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## WEATHER AND CLIMATE MODIFICATION

(Remarks to the Senate Commerce Committee 21 February 1966)

By

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(Served as Chairman, Special Commission on Weather Modification)

Gentlemen, it is a pleasure to discuss with you the results of the work of the National Science Foundation Special Commission on Weather Modification as you consider S. 2916. The Commission was chartered to make recommendations to the National Science Foundation and to provide a response for a committee of the Federal Council on Science and Technology. The assignment included consideration of the physical, legal, social, biological and political aspects of weather and climate modification.

### INTRODUCTION

Man's growing knowledge of the natural environment has given him an increasing awareness of the changes taking place in his earthly habitat. Fortunately, his increasing knowledge has also indicated some possible means of deliberate modification of the environment. This knowledge may make it possible, hopefully, for him to plan for conservation and development of the environment for the benefit of man. He is at last learning he cannot consider himself free to heedlessly exploit the air, water, land and growing things of the earth.

The central issue of public policy considered by the Commission was: Do the scientific and engineering possibilities of meaningful deliberate weather and climate modification seem sufficiently promising of social benefit to indicate the time has arrived for the nation to direct substantially larger resources of money and manpower to the many facets of the field? The Commission concluded the answer is: Yes; for reasons of scientific, human, biological, legal and



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international need. Such a national program will require a budget increase of at least \$40 to \$50 million per year by 1970 over the F.Y. 1966 level for weather and climate modification activities.

#### SCIENTIFIC PROSPECTS

The Commission feels the study of weather and climate modification is ready to pass from being considered a speculative field to one ready for a rapid expansion of carefully planned research and development. Many interesting and potentially valuable opportunities are becoming evident that will attract many of the nation's best minds to the field if fiscal resources are made available to support the intellectual talent of industry, academic institutions and government agencies.

The atmosphere can be viewed as a complex physical system in which ascertainable changes in air motion will take place in response to identifiable forces. If the forces are altered, in principle the motion of the air can be influenced. Therefore, in principle, meaningful modification of the weather and climate should be feasible if one can demonstrate the capability to alter these forces so as to produce predictable consequences. In a practical sense, it is necessary to establish only beyond reasonable doubt that the cause and effect are related. Aside from intellectual curiosity, this has been the central problem of weather modification research.

Progress has been made. That seeding (the cause) can dissipate super-cooled fog (the effect) has been so clearly demonstrated it is moving to the operational phase for some airports.

On a larger scale, there is evidence (though somewhat ambiguous) to support the view that precipitation from some types of clouds can be increased by the order of ten percent by seeding. The question of corresponding decreases

outside the target area is unresolved. Hail and lightning research is beginning to show some promise. A program of large, carefully instrumented and statistically designed field experiments is needed. These will take a great deal of money.

The study of the energy levels of atmospheric subsystems such as tornadoes, hurricanes and extratropical cyclones leads to the conclusion that it is not practical to think of altering these subsystems by direct application of energy. Yet the study of instabilities in the atmosphere indicates at least four kinds of instabilities may be susceptible to man's efforts to "trigger" natural reactions. These instabilities--1) phase instability of water, 2) colloidal instability of cloud particles, 3) convective instability of the atmosphere and 4) baroclinic instability of the large scale circulation--will all require a great deal of theoretical, laboratory and field research.

Improved prediction of weather phenomena may be as important in many cases as modification in terms of social and economic benefits. For this end and others a global observation network will be necessary. Numerical simulation studies need to be expanded.

The Commission was greatly concerned about the inadvertent modification of weather and climate underway due to the activities of man. Air pollution from our cities is an example. This is a problem of grave importance. Little is understood of the weather and climate modification being induced by this means.

Non-atmospheric means of modifying weather and climate need to receive increased attention. The atmosphere interacts with the expanses of earth and sea. Man's ability to induce large scale alterations of the land and sea continues to increase. The possible consequences of such alteration on weather and climate need a great deal of study.

The Commission concludes the scientific and engineering prospects of meaningful progress in weather modification are sufficiently attractive that a

great deal more manpower should be drawn into the field. This expansion of activity will require talent from several disciplines. Also required will be a great increase in the logistics support for field and laboratory research and operations. The results of increased intellectual concentration on the field would be important not only to those interested in precipitation augmentation but also the entire field of atmospheric resources.

