mex., March 31, 1976.

Senators MONTOYA and DOMENICI,
New Senate Office Building,
Washington, D.C.

DEAR SENATOR MONTOYA AND DOMENICI: Senate Bill S. 2707 dealing with Weather Modification and Drought, has been introduced by Senator Bellmon. I am writing to urge that you oppose S. 2707 because it is based on the mistaken premise that the seeding technology which we now possess, and which has been used for "Weather Modification" purposes, is a reliable technology and can be used to relieve drought. May I point out that the American Meteorological Society has issued a statement regarding cloud seeding which can be paraphrased as follows: "Cloud seeding cannot be used to relieve drought". This statement is an obvious recognition that there must be water in the atmosphere in order to make rain. Furthermore, it has never really been demonstrated that cloud seeding, applied to summertime convective cloud systems, enhances rainfall. In fact, there is strong evidence that seeding of summertime cumulous clouds may reduce rainfall.

If this bill become law, it will unleash an epidemic of cloud seeding which not only will be costly in dollars expended, but which indirectly may lead to the economically costly and undesirable consequence of reduced rainfall.

Furthermore, those research projects presently working on the difficult problem of trying to ascertain whether or not seeding increases or decreases rainfall will be wiped out completely. Silver iodide, which is generally used as a seeding agent, is carried by the wind and can affect regions of the atmosphere far from the designated "target areas".

Normally, when we prescribe an engineering procedure to solve a problem, we have ample practical experience to back up our confidence. Cloud seeding can not be considered a reliable engineering procedure. It would be a travesty on the engineering profession to treat it with the same degree of confidence as we do most engineering subjects. We do not yet know, after at least one hundred million dollars of investment and more than 25 years of experimentation along with exhortations by cloud seeders in the role of modern medicine men, that we are not reducing the rainfall by seeding the clouds.

I urge you to oppose the passage of this bill. The money contemplated in the act would be much better spent during drought periods by supporting programs which encourage the prudent use of water, improving dams and water ways, and in general conserving what we now have. Experiments on ways to enhance (and also to decrease) rainfall during drought (and during flood periods) are indeed in need of support. Passage of this act will only postpone the time at which we can render an unbiased scientific judgment on whether or not cloud seeding works to increase rainfall.

Sincerely,

MARK BROOK,
Chairman, New Mexico Weather Control
and Cloud Modification Commission.

P.S. A bill, H.R. 12083 similar to S. 2707, has been introduced in the House. I have written Representatives Runnels and Lujan a letter similar to the above.

AMERICAN SOCIETY OF CIVIL ENGINEERS,
New York, N.Y., April 20, 1976.

HON. WARREN G. MAGNUSON,
U.S. Senate, Washington, D.C.

DEAR SIR: Several years ago, at the request of the Director of NOAA, Committees of the American Society of Civil Engineers prepared a suggested procedure for administering and financing emergency State requests for weather modification efforts during severe droughts. This was reviewed by knowledgeable Government and private scientists and engineers and sent to Mr. White. This is enclosed for your information. It is based on the experience of those who were called upon to aid in and report upon the drought relief efforts in states from Texas to

Florida, as a result of the appeals of the Governors of those States to the President.

Our Committees were impressed with the fact that the lack of experience in weather modification techniques in some of these areas and the lack of experience in weather modification work of some of those called upon to perform under these difficult conditions warrants the research program set forth in S. 2706. We would also suggest that these problem areas should be mentioned as limitations in the performance of the work specified in S. 2707.

Sincerely,

WENDELL E. JOHNSON, *Chairman,*
ASCE National Water Policy Committee.

Enclosure.

RESOLUTION ON EMERGENCY DROUGHT CLOUD SEEDING OPERATIONS

ASCE TASK COMMITTEE ON WEATHER MODIFICATION PLANNING AND POLICY

Whereas severe drought conditions reduce economic potential for a large segment of the public. This in turn may bring a request for the state's governor to declare an "Emergency" and to request cooperative federal support.

Whereas the relative roles of public, private, university, and government groups in applying weather modification to *Emergency Drought Relief* to such state requests are the primary concern of this statement.

Whereas it is noted that several weather modification programs were carried out in 1971 specifically in response to drought emergencies, and some of these projects involved joint efforts that included federal military and civilian agencies, state agencies, private contractors, and university groups.

