WEATHER MODIFICATION

HEARINGS

BEFORE THE

SUBCOMMITTEE ON OCEANS AND INTERNATIONAL ENVIRONMENT

OF THE

COMMITTEE ON FOREIGN RELATIONS UNITED STATES SENATE

NINETY-THIRD CONGRESS

SECOND SESSION

ON

THE NEED FOR AN INTERNATIONAL AGREEMENT PROHIBITING THE USE OF ENVIRONMENTAL AND GEOPHYSICAL MODIFICATION AS WEAPONS OF WAR

AND

BRIEFING ON DEPARTMENT OF DEFENSE WEATHER MODIFICATION ACTIVITY

JANUARY 25 AND MARCH 20, 1974

[Top Secret hearing held on March 20, 1974; made public on May 19, 1974]

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Insertions for the record—Continued

WEATHER MODIFICATION

FRIDAY, JANUARY 25, 1974

UNITED STATES SENATE,
SUBCOMMITTEE ON OCEANS AND
INTERNATIONAL ENVIRONMENT OF THE
COMMITTEE ON FOREIGN RELATIONS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 10:05 a.m., in room 4221, Dirksen Senate Office Building, Senator Claiborne Pell [chairman of the subcommittee], presiding.

Present: Senator Pell.

OPENING STATEMENT

Senator PELL. This morning the Subcommittee on Oceans and International Environment is meeting to hear testimony concerning the need for an international agreement prohibiting the use of environmental modification and geophysical modification as weapons of war.

It is regrettable that this hearing must be held. It would not have been necessary if the administration had promptly responded to S. Res. 71, a resolution overwhelmingly adopted on July 11, 1973, as the result of a rollcall vote in the Senate. Six months later, there has not been the slightest indication that the administration is acting to meet a clearly expressed request of the Senate that the U.S. Government seek the agreement of other governments to a treaty prohibiting the use of any environmental or geophysical modification as a weapon of war. I hope this hearing will shed light on the reasons why no such action has been taken. I am sure it will reveal reasons why this action should be taken without delay. As I note below, I am afraid much of the responsibility for no forward movement rests at the door of the Defense Department.

The objective of S. Res. 71 has been endorsed by several national and international organizations. On the international level, the North Atlantic Assembly at its 18th meeting in November 1972, recommended a treaty to ban environmental or geophysical modification except for peaceful purposes. Domestically, in 1971, the National Academy of Sciences Committee on Atmospheric Sciences urged the U.S. Government "to present for adoption by the United Nations General Assembly a resolution dedicating all weather-modification efforts to peaceful purposes. "The President's National Advisory Committee on Oceans and Atmosphere" in its first annual report in 1972, strongly recommended that the United States seek international arrangements to renounce hostile uses of weather modification. Again, in 1972, the Sierra Club joined the Federation of American Scientists in urging that, "The United States should henceforth dedicate all

geophysical and environmental research to peaceful purposes and should actively seek the cooperation of other nations in programs of joint research on geophysical phenomena, their control, and their peaceful use."

However, despite the wide support for this concept, the Administration has failed to articulate a national policy on weather modification. This is due primarily to the intransigence of the U.S. military establishment. The military branches of our Government have steadfastly opposed the development of any policy in order to keep all their options open in the field of environmental modification. This response is, in my opinion, a shortsighted reflexive reaction. It does not represent a carefully considered, well-developed national policy. However, until such a policy surfaces, the military will have the freedom to indiscriminately experiment and operationally use this technology.

This is a situation which I find extremely distressing. If we do not restrict the military use of current environmental modification techniques, we risk the danger of the development of vastly more dangerous techniques whose consequences may be unknown or may cause irreparable damage to our global environment.

Military use of such techniques will affect the very important peaceful international scientific efforts now underway under the auspices of the World Meteorological Organization and the International Council of Scientific Unions—such programs as the Global Atmospheric Research Program [GARP] and "Earthwatch."

Instead of its official silence and actions condoning a gradual drift into environmental warfare, the administration should actively explore the advantages of a renunciation of such operations and the possible benefits stemming from an initiative for a multilateral "no first use" agreement. It is imperative that the United States enunciate a national policy on this subject, in no way blocking their development and in no way moving forward in the enlargement of human knowledge, but simply dedicating these efforts to peaceful purposes.

I hope that these hearings will spur the administration into some form of action to develop such a policy, as well as enlarging the body of knowledge available to the American public as to what geophysical and weather modifications actually imply.

[Text of S. Res. 71 follows:]

93D CONGRESS
1ST SESSION

S. RES. 71

[Report No. 93–270]

IN THE SENATE OF THE UNITED STATES

FEBRUARY 22, 1973

Mr. PELL (for himself, Mr. BAYH, Mr. CASE, Mr. CHURCH, Mr. CRANSTON, Mr. GRAVEL, Mr. HART, Mr. HOLLINGS, Mr. HUGHES, Mr. HUMPHREY, Mr. JAVITS, Mr. KENNEDY, Mr. MCGOVERN, Mr. MONDALE, Mr. MUSKIE, Mr. NELSON, Mr. STEVENSON, Mr. TUNNEY, and Mr. WILLIAMS) submitted the following resolution; which was referred to the Committee on Foreign Relations

JUNE 27 (legislative day, JUNE 25), 1973
Reported by Mr. PELL, with amendments

JULY 11, 1973
Considered, amended, and agreed to

RESOLUTION

Expressing the sense of the Senate that the United States Government should seek the agreement of other governments to a proposed treaty prohibiting the use of any environmental or geophysical modification activity as a weapon of war, or the carrying out of any research or experimentation directed thereto.

