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WEATHER MODIFICATION IN THE HIGH PLAINS REGION: SOME PUBLIC-POLICY ISSUES

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I would like to begin with a quotation:

> I predict that weather modification will be one of the first technologies over which the general public, rather than the scientists who devised the technology and the economic interests who see immediate benefits, will exert control. (1)

Not long ago, this statement would have been regarded as highly irresponsible, if not downright subversive, in cer-tain meteorological circles. It was the sort of thing you might expect a political scientist or sociologist to say--although it happens that this particular prediction was made by an ecologist--but there weren't many atmospheric scientists around who would take it very seriously. It was pretty much of a foregone conclusion that the scientists and engineers who developed a new technology and the economic interests that could benefit from its application would decide if, when, where, and how it would be applied.

But now the great SST battle has come and gone, and our view of the place of technology in our society is changing rapidly. Consider another quotation:

> What the public thinks about weather modification, rather than what the scientists know about it, will play the dominant role in the future of this science. The most expertly

> developed technology, whether it be for augmenting water or for suppressing damaging weather phenomena, will find only limited application in the absence of a strong public demand. (2)

This statement comes not from social scientists or ecologists, but from deep within the atmospheric research establishment. It is from a report of the Interdepartmental Committee for Atmospheric Sciences (ICAS), a subgroup of the Federal Council for Science and Technology made up of representatives of all the federal agencies that have programs in atmospheric science. The report from which I quoted is a carefully phrased proposal for a national program for accelerating progress in weather modification, and it displays the usual disinclination of councils at high levels of government to charge recklessly off in pursuit of radical innovations. In other words, I regard the inclusion of this statement in an ICAS report as pretty good evidence that the atmospheric science establishment has accepted, at least in principle, the axiom that weather modification and public policy are closely linked to one another.

But practice, as usual, is lagging behind principle. To ensure that weather-modification technology is applied wisely and effectively to serve human needs, a third requirement must be added to the combination of expert technology and public demand: new and innovative public-policy mechanisms to bridge the great gulf that often lies between what the scientists know and what the public wants.

The High Plains may be about to witness a striking example of this disparity between scientific knowledge and public demand. The possibility that this region may be starting into a cyclic drought period similar to those of the Thirties and Fifties has spurred a sharp interest among farmers, public officials, and others in the potential effectiveness of applying weather-modification technology to augment inadequate precipitation. This increased interest already has begun to raise a multitude of knotty questions involving ecological, social, legal, economic, and political considerations.

The State Of Scientific Knowledge

A fundamental problem is that public understanding of the present state of weather-modification technology is not very good. This is not surprising, as there is considerable controversy among atmospheric scientists themselves about the effectiveness and limitations of weather-modification techniques in many situations.

A few carefully designed weather-modification research programs, conducted over sufficiently long periods of time, have provided a high degree of confidence in certain weather-modification techniques. The work of Prof. Lewis Grant, of Colorado State University, at Climax, Colorado, on the Continental Divide, has established clear criteria for seeding orographic snowstorms to increase snowfall. This research program, supported by the National Science Foundation (NSF), has provided the scientific basis for the Bureau of Reclamation's pilot project in western Colorado, designed to test the feasibility of seeding mountain snowstorms on a systematic and regular basis to augment the winter snowpack in the Colorado River basin and thus increase the summer water supply in the arid Southwest.

But scientific knowledge is much less certain in other areas of weather modification that are relevant to environmental problems of the High Plains. Hail is one such problem; hailstorms cause millions of dollars worth of crop damage in the region every year. Although many reputable commercial weather-modification operators contract with farmers to suppress hail by cloud seeding, and the Russians have claimed impressive results from their program to protect crops by seeding hailstorms, many atmospheric scientists do not feel that the effectiveness of hail-suppression technology has been adequately demonstrated. The National Hail Research Experiment, which will begin its field operations this summer in northeastern Colorado, is designed to test the feasibility of using cloud seeding as an

effective tool to reduce crop damage from hail. Supported by NSF and managed by the National Center for Atmospheric Research (NCAR), this experiment will focus the efforts of scientists from universities, government laboratories, and other groups in a five-year study, directed by William C. Swinbank of NCAR, that will use a randomized seeding experiment to evaluate the effects of cloud seeding on hailfall.