Whereas it is further noted that some of these weather modification programs carried out in 1971 involved programs in which the federal agencies worked through local-state entities, and decision systems were constructed that required input from state officials so that seeding was carried out only for the locations and at such times as met with prior approval of state authorities.

Whereas a principal source of emergency drought relief program financing is likely to be derived from the Federal Government and the State Governments but the knowledgeable entities in the field of weather modification management and practice are limited to segments if a few Federal agencies, states and universities and private consultants, and

Whereas it is essential that the direction, planning, and actual field weather modification operations be carried on by those public and private entities experienced in these endeavors: Be it

Resolved:

1. A first step in responding to a drought "Emergency" declaration is the determination of the feasibility of the use of weather modification. The normal order of responsibility for making this determination should be: federal government first, and the state/local government second. In this situation university staffs and private consultants should be advisory only; however, in most cases all groups will provide input in reaching a decision. A decision to utilize weather modification for emergency drought relief should be based on a realistic assessment of the relief to be achieved, considering both the capabilities and limitations of weather modification technology.

2. When the federal government becomes involved in using federal funds to help support an emergency drought relief program, its response should be addressed primarily toward an operational approach, in contrast to a research approach.

3. Any project being launched will require an organization to administer the work plan on (a) what is needed, (b) what is available, (c) who will furnish monetary support, and (d) who will carry out specific parts of the project. The normal order of responsibility for such organization and administration should be: federal government, first; and state and/or local government, second. The responsible organization should obtain advice from the private sector in what is needed and what is available, including full consideration of pre-existing weather modification programs and capabilities in the area affected.

4. That responsibility carries with it acceptance for liability and the normal order of responsibility for liability should be state government first, federal government second. In any event the contractor for the weather modification work should be covered within the project formulation.

5. The organization of a specific weather modification program for emergency drought relief should include a mechanism for protection of local interests by providing for local participation in decision making.

6. The actual weather modification field projects will require equipment and personnel with a capability to conduct cloud seeding operations. The normal order of responsibility for conducting such field programs should be: private contractors, first; federal government, second; and state/local government, third.

7. There should be a specific requirement for an independent technology assessment and technical evaluation of emergency drought relief weather modification programs by qualified parties other than those who designed, approved and carried out the programs.

AMERICAN SOCIETY OF CIVIL ENGINEERS,
New York, N.Y., April 20, 1976.

HON. WARREN G. MAGNUSON,
U.S. Senate, Washington, D.C.

DEAR SIR: Ever since its conference in 1964, the American Society of Civil Engineers has followed actively the successes and problems in the field of Weather Modification. Particular attention has been given to potential water resources, effect on agriculture, and hazardous phenomena such as lightning and severe storms. We are aware of the multitude of efforts by various departments of the Federal Government such as Agriculture, Commerce, Defense, and Interior, and the lack of coordinated effort or an adequate over-all status report on these endeavors.

Consequently, for several years we have favored a bill similar to S. 2705, but with provision for a Weather Modification Commission which is responsible to the President and the Congress rather than to one of the above departments. Hearings conducted by such a Commission on the efforts made in the fields of overt weather modification, and the considerable knowledge gained within recent years, are most important before any decision is made on a significant weather modification policy or regulation. Such studies have been made by agencies of government, universities, utilities, airlines. An example is the study of the effect of industrial emissions on weather.

The diversity of opinion expressed by Federal departments at recent hearings on S. 2705, supports the above opinions. An office of Science and Technology would be best suited to direct the work of such a Weather Modification Commission. ASCE has sponsored several workshops with participation by some of the foremost scientists and engineers in cloud physics and other subjects related to weather modification. These workshops which were also sponsored by either EPA or NSF support the above conclusions.

S. 2705 should be amended to:

(1) Remove the proposed Weather Modification Commission from the direction of one of the affected Federal Departments;

(2) Provide for a period of 12 months of hearings at several locations throughout the United States to receive data on—

(a) Long-standing weather modification programs, such as those of the Public Utilities from Washington to California for increased snow in the mountains above hydroelectric projects and irrigated areas;

(b) Dispersion of cold fog at airports;

(c) Continuing work on decreasing damage from hail in the north and central portions of the United States;

(d) University research on thunder storms;

(e) Federal Department research and practical work on hurricanes;

(f) Needed research on tornadoes, and

(3) Study accumulating significant data from such projects as Metromex in St. Louis on inadvertent weather modification from industrial stacks, large cooling towers and the documented effect of particulate matter emissions in the Pacific Northwest.