Whereas there is vast scientific potential for human betterment through environmental and geophysical controls; and

Whereas there is great danger to the world ecological system if environmental and geophysical modification activities are not controlled or if used indiscriminately; and

Whereas the development of weapons-oriented environmental and geophysical modification activities will create a threat to peace and world order; and

Whereas the United States Government should seek agreement with other governments on the complete cessation of any research, experimentation, or use of any such activity as a weapon of war: Now, therefore, be it

Resolved, That it is the sense of the Senate that the United States Government should seek the agreement of other governments, including all Permanent Members of the Security Council of the United Nations, to a treaty along the following general lines which will provide for the complete cessation of any research, experimentation, and use of any environmental or geophysical modification activity as a weapon of war:

"The Parties to this Treaty,

"Recognizing the vast scientific potential for human betterment through environmental and geophysical controls,

"Aware of the great danger to the world ecological system of uncontrolled and indiscriminate use of environmental and geophysical modification activities,

"Recognizing that the development of weapons-oriented environmental and geophysical modification techniques will create a threat to peace and world order,

"Proclaiming as their principal aim the achievement of an agreement on the complete cessation of research,

experimentation, and use of environmental and geophysical modification activities as weapons of war,

"Have agreed as follows:

"ARTICLE I

"(1) The States Parties to this Treaty undertake to prohibit and prevent, at any place, any environmental or geophysical modification activity as a weapon of war;

"(2) The prohibition in paragraph 1 of this article shall also apply to any research or experimentation directed to the development of any such activity as a weapon of war, but shall not apply to any research, experimentation, or use for peaceful purposes;

"(3) The States Parties to this Treaty undertake not to assist, encourage or induce any State to carry out activities referred to in paragraph 1 of this article and not to participate in any other way in such actions.

"ARTICLE II

"In this Treaty, the term 'environmental or geophysical modification activity' includes any of the following activities:

"(1) any weather modification activity which has as a purpose, or has as one of its principal effects, a change in the atmospheric conditions over any part of the earth's surface, including, but not limited to, any activity designed to increase or decrease precipitation,

increase or suppress hail, lightning, or fog, and direct or divert storm systems;

"(2) any climate modification activity which has as a purpose, or has as one of its principal effects, a change in the long-term atmospheric conditions over any part of the earth's surface;

"(3) any earthquake modification activity which has as a purpose, or has as one of its principal effects, the release of the strain energy instability within the solid rock layers beneath the earth's crust;

"(4) any ocean modification activity which has as a purpose, or has as one of its principal effects, a change in the ocean currents or the creation of a seismic disturbance of the ocean (tidal wave).

"ARTICLE III

"Five years after the entry into force of this Treaty, a conference of Parties shall be held at Geneva, Switzerland, in order to review the operation of this Treaty with a view to assuring that the purposes of the preamble and the provisions of the Treaty are being realized. Such review shall take into account any relevant technological developments in order to determine whether the definition in Article II should be amended.

"ARTICLE IV

"1. Any Party may propose an amendment to this Treaty. The text of any proposed amendment shall be sub-

mitted to the Depositary Governments which shall circulate it to all parties to this Treaty. Thereafter, if requested to do so by one-third or more of the Parties, the Depositary Governments shall convene a conference, to which they shall invite all the Parties, to consider such an amendment.

"2. Any amendment to this Treaty shall be approved by a majority of the votes of all the Parties to this Treaty. The amendment shall enter into force for all Parties upon the deposit of instruments of ratification by a majority of all the Parties.

"ARTICLE V

"1. This Treaty shall be of unlimited duration.

"2. Each Party shall, in exercising its national sovereignty, have the right to withdraw from the Treaty if it decides that extraordinary events, related to the subject matter of this Treaty, have jeopardized the supreme interests of its country. It shall give notice of such withdrawal to all other Parties to the Treaty three months in advance.

ARTICLE VI

"1. This Treaty shall be open to all States for signature. Any State which does not sign this Treaty before its entry into force in accordance with paragraph 3 of this Article may accede to it at any time.

"2. This Treaty shall be subject to ratification by signatory States. Instruments of ratification and instruments of

accession shall be deposited with the Governments of the United States of America, , and which are hereby designated the Depositary Governments.

"3. This Treaty shall enter into force after its ratification by the States, the Governments of which are designated Depositaries of the Treaty.

"4. For States whose instruments of ratification or accession are deposited subsequent to the entry into force of this Treaty, it shall enter into force on the date of the deposit of their instruments of ratification or accession.

"5. The Depositary Governments shall promptly inform all signatory and acceding States of the date of each signature, the date of deposit of each instrument of ratification of and accession to this Treaty, the date of its entry into force, and the date of receipt of any requests for conferences or other notices.

"6. This Treaty shall be registered by the Depositary Governments pursuant to Article 102 of the Charter of the United Nations."

Senator PELL. Our first witness today will be the representative of the Department of State, the Director of the International Scientific and Technological Affairs Bureau, Mr. Herman Pollack.

STATEMENT OF HERMAN POLLACK, DIRECTOR, BUREAU OF INTERNATIONAL SCIENTIFIC AND TECHNOLOGICAL AFFAIRS, DEPARTMENT OF STATE

Mr. POLLACK. Thank you.

My statement this morning will be brief.

Since I testified on an earlier version of this resolution in July 1972 the Senate adopted S. Res. 71 on July 11, 1973. In addition, you and the Secretary of State discussed S. Res. 71 during his confirmation hearings on September 10 and he has written to you on this subject on November 5.

As you know, in that letter the Secretary expressed regret that it was not yet possible to provide a coordinated executive branch response on S. Res. 71. He assured you that the matter would be looked into closely to determine how the executive branch might be responsive to the resolution's recommendations.

In this regard the President has directed that a study of the military aspects of weather and other environment modification techniques be undertaken. Further steps will be determined subsequent to the findings of this study and the review of those findings.

Mr. Senator, that concludes my statement. I will be glad to respond to any questions that you may have.