Drought is another serious weather problem in the High Plains. During the drought of the Fifties, commercial cloud-seeding operations were conducted in many parts of the region to try to stimulate extra rainfall for the farmers' parched crops. The results were equivocal, to say the least. Although it seems possible that the cloud seeders produced some extra precipitation in the course of their efforts, there is no way to tell why they succeeded--when and if they did--or why they failed. The folklore of the High Plains was enriched with many tales of cloud-seeding adventures--I hardly ever talk with a group of Colorado farmers without hearing a tale, told with great glee or equally great chagrin, about the time the cloud seeder supposedly brought on a catastrophic flood or triggered a barrage of hailstones as big as grapefruit.

As the drought of the Fifties tapered off, so did enthusiasm for cloud seeding. But if we find ourselves going into another dry spell, the rainmakers will be back in business across the High Plains. And, in spite of advances that have been made in other areas of weather modification, it appears that we know very little more about the effectiveness of cloud seeding for augmenting rainfall from High Plains convective storms than we knew a couple of decades ago.

Joanne Simpson, William Woodley, and their colleagues at the Experimental Meteorology Laboratory of the National Oceanic and Atmospheric Administration (NOAA) in Miami have demonstrated that, given the proper combination of conditions, they can stimulate the growth of single semitropical convective clouds by seeding them with silver iodide, resulting in more rain than the cloud would have dropped naturally. However, it is a long jump from these limited scientific conclusions to the large-scale application of cloud seeding technology to augment precipitation over large areas of the High Plains.

In spite of the uncertainty of the scientific basis for such projects, a number of proposals have been put forward to establish large operational programs for increasing precipitation in the High Plains region. Several states have set themselves up in the weather-modification business, and others seem inclined to follow their example. A plan currently under discussion would establish an operational cloud-seeding program for a five-state area in the northern Great Plains.

I am not competent to judge the steadiness of the scientific underpinnings of such efforts. But I do see a clear danger that the public may expect too much of weather-modification technology, and that the field may suffer a severe setback if over-optimism gives way to total disillusionment. If the High Plains do enter a period of drought, and if weather-modification technology is called on to break the drought and fails to do it, I foresee a long dry spell of a different sort for atmospheric scientists who seek public funding for their weather-modification research.

Courses of Action

It seems to me that two clear courses of action are indicated here for the atmospheric sciences community. The first is to support efforts to establish a carefully designed experiment to test the effectiveness of cloud seeding for augmenting precipitation over the Great Plains. Such an experiment probably will require cooperation among groups and individuals who have disagreed with one another on various points of weather-modification theory and practice. It appears that they would do well at this point to overlook their differences and consider the potential benefits of enthusiastic cooperation. A

second need is for atmospheric scientists to work to improve public understanding of the current state of knowledge concerning weather modification. Although it is important for the general public to have some understanding of this subject, it is even more important for information to be communicated to decision-makers--to legislators who will be considering new laws on weather modification, to farmers' organizations that will exert strong pressures on weather-modification policy-making, to state officials who will regulate weather-modification activities. I am not talking about lobbying or propagandizing for weather modification; what is needed is clear and accurate information about what atmospheric scientists know and what they do not know.

I recently had an opportunity to study an active interface between weather modification and public policy during legislative committee meetings and public hearings on the Colorado Weather Modification Act of 1972, which has been passed by the legislature and is now awaiting the governor's signature. Professor Grant and I were asked to serve as professional advisors to the interim committee that drafted this bill. For me, this was a fascinating introductory course in applied political science, in which I discovered that there is a great deal of truth in the hackneyed old definition of politics as the art of the possible.

I will not attempt to comment in detail on the provisions of this act, but I would like to say that it appears to provide a sound and workable framework for state regulation of weather-modification activities--something that Colorado does not have under its present law. I believe that the decision of the legislators to call on Professor Grant's scientific expertise was a major factor in producing a law that provides a matrix for intelligently analyzing and attacking many problems of weather modification and public policy. Such working relationships between scientists and decision-makers are becoming more and more essential as science and technology exert an ever-increasing influence on the affairs of our society.

Two Broad Requirements

Thus far, I have spoken rather generally about some problems related to weather modification and public policy in the High Plains region. Now I would like to present my personal view of some things that are needed to keep those problems from compounding themselves to produce a situation in which public rejection of the whole concept of weather modification could deprive us of considerable potential public benefits that may derive from its intelligent application.

I am a generalist rather than a specialist, and generalists often have a habit of glibly prescribing plans and solutions that call for specialists to perform tremendous amounts of difficult and detailed work. I am not about to instruct the specialists about what they must do, but I would like to raise some questions that can be answered only by highly organized programs of specialized research in a variety of disciplines.