After such hearings have been concluded, the procedure outlined under Section 4(a) of S. 2705 would be appropriate. The preliminary report should be prepared within six months after the aforementioned hearings and the final report to the President and the Congress at the end of the next six months. The final report should make recommendations as to whether a permanent Weather Modification

Commission or individual State control or both could most beneficially enhance and regulate the use of weather modification and its current occurrence where deemed advisable.

In our opinion, the uncoordinated Federal efforts and the lack of a sound national policy on weather modification prevent the proper use and restriction of this significant scientific tool in a useful and knowledgeable manner.

We hope that these comments will be useful to you.

WENDELL E. JOHNSON,
Chairman, ASCE National Water Policy Committee.

SELECTED EXCERPTS FROM REPORTS BY THE NATIONAL ADVISORY COMMITTEE ON
OCEANS AND ATMOSPHERE

SECOND ANNUAL REPORT—JUNE 29, 1973

Weather modification and control

Last year NACOA noted that we stand on the threshold of a new area of environmental control. We also emphasized that the field needs a balanced approach on several fronts. Public Policy issues with both domestic and international ramifications are intensifying. Legislation, as well as studies of social and economic impacts, are needed. Further, the relatively modest funds allocated to research need to be focused to permit the program to move head in a coordinated fashion.

As we pointed out last year, weather modification within the Federal Government is carried out by seven agencies to meet their mission needs. The Departments of Agriculture, Interior, Transportation, and Commerce are all concerned with weather modification possibilities related to their responsibilities such as: precipitation and water resources management; reduction of damage from hail, lightning, and violent storms; abatement of hurricane intensity; and improvement of the capability to use airports where visibility is reduced by fog. What NACOA found lacking is a central strategy for the overall research effort. There is a common dependence on increased theoretical understanding of the processes involved, which is in turn dependent on accurate measurements, improved instrumentation, facilities for experimentation, computer simulation, and the ability to mount and manage large-scale field experiments. We had recommended increasing the NOAA lead role because it possessed the bulk of the capabilities required. We regret to note that this has not taken place, and further, that a step has been taken in the opposite direction—the assignment of lead responsibility for precipitation enhancement was transferred from NOAA in Commerce to the Bureau of Reclamation in Interior. Further, the budget was cut in half at the same time. It is important to note that precipitation enhancement is not readily for general operational use, and will not be, without much greater effort in research.

To elaborate, there is a common thread that winds through all the weather modification objectives that are supported by the various Federal agencies. This thread is the importance of understanding the fundamental physical processes involved. The traditional heavy reliance on statistical inference from experiments, where only the gross features of the phenomena could be observed, has carried the field forward to where it is today. Now, however, it is time to probe more deeply into the machinery of these phenomena if we are to go from modification to control.

For this reason, NACOA is concerned with the decline of the overall research effort in atmospheric and cloud physics. The resource levels which support basic laboratory and field work in cloud physics have declined to the point where the small cadre of experts built up over the last twenty years is in danger of being dispersed. There is a danger that the funding authorities, in their quite proper zeal for practical results, will underestimate and undervalue the still extensive research that must precede reliable operational use.

At the same time a national research strategy must be guided in selecting priorities for its research effort by the prospects for practical payoff. These prospects have two dimensions: first, the "ripeness" or time to payoff; second, the importance of the payoff. Time to payoff involves primarily scientific judgment. The importance of the payoff in practical terms, however, involves a great variety of considerations regarding costs and benefits of all the alternatives, with weather modification being only one.

Two recent studies, still in prepublication form, have come to our attention. One is, "Weather Modification in the Public Interest," by R. G. Fleagle, J. A. Crutchfield, R. W. Johnson and M. F. Abdo at the University of Washington. The study undertakes to appraise the steps taken so far in developing the capability to modify weather, to identify critical issues which limit development or which influence the ability to direct weather modification in a socially responsible manner, to consider a means for rational systematic examination of weather modification programs, and to develop a policy for its implementation.

The study is concluded with a set of recommendations to insure the effective development and utilization of the capabilities of weather modification for socially beneficial goals. Among the actions recommended is the designation of NOAA as the lead agency in coordinating Federal weather modification activities and for managing a research program addressed to the critical scientific problems; the passage of legislation designating the Administrator of NOAA as the responsible official for decisions regarding weather modification activities that are directly related to the saving of lives or to other critical aspects of the national welfare; and the establishment of an institute which would conduct objective and thorough studies of policy alternatives and the impacts of weather modification activities. NACOA made similar recommendations in its first Annual Report last year.