Senator PELL. Thank you very much.

DOD STUDY OF MILITARY ASPECTS OF ENVIRONMENTAL MODIFICATION

You are right, that is a very short statement indeed. Really it is a no statement statement, a no policy statement, but I am delighted to see that finally the President has directed that a study of the military aspects of weather and other environmental modification techniques be undertaken. I would like, if I could, to flush out public knowledge of this study.

When was this study requested? Of whom was it requested? And when is it expected that the reports will be available to the executive and to the public?

Mr. POLLACK. The study is directed to the Department of Defense. My understanding of the time available is not precise but I gather it has a deadline of several months given the scope of the area to be studied.

The decision to proceed with this directive was taken very recently.

Senator PELL. Do you recall the date when the assignment was given?

Mr. POLLACK. No.

Senator PELL. It was given within the last week or so?

Mr. POLLACK. Yes.

Senator PELL. Was it done through National Security Council [NSC] framework?

Mr. POLLACK. I believe so, yes, sir.

Senator PELL. And the Defense Department was given the lead assignment in directing the study?

Mr. POLLACK. I don't think it is in terms of a lead assignment; I think it has the assignment to produce this product.

Senator PELL. And is there any indication as to who would be chairing the study? Would it be the Under Secretary of Defense?

Mr. POLLACK. I don't know, sir.

Senator PELL. But it is a Defense study and will be the same as the National Security Council interagency study?

Mr. POLLACK. My understanding, sir, as I reported, is that the President has directed the Department of Defense to do this. Precisely how it is to be described in terms of a NSC study I just cannot answer; I just don't know.

Senator PELL. Do you know if this is the first such study in the executive branch of the Government?

Mr. POLLACK. No; I think I reported in our last hearings a year and a half ago that an interagency study had been conducted. That study incorporated an examination of military aspects of weather modification but it reached no conclusions.

Senator PELL. That is right, it was a study but, as you pointed out, no conclusions were reached as to whether we should move ahead or not.

Mr. POLLACK. That is right.

ADMINISTRATION'S RESPONSE TO S. RES. 71

Senator PELL. Can you hypothesize for us as to why the inordinate delay in the administration's responses to the clearly expressed will of the Senate? I think it was with an 80-something to 10 rollcall vote that we requested the administration to move ahead in this field. Actually, I think it was a rather unique occurrence.

The Secretary of the Senate, if my recollection is correct, sent a letter to the President enclosing the resolution asking that action be taken. That was last June, I think, or July. It is now 6 months later; we are into 1974. What is the reason for this delay?

Mr. POLLACK. I don't believe I can illuminate that subject, I do not personally have the knowledge that would permit me to do so.

Senator PELL. Is it the view of the Department of State that movement in this direction would be advantageous to the national interest of the United States? Has the Department of State formulated an opinion itself?

Mr. POLLACK. I think your first statement would more accurately reflect our position. We do think this is a question that does need at some point to be determined, a position tentatively or otherwise taken. It remains our view as of this point that there is still an inadequate basis of information available to permit the kind of judgments that should precede a decision by the United States to pursue or not pursue a treaty on a subject of this complexity.

I would anticipate that we will possibly be in a better position to judge what our next steps should be when the review of the study that has been directed now by the President to the Department of Defense is in hand.

LEVEL OF SECURITY CLEARANCE FOR INTERAGENCY COMMITTEE MEMBERS

Senator PELL. In connection with the study that you chaired, the interagency committee, there are a couple of querries.

Do you happen to recall the level of security clearance that was generally held by the members of your committee?

Mr. POLLACK. By the members of that committee?

Senator PELL. Yes.

Mr. POLLACK. The committee members would have been cleared for top secret.

Senator PELL. And presumably that is certainly your clearance, if not higher.

ACCESS TO INFORMATION ON MILITARY USE OF WEATHER MODIFICATION

Why was your committee refused access to information at that time on the current military use of weather modification technology?

Mr. POLLACK. This question is one that we pursued at our last hearing.

Senator PELL. Correct.

Mr. POLLACK. And I don't recall exactly to whom the correspondence was addressed, but my recollection is Secretary Laird had established a position respecting the classification of activities in this area that makes it still impossible for me to deal with that subject in an open hearing.

Senator PELL. Right. My recollection is that Mr. Laird refused in open or closed hearing to discuss this problem in depth at all.

Mr. POLLACK. You may be correct.

Senator PELL. I would have thought it would have been hard for your committee at that time, in fact not only hard but impossible, to develop policy recommendations without knowing all of the facts, including military applications.

INTERAGENCY STUDY

To whom was your own final report submitted, the interagency study that you——

Mr. POLLACK. We submitted that to the Deputy Secretary of State, chairman of the Under Secretary's Committee.

Senator PELL. And did you have any recommendations or any results in the final part of that study?

Mr. POLLACK. The recommendations of that study were on the civil aspects. With respect to the military aspects, there were no conclusions reached.

ARGUMENTS AGAINST PROHIBITING USE OF ENVIRONMENTAL WARFARE

Senator PELL. What do you see, Mr. Pollack, as the arguments from the American viewpoint against such a prohibition?

Mr. POLLACK. I am sorry——

Senator PELL. What do you see as your own views with regard to the arguments against an agreement prohibiting the use of environmental warfare? What do you see as the negative arguments from your own knowledge?

Mr. POLLACK. From my own knowledge, I think I suggested some questions that need to be pursued but they are not in the nature of argument. There are some things I think undoubtedly will need to be examined at greater care.

Among them the difficulty of verification would have to be examined, I would think, with a great deal of care. The nature of some aspects of environmental activity such as rain cloud seeding, possibly done with very small planes would be very difficult to establish in a hard factual manner. Techniques may one day be developed that would make that possible. This is one of the things that would have to be examined with great care.