#### BIOLOGICAL RELATIONSHIPS

Anything that has a significant effect upon plants and animals is of primary concern to man. Plants and animals are the foundation of his existence. Modifying weather and climate may initiate changes in the abundance of certain plants and animals. It may also induce instabilities in numerous biologic populations--including those that prey on man and challenge his existence. Thus, a national program of weather and climate modification must include support for a substantial research program in ecology and related biological sciences.

The present state of knowledge is very inadequate for making good predictions of the biological consequences of specific weather modification projects except under limited conditions. The ecological system of agricultural fields is well enough understood that reasonably good predictions can be made. But in a more complex system such as that of large uncultivated watersheds containing many species of interacting plants and animals it is not now possible to make quantitative predictions.

Living things are adapted to the weather that prevails. Any change in the weather will be generally deleterious to them. Weather and climate modification over large areas of a few hundred square miles or larger for long periods of time is likely to induce a decreased stability of biologic communities. This instability would manifest itself as an increase in pests, weeds and pathogens.

It is extremely important that a national weather modification program involving large areas for field experiments have fiscal support for ecological studies by numerical simulation and field study. To obtain a net benefit from a biological point of view will require much better knowledge than now available of the interactions of weather and organisms. Such research is expensive. Such studies span many years for obtaining meaningful conclusions.

The largest social credit item for weather modification is likely to be an increase in primary plant production of the drier parts of the land surface.

#### STATISTICS

As is well known, a controversy among statisticians over the validity of the conclusions of early research did not encourage weather modification research during the late 1950's. The situation is better now. The current central question on the role of statistics in weather and climate modification research is not whether to use statistics but how to use it in the early design through to the analysis of the research data.

The national program in weather and climate modification needs to provide for support of statisticians to work on all facets of physical, engineering and biological studies in the field. Furthermore, support is needed for basic statistical methodology research.

#### HUMAN EFFECTS

Sound public policy in the face of uncertainty about the techniques of weather modification requires that research also be initiated on the social and economic effects. Such research is needed to fully exploit what may be an historic opportunity to improve the environment for society, and at the same time be prepared to avoid activities which might be detrimental to man. So intricate

are the interlocking motivations in human behavior that subtle changes may be initiated by weather modification and not even be detected. Some beneficial changes, such as bountiful crops and their impact on the economy, can be readily followed. But because the organization of society is so complex it is not evident whether the quality of life may be enhanced or degraded by every possibility of weather and climate modification. It seems clear, for example, that the power and motion of severe storms provides some of the most exhilarating opportunities that the human mind experiences. Would it be of social benefit to completely control weather and remove these phenomena from the realm of human experience? How could one put a value on such a possible degradation of the quality of the life experience?

From an economic point of view many effects of precipitation augmentation for crops, hydroelectric power, etc. can be fairly readily measured. But other effects might not be so simple to evaluate. As an example, what would be the economic, social and political problems of shifting a hurricane so it hit North Carolina rather than Florida? To learn how to deal with such problems in advance of the technological capability, in the face of large uncertainty about the ability to modify weather, will require a great deal of effort.

Several areas of potential conflict of interest are already recognizable. Public policy should seek to provide a means to reconcile conflicts equitably. It should seek to prevent victimization, either by people who mistakenly think they are gaining benefits or of individuals who are unaware of damages being inflicted on them. Conflicts may arise between those trying to conduct experiments and those wishing to carry out operational projects for utility or agricultural clients.

A national program on weather and climate modification should include support for research on the social and economic consequences of alternatives. For example, it might be more profitable to pursue research in crop genetics to

improve drought resistant crops than to augment precipitation. Further, if weather modification induces serious pest and weed problems the costs of these might overshadow the benefits of increased crop production. Because the answers to such questions are not known, research is needed.

Research is needed on the basic relationships between weather characteristics and human behavior. The decision-making process of man in the face of uncertainty needs further study. The social effects of inadvertent weather and climate modification need further investigation. The social consequences of commercial operations and field experimentation need to be studied.

The providing of indemnification against damages for Federally supported work would encourage more academic, industrial and private scientists and engineers to seek support for research and development work.

#### LAW

A demonstrated capability to modify weather and climate over areas of substantial size presents legal problems of great difficulty. Yet even before such an ability is assured the law is involved on at least two counts: 1) the rules over responsibilities and liabilities of weather and climate modification to other members of the public, and 2) regulation by government.