I see two broad requirements at this point. The first is a greatly accelerated research program aimed at solving not only the physical problems of weather-modification technology, but also those of environmental, social, economic, and legal implications of the large-scale application of such technology.

First, of course, we need to know what is physically possible. We need the sort of detailed scientific knowledge that came from Professor Grant's work at Climax and that we expect to come from the National Hail Research Experiment. As far as the High Plains region is concerned, we particularly need to learn what can and cannot be done to augment precipitation from summer convective storms.

Along with research on how cloud seeding affects the physics and dynamics of weather systems, we also must consider other environmental consequences of weather modification efforts. The material most commonly used for cloud seeding is silver iodide. What will happen if silver iodide is disseminated into the atmosphere over a particular area regularly and systematically over a period of many years? Will it have direct effects on plants and animals? Is there any possibility that it might be concentrated through the food chain to produce dangerously high levels in some plant or animal species? These problems have been surveyed, and intelligent guesses indicate that the likelihood of such dangerous side effects is slight, but detailed, long-term research has not been done. Both the Bureau of Reclamation and NCAR have built such chemical and ecological studies into their research plans, and it seems to me that similar studies must be included in all major weather-modification research programs.

A second sort of environmental study has to do with the ecological impacts of intended results, as opposed to unintended side effects. A great many charges have been leveled at snowpack augmentation programs concerning possible effects of increased average annual snowfall on the distribution of plant and animal species in the target area. Again, there are many guesses but few scientific conclusions. Research should be undertaken to ensure that by the time we determine what weather-modification technologies are feasible, we will also be able to assess the environmental impacts of their large-scale application.

However, knowledge of what is physically feasible and environmentally acceptable will not have much practical value unless it can be cranked into some sort of rational public decision-making system. Here is where the social scientists come in. They must consider broad societal questions such as how the public views weather modification and whether or not particular technologies will be accepted by the public as useful ways to solve weather-related problems. Precise quantitative methods for weighing costs against benefits must be developed. For example, it will be impossible to judge the economic feasibility of a precipitation-augmentation program unless a realistic price tag can be put on the extra water that is expected to fall on the target area. Up till now, we have had a pretty difficult time agreeing on just what an acre-foot of water is actually worth in any particular part of the semiarid High Plains or the arid Southwest.

The report that I quoted earlier, *A National Program for Accelerating Progress in Weather Modification*, attempts to establish a framework for getting a massive national research effort underway. In effect, it proposes that federal weather-modification efforts be focused in seven designated national projects, each with its own lead agency. This could, of course, become an exercise in lip service, with each agency riding off in six different directions while budgeting and reporting them all as part of its assigned national project. I hope that this will not happen, and I think the ICAS plan is clearly a move in the right direction. Earlier efforts to assign the total federal responsibility for weather modification to a single agency have met insurmountable political barriers, and there seem to be other good reasons as well for working toward a coordinated multi-agency effort rather than creating a single massive federal weather-modification entity.

Assuming that the necessary research effort is under way, the second need is for effective government regulation of operational weather-modification projects. An effective regulatory framework, whether it is at the federal or state level, must bring together scientific experts and representatives of the public and must give them the apparatus to make intelligent decisions. These decisions will determine, first, if a particular weather modification project should be done and, second, if it is, how it should be done to best serve the public interest. I make this sound very simple, but of course it is not. Let me give a very elementary example. The Colorado Weather Modification Act of 1972 gives regulatory power over weather modification in the state to the director of the Colorado Department of Natural Resources (DNR). In the course of a hearing before a senate committee, a representative of the Colorado Student Lobby proposed an amendment requiring weather-modification operators to make sufficient

measurements before and during their operations to permit the DNR Director, assisted by an advisory committee, to resolve issues of liability for damages caused by storms that have been seeded.