The difficulty of distinguishing between civilian and military research will be also, I think, a matter that will have to be looked into thoroughly. A good deal of work is being done at the moment with respect to fog dissipation directed at civilian airports. Matters of that kind that will have to be worked over.

CLIMATE MODIFICATION

I would like to amend slightly the answer I gave you to a previous question. As I reported at our last hearing and we had a brief exchange on this point. The Under Secretaries' committee provided the basis for a conclusion that the administration would not use techniques for climate modification for hostile purposes even should they be developed. So to that extent the report did dispose of one possible aspect of military——

Senator PELL. As I recall, the difference between climate and weather modification is basically somewhat similar to that between strategic and tactical warfare. Climate modification means changing the long-term climate or environment of an area that would have an effect over a period of years, whereas weather modification is a shorter term proposition.

Would that be correct?

Mr. POLLACK. Yes; and the other distinction I think I would make is that climate modification would affect and area of indeterminate size whereas weather modification is normally restricted to a fairly measurable and limited amount of territory.

Senator PELL. To give a specific example, the melting of the Greenland ice cap would be climate modification?

Mr. POLLACK. Yes; sir.

Senator PELL. While the reduction of the fog over an airport, no matter whether it is for good purposes to permit planes to land, or bad purposes to clear the air so you can see what you are bombing, that would be weather modification?

Mr. POLLACK. Yes.

GEOPHYSICAL MODIFICATION

Senator PELL. In which category would fall the element of geophysical modification, the artificial reduction of an earthquake a good many miles away by putting an exposure in the floors of the Earth surface?

Mr. POLLACK. You will have witnesses later this morning much better qualified than I to answer that question. My understanding is we

really do not at this point know enough about the consequences of that kind of activity to be able to provide you with an answer to that question.

CREATION OF HURRICANE

Senator PELL. What about the question of the creation of a hurricane; would that be weather or climate modification, in your view?

Mr. POLLACK. Well, the single hurricane, I would speculate, probably weather modification. But if the process by which a hurricane was created became subject to human manipulation, not knowing what that process would be, and whether it could be turned on and off, the consequence would be very significant climate modifications.

WEATHER MODIFICATION ACTIVITIES IN INDOCHINA

Senator PELL. Returning to the formal line of questioning, do you think that, although not admitted on the part of the Federal Government, that the fairly general assumption that the United States engaged in weather modification in Southeast Asia has any bearing on the executive branch's attitude with regard to possible future prohibition of such activities? If that is the case, I think we should be looking ahead and not behind.

Mr. POLLACK. Sir, since the question of whether or not the weather modification activities were carried on in Indochina, it is also a subject on which it is not possible for me to speculate on in an open or closed session for that matter. I can't find a way to respond to your query.

Senator PELL. I recognize your predicament and deplore the policy of the executive that puts you in that position.

INFORMATION PROVIDED ON WEATHER MODIFICATION

Is your department fully informed of all weather modification activities carried out by persons and agencies subject to the jurisdiction of the United States?

Mr. POLLACK. By persons or——

Senator PELL. By persons and agencies subject to the jurisdiction of the United States. In other words, are you informed of any weather modification activities that occur in the Pacific Ocean and the high seas or in the Far East or Sahara, as a matter of course?

Mr. POLLACK. Yes, I believe so.

Senator PELL. Even if done by the Defense Department or CIA or any other department, if outside the United States?

Mr. POLLACK. Any activity that is being carried on outside the United States. The thing that triggers the Department of State with respect to weather modification activities is the location of the activity. If it is overseas or would affect a foreign nation, the committee that we chair is involved. The committee's attention is triggered usually from a foreign government for either advice or support in rainmaking.

Senator PELL. I think perhaps like Watergate it was not that important compared with the interest that has come out after the bugging incident. This rainmaking in Southeast Asia is not all that important compared with the whole issue that we are discussing, but it is, I think, basic to it just like Watergate is basic to the whole crisis of Government today.

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And in that connection, now that the war is over, and in view of the new spirit of cooperation that we do see with Dr. Kissinger as Secretary of State and his really very open relations with the Congress and with this committee, do you think this question can be settled as to whether or not we did engage in weather modification? I don't see anything awfully terrible if we did—what I do think is terrible is that the competent committees cannot be informed of it; the Congress cannot be informed and the American people cannot be informed of it.

As I said, it is very like the incidents of Watergate which have grown up much bigger. It is the same thing here. And I was wondering if you thought that this situation might change in light of the new spirit of cooperation which Dr. Kissinger referred to in his nomination hearings and which I think is really in being now.

It is a tough question.

SECRETARY KISSINGER'S ATTENTION TO QUESTION

Mr. POLLACK. No, not so tough. I think I could say with respect to that that you have played a major role in bringing Secretary Kissinger's attention to this question especially in the last 6 months and I have no question in my mind that your interest has had a constructive impact on the decision taken recently by the President in directing this study.

What I am unable to do is to anticipate either the consequences of the product of that study or the results of the review of it. But certainly there is now, there is now motion or movement——

Senator PELL. I appreciate that. You are quite right, I harrassed the Secretary publicly, privately, telephonically, on this subject because I think it is very important. It will give us an opportunity to take the lead as a peace-loving, peace-promoting Nation, and we did the same with the Outer Space Treaty.

OPPORTUNITY FOR U.S. TO TAKE LEAD

I remember when I first proposed the idea of a regime of law for the seas there was a good deal of laughter and reluctance, but we have actually accomplished a small portion of it in the Seabed Disarmament Treaty. I can see the opportunity here for the United States to take the lead in really a very important step toward world peace and toward preserving the environment. Thus, I keep pressing in this direction.

OPPOSITION WITHIN DOD

I can see no opposition anywhere except within the Defense Department.