It does not seem possible to recommend, without a great deal of further study, appropriate rules of law to govern "property rights in weather". Easy analogies to the law regarding water, land, air space, etc. do not seem adequate for the problems of weather modification. The liability of weather modifiers with respect to those claiming injury to their person or property, for example, need to be decided on their own merit. The few court cases to date do not give much basis for predicting how the law will develop.

Some twenty-two states have enacted laws regulating weather modification. Most of these states require licenses. Effective 1 January 1966 the NSF increased its record-keeping requirement and imposed on all operators a requirement of advance notice to it of any activity. This information is an aid to the Federal research and development effort.

The Commission concluded that Federal legislation should be enacted adequate to:

1) Delay or halt all activities--public or private--in actual or potential conflict with weather and climate modification programs of the Federal government, whether these programs are conducted for the Federal government by its own agencies, or by its public or private grantees or contractors.

2) Immunize Federal agents, grantees and contractors engaged in weather and climate modification activities from state and local government interference.

3) Provide to Federal grantees and contractors indemnification or other protection against liability to the public for damage caused by Federal programs of weather and climate modification.

These recommendations are restricted in scope because it is felt that regulation should be only the minimum necessary for permitting accomplishment of immediate goals. As knowledge develops more comprehensive regulation will be required. And since weather transverses national boundaries study needs to be made of international legal problems.

#### INTERNATIONAL

As weather and climate modification research and development continue to expand, some form of international collaboration will be essential in the planning and carrying out of operations which may affect localities of other countries and

continents far distant from the scene of the operation. Such events have a bearing on the political relationships among nations.

With weather modification still in its infancy, it provides an inviting opportunity to encourage multi-national interest in mutual cooperation among the people of rival nations. Weather and climate modification could serve as an avenue to widening the areas of common interest among nations, thereby helping in accomplishment of the objectives of easing tensions. In the process the field of weather modification may be able to contribute significantly in the growing international food crisis.

The international aspects of weather modification require careful study of the biological, social, economic and political factors. The results of study of these fields in the United States may not be directly applicable to many of the developing countries where the social institutions, biological environment and political system are different.

Now is the time to start the steps, in concert with other nations, to explore the international institutional mechanisms that may be appropriate to foster international cooperation.

To provide an appropriate public policy setting for weather and climate modification, the Commission feels the nation should enunciate policy containing these two points:

- 1) It is the purpose of the United States, with normal and due regard to its own basic interest, to pursue its efforts in weather and climate modification for peaceful ends and for the constructive improvement of human life throughout the world.

- 2) The United States, recognizing the interests and concerns of other countries, welcomes and solicits their cooperation, directly and through international arrangements, for the mutual achievement of human well-being.

## FISCAL NEEDS

The Commission concluded that weather and climate modification research and development activities of the Federal government should be increased by \$40 to \$50 million per year by 1970, excluding any national laboratory type capability which might be initiated.

These figures were derived by estimating the program needs which should be increased from the F.Y. 1966 level of \$7.2 million of agency budgets, excluding logistical support provided by the Department of Defense. About half of the increase will be needed for basic research, including such things as much larger computer capability. Much increased support is necessary for conducting carefully designed and adequately instrumented field experiments.

The budget increases should definitely include funds for the physical sciences, statistics, engineering, the social and biological sciences, and the law.

No estimate beyond 1970 was made by the Commission. It was felt the level of funding for the 1970-1980 period could be much better estimated after a couple more years of experience. The field is capable of going ahead so rapidly that long-range cost estimates would probably have little validity.

## ORGANIZATION OF GOVERNMENT

The field of weather and climate modification needs to have the services of government, private industry and academic institutions. It must be able to accommodate participation by the individual scientist who only needs pencil and paper to the large complex organization necessary for a massive field experiment. The following factors enter into analysis of the organizational needs:

- 1) There is need to bridge the organization gap between laboratory

research and large scale field experiments; this gap can exist even in the basic research aspects. There is need for organizational arrangements for enough applied research to develop the field, while preserving scientific objectivity in the basic research effort. The economic, political and spectacular aspects of weather and climate modification operations must not be permitted to crowd out the basic research.

2) There is need for biological and social science research to go hand in hand with the physical science and engineering research in support of the missions of all agencies, contractors or grantees concerned with weather modification. There is need to preserve diversity in the research effort, but there is the need also to establish a Federal organizational mechanism for accomplishing what cannot be done through diverse research activities.

3) Responsibility should be clearly assigned for the formulation of arrangements for appropriate scientific cooperation with the governments of other nations.