Although I sympathized with the intent of this proposed amendment, I recognized that it was asking something that simply was not possible. In response to a request from one of the committee members, I submitted the following statement:

> I will confine my comments to a single weather phenomenon, the hailstorm, as that is the area of weather modification in which my organization is currently working.
>
> If a thunderstorm cloud that is expected to produce hail is seeded, several assumptions can be made about the results, First, if hail does not fall, it can be assumed that the cloud seeding suppressed the hail. However, this is not certain--maybe the storm would not have produced hail if it had not been seeded. Scientifically, we have no way of knowing for sure.
>
> If hail falls from the storm, two assumptions can be made. The first is that the seeding caused the hail. Scientific opinion is divided on whether or not this is possible under certain circumstances, and we do not have a positive answer now.
>
> The second assumption is that the seeding simply failed to suppress the hail. and that it fell just as it would have if the storm had not been seeded. This is very likely to happen. Even the most optimistic commercial cloud seeder is unlikely to claim 100 percent success, or would accept a contract that stipulated that he would not be paid anything at all if any hail damage at all occurred in the area he was hired to protect. Weather modification technology is not that precise, and the possibility of failure is always present.
>
> Some recent discussions before this committee seem to be based on the assumption that by requiring a weather modifier to collect sufficient data, and by obtaining the services of scientific experts to evaluate the data, it will be possible to determine with reasonable certainty whether or not cloud seeding was the cause of damage inflicted by a particular storm.
>
> This assumption is not valid. With the present state of knowledge, it is impossible to determine precise cause-and-effect relationships in the behavior of an individual seeded thunderstorm. The interactions are too complex, and the violence of the storm makes it difficult or impossible to observe many of them in any detail. As you know, the federal government is planning to spend five years and several million dollars studying the behavior of seeded and unseeded hailstorms in northeastern Colorado. However, this is a statistical, randomized experiment designed to determine whether or not seeding can be used to achieve a long-term overall decrease in hail damage to crops. We hope that its results also will help us say with reasonable certainty just what goes on inside a particular storm , seeded or unseeded, but we definitely do not have that ability now.
>
> My concern is that the language of this proposed amendment may lead the legislators who decide whether or not it becomes law, the civil servants who must administer it if it passes, and the people who will be affected by it to expect too much from it. No matter how carefully the bill is worded or how conscientiously the law is administered, the scientific knowledge is not available at this time to distinguish precisely between the work of man and the work of nature in the behavior of a single thunderstorm that has been seeded.

My point is this: any system for regulating weather modification must be firmly based on the current state of scientific knowledge as well as careful consideration of the public interest.

Another essential element of fair and intelligent regulation of weather modification is a realistic system for matching costs to benefits and adjusting any inequities that may emerge. To use a rather simple-minded example, a project to increase the mountain snowpack in a river basin may have great benefits for farmers and cities downstream, but involve direct and calculable costs for people in the target area. A cattleman who grazes his stock in mountain meadows in the summer may find that the extra increment of snow keeps his pastures from being grazed for an extra two weeks in the spring. This should not mean that the project will not be permitted; it may mean that the structure of the project will provide payment to the rancher for an extra two weeks worth of feed and that this payment will be included as a cost. To take a more subtle example, suppose that ecologists discover that increasing the average annual snow accumulation changes the patterns of vegetation in the area, and that the pastures become overgrown with plants that are less suitable for grazing. If this represents a serious threat to the ecological stability of the area, perhaps the project should be abandoned. If its ecological impact is not serious, I propose that the project accountants should include fair compensation to the rancher for the reduced value of his grazing land as a debt item on their balance sheet.

I am sure some weather-modification enthusiasts would oppose these suggestions, maintaining that they won't ever be able to get anything done if we make it so complicated. My answer is that you can get it done if it is important enough to enough people or, in other words, if it is really in the public interest. As things stand now, we don't know enough to decide what is in the public interest as far as weather modification is concerned, and we don't have mechanisms for implementing such decisions even if we could make them intelligently.

Although I have only skimmed the surface of a tremendously complex subject, I will conclude this general and perhaps superficial discussion here. In summary, my main point is that both innovative approaches and rigorous study are needed on many complex issues such as legal aspects of weather-modification operations, public involvement in weather-modification planning and regulation, realistic cost-benefit accounting for weather-modification projects, and the kind and extent of government regulation that should be exercised over weather-modification activities.

Although many organizations, including my own, are examining questions of this sort, there is a pressing need for more studies of public-policy implications to be conducted concurrently with research programs on the physical problems of weather modification. The atmospheric scientists will be able to tell us what we can do to change the weather, but we must call on the ecologists, sociologists, economists, lawyers, legislators, and experts from many other fields to help us decide what we should do.

References

1. Charles F. Cooper, "Predicting Ecological Effects of New Technology: The Case of Weather Modification." Discussion paper prepared for the Center for Study of Democratic Institutions, Santa Barbara, California, 1972.

2. Interdepartmental Committee for Atmospheric Sciences, *A National Program for Accelerating Progress in Weather Modification*, ICAS Report No. 15A, Washington, DC, 1971.

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