Do you have knowledge, Mr. Pollack, of any opposition anywhere else in the Government besides the Defense Department?

Mr. POLLACK. Sir, I don't think it is a question of opposition as much as it is a question of inability to arrive at the kinds of judgments you like to have with you when you make a determination respecting initiating or supporting an action as important as a treaty in which the United States undertakes obligations of solemn character.

LENGTH OF TIME TO COMPLETE STUDY

Senator PELL. All right, I thank you very much for being with us this morning. I hope that the study will proceed.

Can you refine in any way the several months in which you think it will be completed?

Mr. POLLACK. When I used the term several months, I had in mind something like 3 to 4. That is at this point not a firm statement of how long it will take but that is my understanding——

Senator PELL. Right.

Mr. POLLACK [continuing]. Of the time.

Senator PELL. Thank you. Thank you very much indeed.

Our next witness will be Mr. Forman from the Defense Department.

STATEMENT OF BENJAMIN FORMAN, ASSISTANT GENERAL COUNSEL, OFFICE OF SECRETARY OF DEFENSE

Mr. FORMAN. Mr. Chairman, my opening remarks will be equally brief.

POLICY OF DEPARTMENT OF DEFENSE

Pending the outcome of the study to which Mr. Pollack referred, the position of the Department of Defense at this time remains the same as it was when I last testified, and specifically the position is as printed on page 35 of the last hearings.

Senator PELL. That is, with respect to the resolution?

Mr. FORMAN. Right.

Senator PELL. You might have been a little more courteous to the committee if you had that in writing rather than having us look it up. You ask a man what he has been doing and he said, "Read Who's Who, page 722." But I am looking it up here.

My vivid recollection is that your policy 18 months ago was a no policy policy, wasn't that correct?

Mr. FORMAN. Well, I wouldn't say it is a no policy policy. It is as Mr. Pollack just stated, that we don't have enough knowledge to make an informed judgment as to whether a treaty along the lines of the resolution would be in the national interest, that we don't have enough knowledge to draft one, and we don't have enough knowledge to know what would be required by way of verification or whether we would be able to verify such a treaty and, therefore, we took the position then and at this time still take the position, not that we are opposed to the treaty, but that the treaty be held, or the resolution or any efforts along that line be held, in abeyance.

EXECUTIVE BRANCH SHOULD PURSUE CONCEPT OF TREATY

Senator PELL. As you know, the Senate adopted this by a rollcall vote of 82 to 10 with some discussion both in the committee and on the floor and it was, as you know, unanimously adopted by all of the member nations of the North Atlantic Treaty Organization.

I would think that this would be a pretty strong indication to the executive branch that its job is to execute the policies set forth by the Congress, to carry out the laws of the Congress. This should be pursued more vigorously.

Why is it not being pursued more vigorously?

Mr. FORMAN. I am not sure I understand what you mean by pursuing something more vigorously. The concept of a treaty or our state of knowledge?

Senator PELL. The concept of the treaty. I think when we did the Outer Space Treaty our knowledge was very limited. I am not sure at that time we had men landed on the Moon. I think it was concluded before we landed the first man on the Moon, so knowledge was limited and yet we were able to move ahead.

Why can't we do the same with the weather and geophysical modification treaty?

Mr. FORMAN. As far as I recall our knowledge of space and space possibilities was far greater with regard to outer space than it is with regard to the environment.

I would like to amend or add to the opening statement I just made.

DOD WITNESS FOR CLASSIFIED HEARING

During my prior appearance you asked some questions which I was unable to respond to with respect to classified aspects of Department of Defense activities. The Department of Defense is now willing to provide a witness to this committee to testify in executive session on those classified aspects.

Senator PELL. Right. I appreciate that.

As you know, I have not sought a classified hearing because I think many of these things should be open and available in the press and available to the American public. I appreciate the willingness of the Defense Department in that regard and may well take advantage of this opportunity.

WEATHER MODIFICATION ACTIVITIES FOR MILITARY PURPOSES IN SOUTHEAST ASIA

But in our last open hearing, you indicated that you were under explicit instructions not to discuss the operation and use of weather modification activities for military purposes in Southeast Asia.

That is water over the dam, now, I realize that, but are you again operating under the same instructions as far as this open committee hearing goes?

Mr. FORMAN. You mean with respect to Southeast Asia?

Senator PELL. Correct.

Mr. FORMAN. Yes, sir.

Senator PELL. Even though its ended and over?

Mr. FORMAN. Again, I don't wish to leave any implication by my refusal to answer any questions in this open session that we either conducted such activities or did not conduct such activities.

LANGUAGE OF SEABED ARMS CONTROL TREATY

Senator PELL. Right. I was rereading the testimony last night, and the last time around on page 50 you said there that the Seabed Arms Control Treaty had similar language in its text, in that you were referring to the loophole that was put in at Stockholm at the request of the Defense Department with regard to environmental modifica-

tion. I asked my staff to look up the Seabed Arms Control Treaty and we could not find such similar language.

I was wondering if you could draw our attention to the phrase you were talking about.

I played a role, as you know, in this treaty and I was curious as to what you were referring. I think we are talking about the same one, the treaty on the prohibition of the placement of nuclear weapons.

Mr. FORMAN. Yes, sir. It may be that I referred to the wrong treaty.

I am sorry, sir, I can't find it at this point. My recollection was it was in this treaty, having worked on it actively. The natural conjunction of the fact that you had initially proposed it also led me to think it was in this treaty. But I do have the recollection of such language being in one of these arms control treaties.

Senator PELL. I think it may be in the Nuclear Test Ban Treaty, something of that sort, but I don't think it was in that one. I was reading it last night. I wondered where it was. Thank you.

[The information referred to follows:]

DEPARTMENT OF DEFENSE,
OFFICE OF GENERAL COUNSEL,
Washington, D.C., January 25, 1974.

