

**SECRET**SURVEY OF WEATHER MODIFICATION*March 1958*Sources of Information:

This brief survey of the status of weather modification is based on information from the following sources: (a) Dr. Earl G. Droessler of the Office of Secretary of Defense (Asst. Secretary, R&D). Dr. Droessler is responsible for the coordination of Department of Defense R and D in Meteorology and is the author of a portion of the final report of the Advisory Committee on Weather Control. (b) Mr. Malcom Ross, ONR. (c) Final Report of the Advisory Committee on Weather Control, Dec. 31, 1957.

Present Capabilities for Weather Control:

Up until about ten years ago our accomplishments in the field of weather control or modification were very small, being limited to examples such as the heating of citrus orchards to control frost and the small scale dissipation of fog over airports by heating. During the past ten years interest has expanded to cloud nucleation studies (cloud seeding). It has been quite well demonstrated that the seeding of suitable cloud formations in suitable geographical areas will usually induce variable amounts of precipitation. At present, this is best demonstrated in mountainous regions. The suitable clouds and topography usually constitute conditions which would ordinarily be expected to produce precipitation. What is usually induced by seeding is a small increase in local precipitation over that which would be expected if the same cloud formation were not seeded.

Some interesting results have been obtained in the dissipation of cloud formations. In some cases fog, stratus, and small inactive cumulus clouds can be dissipated by seeding from above. In field tests it has sometimes been possible to clear "holes" in an otherwise solid deck of stratus, thereby making it possible for the ground to be seen from an aircraft. (Such applications may be of interest to WAD.)

Equivocal results have been obtained from attempts to suppress the formation of hail by seeding.

In general, the present known capabilities for controlling the weather are quite modest.

Present Government Sponsorship of R&D:

A number of Federal Government organizations have been and presently are engaged in activities in the field of weather modifications and cloud physics. The most active groups are the Army, the Navy, the Air Force,

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the U. S. Weather Bureau, and the National Science Foundation.

The Army work on cloud physics and weather modification is centered at the Signal Corps Engineering Laboratories, Fort Monmouth, New Jersey. They have studied the effectiveness of various seeding materials and the dissipation of supercooled stratus by seeding. In addition, laboratory work at Fort Monmouth covers a range of basic experimentation on cloud particles and environmental effects. Large cold chambers are utilized in this work. In Volume 5 (Geophysical Sciences and Engineering) of the 1958 Annual Research Task Summary (U. S. Army), the Army projects are listed as being under the direction of D. Deisinger, Chief, Physical Sciences Division, ESL, with the principal internal investigator being Dr. H. K. Weickmann of Fort Monmouth. A notation on the description of a project on cloud modification (purpose: research into physics of cloud dissipation and potentialities in tactical operations) indicated progress was reduced by the unavailability of a research aircraft.

The Navy has devoted most of its attention to basic problems in cloud physics. The Cornell Aeronautical Laboratory, under Navy contract, is interested in the conversion of freezing rain to a less hazardous form of precipitation and the suppression of aircraft contrails. The Institute of Atmospheric Physics at the University of Arizona is accumulating data which it is hoped will give an idea on the movement and variations of flux of water available for precipitation. Various other contracts deal with various problems in cloud physics.

The Air Force activity is centered at the U. S. Air Force Geophysics Directorate, Cambridge, Mass. Laboratory work is in progress on a group of investigations related to artificial nucleating materials, natural nuclei, cloud droplets, ice crystals, etc. They are interested in the inhibition of ice crystal formation in supercooled clouds, the modification of aircraft contrails, factors related to visibility, etc. They have measured and studied various detailed conditions in and around cumulus clouds, and have done some interesting experiments on the dissipation of stratus and fog by seeding from above. In one such field test conducted in 1957 a clearing about 70 miles in length was made in a cloud deck (supercooled stratus) more than 3000 feet thick, making it possible for aircraft to make VFR landing approaches in an otherwise solid overcast condition. Contracts with the University of Chicago and the University of Arizona cover investigations on large scale factors which affect cloud growth, precipitation, and weather modification. This includes experimental seeding of clouds.

The U. S. Weather Bureau activities include collaboration with other agencies and some fundamental laboratory studies by the Physical Research Division.

The U. S. Forest Service has sponsored or cooperated in several weather modification projects.

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The National Science Foundation has made a number of grants for the support of basic research in cloud physics and related subjects. There are some eight such projects at five universities and one commercial laboratory.