4) Adequate enforcement power needs to be provided an administering agency so as to insure the filing of information relative to all weather modification field experiments and all commercial operations. The agency assigned regulatory functions should have a regional or field office establishment.

5) The conduct of research and development in this field should be kept insulated from activities involving the regulation of weather modification operations, but at the same time the two types of activity should be sufficiently proximate organizationally to assure immediate access to data derived from the operations being regulated.

Based on these considerations, plus the fact several Federal agencies have missions (such as Defense) that require weather modification knowledge, the Commission concluded a pluralistic organization for assignment of responsibility would best insure progress of an expanded national program. The suggested

assignment of responsibilities can be summarized as follows:

1) The mission of developing and testing techniques for modifying weather and climate should be assigned to an existing or new agency in the Executive Branch of the Federal government. The mission should include support and conduct of research and development and such operational activities as are needed for the furtherance of the technology of weather and climate modification. Substantial authority to contract for services should be provided. This agency should have major but not exclusive responsibility, in collaboration with the State Department, for formulating and implementing programs of weather and climate modification involving international cooperation.

2) The National Science Foundation should continue and expand its support of research in the atmospheric sciences, including its program directed at providing a satisfactory scientific basis for weather and climate modification. This should be carried on primarily at universities and colleges. The National Science Foundation program has been the major source of funding for development of manpower for weather modification activities. NSF should be given increases in funds for expanding this support since the manpower needs will continue to grow. NSF should continue maintenance of the National Center for Atmospheric Research as a facility for the conduct of basic research on a scale beyond that feasible for individual university investigators. The degree of continuing and special attention given by the Foundation to the support of the physical sciences, engineering, the biological sciences and the social sciences aspects of weather and climate modification should be reviewed from time to time in the light of the progress of the over-all national program.

3) Federal agencies should undertake such operational activities as may be required for the effective discharge of their missions. Also, pursuant to Executive Order 10521, Federal agencies should be free to conduct and support

such research and development as may be required in the discharge of their missions.

The Commission also felt that a national laboratory type of capability is needed for an expanded interdisciplinary program encompassing all the relevant disciplines. Yet it is not clear that creation of a national laboratory per se is the answer. The President's Special Assistant for Science and Technology could perhaps be called on to initiate appropriate feasibility studies.

Insofar as the nature of a regulatory agency is concerned, care must be taken to insure access of all agencies to the information generated, while at the same time keeping regulation organizationally separated from research and development. Whether the regulatory function needs to be divorced completely from the operating agencies, or can be assigned to a separate branch or subagency of an existing agency, will depend largely on the extent of activity and the degree of regulation required.

As to the jurisdiction of a regulatory agency over other Federal agencies, to the extent regulation involves requirements of notice, reports, licensing of activities, etc., there seem to be good reasons why all agencies should be subject thereto. In addition, the regulatory agency should be given power to resolve minor conflicts between agencies, such as the timing of particular experiments.

The Commission recommends that the Office of Science and Technology consider establishment of a special mechanism for the coordination of weather and climate modification policies and programs. Such an entity could not only serve to resolve major conflicts but could serve to promote unity in policy and deployment of funds and manpower with optimum effectiveness.

Both the Executive Branch and the Congress may wish to have available scientific and public policy advice from a group of knowledgeable people from outside the Federal government. This need might well be met by the appointment of a standing committee in the National Academy of Sciences, in cooperation with the

National Academy of Engineering. The group should include persons with experience in the physical, biological and social sciences and engineering.

#### CLOSING AND SUMMARY REMARKS

In closing the Special Commission on Weather Modification was made up of eleven men from several disciplines. They were provided background data by numerous individuals and groups such as:

- 1) Panel on Weather and Climate Modification of the National Academy of Sciences,
- 2) Study Committee of the Ecological Society of America,
- 3) University of Minnesota conferences on statistics and weather modification,
- 4) Participants in the University of Chicago Symposium on Economics and Social Aspects of Weather Modification, and the
- 5) Southern Methodist University study of certain legal aspects.

In summary, the Commission feels the time has arrived for the United States to initiate a much expanded interdisciplinary research and development program in weather and climate modification. This program should be adequately organized and funded. Provision should be made for participation by individuals, educational institutions, private firms, the several levels of government and foreign countries. Regulation should be kept to a minimum consistent with available knowledge.

To be able to deliberately modify our environment in a predictable manner may be our salvation as a society on this planet.