Hon. CLAIBORNE PELL,
Chairman, Subcommittee on Oceans and International Environment, Committee on Foreign Relations, U.S. Senate, Washington, D.C.

DEAR SENATOR PELL: During the course of my testimony today on S. Res. 71, you asked me to verify a statement I had made during the earlier Hearings conducted by your Committee in 1972 on S. Res. 281. That earlier statement, as printed on page 50 of those Hearings, is as follows:

"Mr. FORMAN. I think Dr. Pollack has indicated the basic reasons. I don't know that I can enlarge upon what he said other than to remind the chairman that, at least so far as I can recall, it is fairly standard language in these treaties to modify these absolute obligations by such words as 'to the maximum extent feasible' or 'where practicable,' and so forth.

"If I am not incorrect in my recollection, I believe the Seabed Arms Control Treaty, to which reference has been made, has similar language in its text."

Upon reexamination I find that my reference to the Seabed Arms Control Treaty was incorrect. The treaty I was thinking of was, in fact, the Outer Space Treaty of 1967. Article XI of the Outer Space Treaty obligates contracting parties "to inform the Secretary General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, of the nature, conduct, locations and results of such activities." [emphasis added]. In addition, language which has that import, that is, the words "fullest possible," appears in the following treaties:

Treaty for the Prohibition of Nuclear Weapons in Latin America, article 18, paragraph 2e;

Treaty on the Non-Proliferation of Nuclear Weapons, article IV, paragraph 2, and

Biological Weapons Treaty, article X, paragraph 1.

Sincerely yours,

BENJAMIN FORMAN,
Assistant General Counsel, International Affairs.

STUDY REFERRED TO BY MR. POLLACK

Has the Defense Department yet received instruction from the President to move ahead with this study that Mr. Pollack referred to in his testimony?

Mr. FORMAN. So far as I am aware we have not actually received a written document.

Senator PELL. Do you have any knowledge of who will be directing the study when it comes your way?

Mr. FORMAN. No, that would remain to be assigned once the document is received. It is possible that it might be under the aegis of the Director of the Defense Research and Engineering.

SELECTION OF COMMITTEES BY DOD FOR INFORMATION

Senator PELL. The information from this study is naturally of much interest to this committee. In earlier testimony, 1½ years ago, you indicated that the DOD had informed the chairman of the two Armed Services Committees and the two Appropriations Committees as to the classified nature of certain aspects of the Department's weather modification.

What is your basis for the selection of committees by DOD to inform?

Mr. FORMAN. Sir, that was answered last year in the record. I can't enlarge on that any more than we did last year. The correspondence begins at the bottom of page 41 and runs on over to page 43.

However, I would suggest that that in effect is water over the dam in view of the statement I made earlier that we are willing to provide a witness to testify before this committee.

AVAILABILITY OF RESULTS OF STUDY

Senator PELL. And would that include the results of the study when the time comes?

Mr. FORMAN. I can't speak to that. I don't know what the study classification will be, and since it is a study which we would be producing at the direction of the President and a report to him, that decision would be up to the White House. It would in effect be a White House or NSC document.

WEATHER MODIFICATION CAPABILITIES OF OTHER NATIONS

Senator PELL. Are you aware of any other nations that have the capabilities to use weather modification as a weapon of war?

Mr. FORMAN. It depends on what you mean by a weapon of war, how you define weapon of war. Certainly other nations do have a capability of engaging in certain weather modification activities such as fog dispersal or rainmaking. We have given that capability to some countries, as I think probably Dr. Amand will testify, as a result of our prior activities in those countries. When I say "we," I mean the U.S. Government or contractors working directly with those countries.

And, of course, as I said last time, sir, the research in this area conducted by the DOD as well as by other Government agencies is totally unclassified, so to that extent that research is readily available to anyone in the world. It can, of course, be used.

POTENTIAL USES OF WEATHER, GEOPHYSICAL MODIFICATION

Senator PELL. Is the research connected with weather and geophysical modification potential uses in the DOD unclassified?

Mr. FORMAN. Potential use? As distinguished from the actual research or any operations? Potential uses are classified but the actual research themselves and all operations conducted by the DOD are unclassified.

WHAT IS REASON FOR DOD OPPOSITION?

Senator PELL. As you know, we have been sparring with each other—your Department and this subcommittee—for quite a period of time. I remember the activities of your representative at the Stockholm Conference on Environment when I felt the position on environmental modification was somewhat gutted. I am left with the conclusion that the reason why the DOD is so opposed is either they want to keep their options open, which is a normal military viewpoint, or they are on the threshold of some really dreadful weapon that would be of use in war, or that it is simply a question of not wanting, of not knowing what its use would be and wanting to stand still. I was hoping that you could give us some sort of specific reasons in this committee based on the studies that have gone on already, or reasons of a general nature, your philosophical reasons if nothing else, as to why your Department really has been the main block in movement of this treaty. I am informed enough about the ways of the Government to know that it is not the Department of Commerce, the Central Intelligence Agency, or the National Security Agency, or the Agriculture Department that is opposing this treaty. It is basically the DOD.

I am trying to figure out the reason for the DOD position on this matter. Can you enlighten me in any way?

Mr. FORMAN. I don't think I can enlarge upon what I said last year and read into the record again that we just don't have enough knowledge to know whether such a treaty either as a whole or maybe some aspects of it would be desirable and in the national interest. We don't know enough.

POSSIBILITIES OF LANGUAGE CHANGES IN TREATY

Senator PELL. Do you see any possibilities of language changes that would safeguard the interest of the DOD in the sense that such lifting of fog so you could rescue a downed airman or lifting of fog from an airport, would be permitted? I can't imagine a treaty that would exclude them.

I would think there would be possibilities of working out language. Do you see that happening?