The other study is a report by the Panel on Weather and Climate Modification of the Committee on Atmospheric Sciences, NAS/NRC entitled "Weather and Climate Modification: Problems and Progress." Three major goals proposed are:

Identification, by the year 1980, of the conditions under which precipitation can be increased, decreased and redistributed in various climatological areas through the addition of artificial ice and condensation nuclei.

Development in the next decade of technology directed toward mitigating the effects of the following weather hazards: hurricanes, hail storms, fog, and lightning.

Establishment of a coordinated national and international system for investigating the inadvertent effects of manmade pollutants, with a target date of 1980 for the determination of the extent, trend, and magnitude of the effect of various crucial pollutants on local weather conditions and on the climate of the world. (NACOA wishes to point out that a relatively new candidate as a major pollutant for inclusion in the third goal is waste heat. Projected trends indicate this could be an observable factor in the general circulation of the atmosphere by the year 2000.)

NACOA supports these goals and believes that specific sets of research projects can and should be defined to insure their accomplishment.

We believe that NOAA should take the lead in developing and coordinating the implementation of such a program. Although the track record of the Interdepartmental Committee of Atmospheric Sciences (ICAS) is generally excellent, and ICAS should prove of value in this program as well, the dispersive forces serving to fragment the program are strong. We feel that a formal lead agency assignment is desirable and that NOAA is the appropriate candidate.

We believe also that the details of this program should be guided by a series of "requirement" analyses and that the appropriate mission agencies, such as Interior, Agriculture, etc., have a vital role to play.

Finally, as capabilities approach the stage of operational readiness, a systematic assessment should be required for approval of candidate operations. We suggest that mission agencies develop the capability to generate plans which provide cost and schedule estimates for the acquisition, implementation, and operation of weather modification systems. These plans should:

Show that the technology needed is sufficiently in hand—that primarily engineering rather than experimental effort is required;

Show that the mission and performance envelopes are defined;

Show that the best technical approaches are planned for utilization;

Show that trade-off analyses have been made to demonstrate that the proposed operational program is cost-effective in comparison with other techniques that could be used to satisfy the need;

Show that cost and schedule estimates are credible and acceptable; and

Show that legal, social, economic, and environmental impacts have been assessed.

Operational weather modification programs which can be depended upon to be effective in mitigating the effects of large-scale weather generated disasters

are not in hand. Major technological problems still remain. The search for solutions to these problems will require the design and accomplishment of extensive field tests, the execution of laboratory experiments, the development and test of complex numerical models, etc. Solutions to the many legal, social, moral, and economic problems associated with increased technological capability in weather modification will have to keep pace. In view of the anticipated difficulties, both technical and otherwise, and recalling our earlier discussion of the problem of providing adequate disaster warning, we again recommend that attention be given to providing incentives for the reduction of hazards through controlled use of areas susceptible to flooding by rivers and inundation by high tides associated with coastal storms and hurricanes. In the long term, the most effective measures of all may be preventive and protective measures for reducing vulnerability.

THIRD ANNUAL REPORT—JUNE 28, 1974

Weather modification and food

There now exists marginal capability in some types of weather control, but steady improvement or more than marginal operational usefulness is by no means automatic. It was to this, the necessary sharpening of effort, that we addressed our attention in previous years by stressing:

The need to overcome the existing fragmentation of Federal programs in weather modification now scattered amongst numerous Federal agencies;

The need for greater emphasis on research in the physics of cloud formation and on the science and technology of rainfall augmentation; and

The need to confront legislative and public policy issues governing the proper use of a new technological capability which has the potential of doing harm as well as good.

In light of the current need to increase world-wide agricultural productivity, the effect of the increase in market value of food on the benefit-cost ratio of weather modification could be sufficient to encourage the operational use of modification techniques whether we are ready for it or not. The evidence suggests, although it is not conclusive, that a one- or two-inch increase in rainfall could be stimulated during the growing season in certain areas of the central plains. South Dakota, for example, is now preparing to carry out rainfall augmentation operations over 60% of its area this summer with the goal of increasing rainfall by one or two inches and decreasing the occurrence of damaging hail. About \$1 million will go into this effort (about 75% State, 25% county funding) with a target benefit-to-cost ratio of ten to one.