Magnitude of Federal Government Efforts:

It is difficult to place a dollar value on the Federal Government expenditures in the field of weather control because it is difficult to determine where among the various projects in cloud physics the line should be drawn. However, Dr. Earl Droessler of the Office of the Secretary of Defense indicated the total Federal Government expenditures in the field of weather control and reasonably related areas in cloud physics is approximately \$500,000 per year. The Navy devotes about half of the budget of the Geophysics Branch, ONR, to cloud physics projects. This would be about \$170,000 per year. According to the Final Report of the Advisory Committee on Weather Control, the National Science Foundation support amounts to around \$75,000 per year. These figures would indicate the combined Army, Air Force, and Weather Bureau contribution is a little over \$250,000 per year.

According to Dr. Droessler it is quite possible the Defense Department agencies will have somewhat more money available for this type of work in the future.

There are no apparent places where money is available for expenditure on weather control but is not being used for one reason or another.

There appears to be no consensus of opinion as to whether further funds could profitably be used in this area. Dr. Droessler indicated in effect that he felt the current level of effort is quite adequate to support the work that can presently be done profitably and in a competent manner. However a more realistic appraisal would probably be that increased efforts directed toward increasing our basic knowledge of the mechanisms involved in various weather phenomena would be quite desirable. Such a conclusion would be in agreement with the Advisory Committee on Weather Control. One difficulty is that there is probably quite a limited number of competent investigators available in this area.

Future Possibilities:

It is of interest to consider where present and possible future efforts may reasonably lead. Apparently the major interest so far (from an applied standpoint) has been directed toward the modification of clouds by seeding. It is becoming increasingly well established that this can be done under suitable conditions on a local scale, and it may be possible that in the future this can be extended to larger areas. However, it should be pointed

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out that large scale cloud modification would seem to imply equally large scale alterations in atmospheric circulation patterns by some means. Present knowledge appears to offer no really sound basis for the belief that weather, on a large scale, can be altered by seeding.

Various possible routes toward large scale weather modification have been proposed by various people. For instance, it appears obvious that a factor in major air circulation patterns is the balance between heat input into the atmosphere and heat output. One factor in this process is the nature of the surface of the earth. Thus it is postulated that weather patterns could be altered by large scale alterations in patterns of vegetation, or by reducing the reflectivity of the surface in polar regions (for instance by spreading carbon black), by changing ocean currents, etc. Also, it appears obvious that the evaporation of water from oceans and other large bodies of water is a factor in observed weather and climate. It has thus been postulated that the production of a large scale alteration in availability of water vapor (for instance by decreasing evaporation by spreading cetyl alcohol on the surface of a body of water, or by flooding of large areas) should alter weather patterns. However such proposals are generally based on assumptions (rather than knowledge) of the dynamics involved in major weather systems and even if they would work, logistically such plans would require a major national effort to carry out.

Although the above and other possible applications of weather control have been proposed, the true need in this field is a great deal of rather basic research directed toward establishing a foundation of fundamental knowledge to provide a more adequate basis for further applied efforts.

The areas in which fundamental knowledge is seriously lacking cover almost all areas of cloud physics and meteorology related to weather control. A few examples can be cited.

Although nearly all commercial cloud seeding involves introducing freezing nuclei into supercooled clouds, very little is known about this nucleation or freezing process. For instance, regarding the nuclei, what is the relationship of such factors as chemical structure, size, impurities, temperature, moisture? Very little is known about natural nuclei. Can nucleation be prevented (the nuclei "poisoned")?

In many areas natural rain results not from freezing and sublimation of water on nuclei but rather on condensation on nuclei. Theoretical, laboratory, and field studies would be required to adequately understand this process.

The mechanisms related to the normal inception, growth, trajectory, and decay of clouds is very inadequately understood.

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It is known that electrical phenomena are associated with weather, but it is not known how they are related. Are the electrical effects primarily by-products of other meteorological effects or are they major factors in weather production?

Attempts are being made to construct increasingly more realistic mathematical models of the atmosphere. When such a model incorporates the important features of the real atmosphere we will have an excellent tool for exploring the effects of artificial modifications and a basis for the intelligent planning of further physical experiments.

Conclusions:

The present status of weather control is such that limited local modifications are possible under proper cloud and geographical conditions. Certain areas, such as stratus dissipation and the modification of contrails, would probably be of interest to WAD. Beyond this, it is difficult to see obvious applications of capabilities available at present or in the immediate future. For example, the production of precipitation by seeding requires specific conditions, and even then a statistical increase in precipitation is all that has been demonstrated.

Potential capabilities, however, would certainly make it of interest to the Agency (and probably TSS) to follow the current activities of others in this field and to evaluate ideas postulated from time to time.

The most obvious area in which further research is needed is in various rather basic facets of cloud physics and meteorology. Government financial assistance in this field is undoubtedly justified, from economic, military, and defense standpoints. However, whether or not active participation in the area of weather control is within the responsibilities of TSS is a question which the writer feels is beyond the scope of this survey.

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