Mr. FORMAN. It is difficult for me to see that happening except possibly in reverse. Rather than working from what should be excluded from the treaty, working the other way might be more profitable, that is to say, as to what should be included.

We already, for example, have a Presidential decision made public in 1972, which renounces on the part of the United States the use of climate modification activities as a weapon of war.

Clearly, therefore, the executive branch is on record that we would have no opposition to a treaty which banned that particular technique as a weapon of war. So if you go from that point down the scale, there might be some possibilities. But to work from the bottom of the scale up you get into the problem of what do we know about the subject and do we know enough to be able to say we are willing to renounce a

particular technique. On the other hand, it is conceivable that we might be willing to say that no matter what we know about the technical possibilities, it is so horrendous, such as climate modification, or biological weapons, that it should be renounced.

Senator PELL. The fact of the matter is we have more knowledge—although we renounced climate modification as a weapon of aggressive war—we have more knowledge about weather modification than we do about climate modification, don't we?

Mr. FORMAN. Yes, sir.

Senator PELL. We renounced the use of the weapon of which we have the least knowledge. If we go against your view that we shouldn't go ahead with this because we don't have enough knowledge——

Mr. FORMAN. But, Senator, your treaty—for example, you just said that of course fog dispersal shouldn't be covered. Well, there is nothing in your draft, as I read it, that excluded it.

Senator PELL. Fog dispersal for humanitarian and peaceful purposes.

Mr. FORMAN. I am not sure I understand what you mean by that.

Senator PELL. By that I mean fog dispersal to rescue a downed airman or clear a civilian airport, yes. Fog dispersal to clear a factory so that it can be more visible to be bombed, no. That is the purpose of the treaty. The language can be changed going in that direction but obviously——

VIEWS OF DOD

Mr. FORMAN. Senator, I have difficulty in responding to this line of questioning because, as I say, the position of the Department of Defense is as I have stated.

Now if you wish me to respond, not on behalf of the Department of Defense, but speaking personally as an individual, I would be happy to do so.

Senator PELL. Well, I appreciate that, but I am particularly interested in the views of the Department of Defense.

Mr. FORMAN. The Department of Defense doesn't have any views other than the views I have stated several times now and reiterated what we said last year.

PERSONAL VIEWS OF WITNESS

Senator PELL. Speaking personally, then, do you see the possibility of moving in the direction that I have suggested?

Mr. FORMAN. Speaking personally, I have a number of difficulties, and again I reiterate I am not speaking for the Department of Defense but speaking individually as a lawyer and someone who reads the newspapers. There shouldn't be any implication read into what I am about to say that it represents the position whatsoever of the Department of Defense, any views of the officials of the Department of Defense, or that it is what we are actually thinking along these lines.

Now, first let me say, before I get into an analysis of your resolution, that while it is undoubtedly true, as you say, your resolution has found some support, particularly in the Senate, the NATO Parliamentarian Conference and some other bodies, I don't believe it has that support among other nations at this time.

DIPLOMATIC CONFERENCE ON INTERNATIONAL HUMANITARIAN LAW

As you probably know, there is going to be an international conference covened in Geneva beginning in February and running for 6 weeks on some of the Laws of War. Two protocols have been prepared by the International Committee of the Red Cross. There are a number of proposals pending by other nations.

Some of those proposals would lead, if adopted, to the banning of some items of ordnance such as napalm. I know of no proposal by any country, however, which would ban any form of weather modification as an illegal weapon or method of warfare or means of warfare.

Senator PELL. Excuse me for interrupting here, but I follow that conference fairly closely and hope to attend it at some point. As you, I think, must know, it is not intended to deal with such a general and somewhat theoretical and future subject as weather modification, but with the specific applications of rules of warfare now to civilian populations, and as you suggest, to some of the specific weapons in hand.

Mr. FORMAN. Well——

Senator PELL. I think it would be improper to bring up weather modification at the Diplomatic Conference on International Humanitarian Law.

Mr. FORMAN. My own view is it would be improper to bring up the specific weapons because basically that conference is a conference not on the laws of the war—that is, conduct of actual hostilities—but on what you do after hostilities have ended.

Senator PELL. Correct.

Mr. FORMAN. But there is an effort by some countries to get into what we call the laws of war; that is, the Hague regulations, as distinguished from the Geneva Conventions of 1949. I merely make the point that despite the interests there may have been among such organizations as the Parliamentarians Conference of the North Atlantic Treaty Organization, or scientific bodies, that pressure has not made itself felt in the official positions of government in this forthcoming conference, and there are at least some countries that are desirous of banning some weapons. I make that as an aside.

Senator PELL. But also the law of the sea, which is obviously of some interest now, moving to the conference in Venezuela; the only voice that was raised for it was the voice of Malta, not the greatest nation in the world, and in the Congress here, my own; but these ideas do move along.

I think the fact that it is not being discussed at the Diplomatic Conference on International Humanitarian Law in General is really rather immaterial.

At any rate, carry on.

CRITIQUE OF RESOLUTION

Mr. FORMAN. With regard to your resolution, my first observation is that it is too broad in scope. I think you have indicated by your own statements just a few moments ago that it is too broad in scope.

I don't believe it can be said, as your resolution says, that all modification activities constitute a great danger to the world's ecological system. I don't think there is evidence all such activities do that.

Similarly I don't think there is any basis for the statement that all weapons-oriented—depending on what you mean by weapons-oriented—modification activities create a threat to peace in the world. Certainly the fog dispersal doesn't.

Now, paradoxically—and this is my second point—I don't think your treaty is broad enough in that you are dealing solely with the use in wartime of these activities.

If there is a danger to the world's ecological system—and I don't dispute there is a danger that certain activities can produce to the world's ecological system—that danger is equally great, if not greater, in peacetime activities than it is in wartime activities.