In the last two years NACOA has made numerous recommendations having to do with weather modification. While there has been progress in some areas, others, we regret to say, have shown little change. And also, the failure to establish Federal regulations and procedures to minimize conflict and litigation arising from planned and actually performed weather modification operations is paralleled by our failure to take the initiative in establishing international agreement on a mechanism to insure that all modification effort be devoted to peaceful and mutually beneficial purposes.

FOURTH ANNUAL REPORT—JUNE 30, 1975

Weather modification

In previous years we, along with many others, have urged that the fragmented Federal effort in weather modification research be consolidated under NOAA as lead agency with greater emphasis on basic studies of cloud physics and dynamics, and that the legal, social, and economic impact of weather modification be examined and appropriate legislation sought.

We note with regret that there has been no action in response to these recommendations. The Office of Management and Budget, we are told, takes the view that weather modification represents one of the many options available to a mission agency facing weather-related problems, and that research with an eye to user requirements within the using agency itself would be more effective than if it were centralized and susceptible to working up momentum for its own sake.

This view seems to ignore the critical inadequacy that, with a few exceptions, weather modification is not yet an operational tool. Considerable basic research is needed before it can become dependable and predictable, in fact before one can be sure that it can be safely used in any consistent way.

Progress in weather modification at this point calls for field experiments for which no one agency has the complete facilities, and progress calls for a greater emphasis on cloud physics. That means that the funding should be managed with an eye to scientific priorities and that the field experiments should in many cases be cooperative projects. They must be planned in advance and carefully coordinated. Yet typically each agency's contribution, while essential to such a combined effort, is of sufficiently low priority within the agency's primary mission that it is always in danger of being cut and sometimes is. Without coordinated effort the individual agency programs can be leaned on more heavily for practical application than their actual scientific strength warrants. This could be dangerous in a touchy business.

What seems most important at this time is that a coherent, integrated national program of research be established, with NOAA designated as lead agency, emphasizing: (1) research on the basic processes in the formation of rain, snow, hail, etc.; (2) closely controlled and integrated field experiments; and (3) an evaluation of the legal, economic, sociological, and political aspects that should be incorporated in legislation and subsequent regulation for the control of weather modification activities in both the public and private sectors.

We are not necessarily recommending that more money be put into weather modification research, but rather that the funds currently allotted to weather modification be managed more effectively by designating a lead agency, i.e., an agency with primary responsibility for coordinating and for defending a sound and balanced program.

We believe this agency should be NOAA, because it has the necessary meteorological expertise. But all must recognize the major role in this field of activity to be played by the mission agencies such as the Department of Agriculture, the Department of the Interior, the National Science Foundation, the Department of Defense, the Energy Research and Development Administration, etc. In particular, the Department of Agriculture, since food production is the principal prospective beneficiary of weather modification, is urged to undertake a substantial effort in weather modification research coordinated with the NOAA program which would include the social, economic, ecological, environmental, and institutional aspects.

As we write this, the Federal effort in weather modification is once again under review, this time by the Domestic Council Subcommittee on Climate Change. We hope that this review will, at last, be followed by action which suits the state of the art.

The first part of the report deals with the general situation of the country and the progress of the work during the year. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and a list of the names of the persons who have been engaged in the work.

The second part of the report deals with the financial situation of the country and the progress of the work during the year. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and a list of the names of the persons who have been engaged in the work.

The third part of the report deals with the social situation of the country and the progress of the work during the year. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and a list of the names of the persons who have been engaged in the work.

The fourth part of the report deals with the economic situation of the country and the progress of the work during the year. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and a list of the names of the persons who have been engaged in the work.

The fifth part of the report deals with the political situation of the country and the progress of the work during the year. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and a list of the names of the persons who have been engaged in the work.

The sixth part of the report deals with the cultural situation of the country and the progress of the work during the year. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and a list of the names of the persons who have been engaged in the work.

The seventh part of the report deals with the scientific situation of the country and the progress of the work during the year. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and a list of the names of the persons who have been engaged in the work.

The eighth part of the report deals with the health situation of the country and the progress of the work during the year. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and a list of the names of the persons who have been engaged in the work.

The ninth part of the report deals with the education situation of the country and the progress of the work during the year. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and a list of the names of the persons who have been engaged in the work.

The tenth part of the report deals with the environment situation of the country and the progress of the work during the year. It is followed by a detailed account of the various projects and the results achieved. The report concludes with a summary of the work done and a list of the names of the persons who have been engaged in the work.