For example, in the field of climate modification, melting the polar ice caps, let us say, in Canada or Siberia, for purely peaceful purposes—to change the climate of those countries and make it possible to provide more arable land for people to farm, provide access to the metal resources—creates a danger for greater than the remote possibility that nations would use climate modification as a weapon of war.

If these dangers exist——

Senator PELL. I realize it would be very unpleasant for my own State of Rhode Island if that occurred.

Mr. FORMAN. The same thing is true with respect to hurricanes. Research on hurricanes, trying to steer hurricanes or other hurricane modifications, for purely peaceful purposes, is not without danger. If that danger exists, and you believe it exists, then you should be pushing forward for a treaty either to ban these activities, whether it be in time of peace or war, or at the minimum to see to it that these activities are subject to complete international control and supervision, and, possibly licensing.

Third, the point already has been made in the prior hearing that it is impractical to distinguish, as your treaty tries to distinguish, between research for peaceful purposes and research directly to the development of such activity as weapons of war.

The research is the same. Basic research is basic research. What one does with it is something else. One can't discern the potential uses of the research when the research is being done, and one can't verify that research is being done for peaceful as distinguished from weapons of war purposes.

Fourth, I believe you have some technical defects in drafting, Senator.

Your article I, paragraph (1), for example, says—

> That States Parties to the Treaty undertake to prohibit and prevent, "at any place," such activity. From a legal viewpoint, however, we cannot prohibit and prevent "at any place."

How could the United States, for example, prohibit some other country or prevent some other country from doing it?

Obviously what has been done here is to leave out language which appears in some other treaties; namely, the words "in any area under its jurisdiction or control." What is needed is a two-part obligation; namely, that a nation undertakes not to use and also to prohibit and prevent in any area under its jurisdiction and control.

Senator PELL. I would agree with you on that.

HOW IS "WEAPON OF WAR" DEFINED?

Mr. FORMAN. You also have a problem when you say use as a weapon of war. How do you define a weapon of war? What do you mean by weapon of war in this instance?

I was doing some scribbling of notes just before I came here and thinking of some of the possibilities as to how weather modification might be used in wartime. I don't know what you would consider to be undesirable or desirable to be a weapon or not a weapon, but certainly weather modification is at least a possible means, method, or tactic in wartime.

Let us take, for example, fog dispersal or lightning and hail suppression. Now that is just one grouping of activities. In analyzing that grouping, Senator, you have to look at it not in the abstract but along various points of departure.

First, where is the activity taking place? Is it taking place on U.S. or allied territory? Is it taking place on enemy territory? Is it taking place over international waters?

And then what is the immediate purpose of it? It can be either aircraft taking off or aircraft landing.

What missions may those aircraft be performing? They can, as you said, be performing a search and rescue of downed pilots on land or sea. They can be search and rescue of the crews of ships that have been sunk. They can be logistic support and administrative flights. They can be medical evacuation. They can be ASW [Anti-Submarine Warfare] patrols. They could be convoy protection. They could be the launch of fighters for interception of aircraft coming from the enemy. They could be close air support of ground troops. They could be tactical air support of naval patrols. They could be for reconnaissance. They could be for bombing of targets. There could be a combination of missions within one time period.

Does it make a difference from your viewpoint whether the fog dispersal or lightning suppression or lightning and hail suppression took place in our own territory or allied territory versus whether it took place in enemy territory and, if so, why?

Some people might say, for example, it is all right to have fog dispersal at our own airfields, in our territory or allied territory, to take off to bomb a target in the enemy territory. I don't know whether you would say that is all right. As I understand it, you do say that it shouldn't be all right to have fog dispersal at the end of the mission so that we can bomb the targets. I don't see the difference. Either way the same technique has permitted you to accomplish the result, and parenthetically, I might add that current international law does not ban bombing when the weather is bad and the target is obscured.

If you say there is a difference, well, No. 1, I don't see it morally. No. 2, in effect you are creating a dual system which penalizes less developed countries more than developed countries. You are saying that a country which might be able to do the fog dispersal, because it doesn't take much scientific knowledge to do that, can't do it and, therefore, can't engage in effective combat. Whereas with respect to a country that has an advanced capability in the electronic field, or in the optical field, to be able to get off an airfield regardless of fog, or be

able to see the target regardless of fog, it is perfectly lawful for them to do it. That doesn't make sense to me. Nor do I understand the morality of prohibiting a means for facilitating the identification of military versus civilian targets.

I could go on along these same lines with regard to fog creation and rain enhancement or inhibition and so forth.

My point simply is that if you want to write a treaty along these lines you can't just say in the abstract it is all bad; you have to look at it in terms of what it is, where it takes place, what the ultimate mission is that the military is doing, and what alternative means or methods of warfare would be used in place of the ones prohibited. It is very hard to draw and enforce the line once you have got all of these possible, sometimes concurrent missions. I have listed 11 just out of my head. I am sure there are far more.

LOCALE WHERE MODIFICATION TAKES PLACE

Also, I don't think you can overemphasize the locale where the modification activity takes place. For example, the problem of devastation or destruction of territory. It may make a difference legally whether one is talking of one's own territory or not. In this connection, you had some testimony last session by Professor Falk and he cited some Nuremberg war crimes cases. His citations were not complete. Not all devastation even in enemy territory is illegal. One of the war crimes cases did acquit some Germans of devastation because it was shown to have been required by military necessity during a retreat.

As to one's own territory, let me remind you, for example, of the War of 1812 where the Russians adopted a scorched Earth policy retreating from Napoleon. More recently, we destroyed, for example, some oil properties in the Philippines to prevent the Japanese from capturing them at the outset of World War II.

There is certainly nothing illegal in destroying your own property in your own country to deny that property to the enemy.

Further, for example, in the contest of rainmaking or snow enhancement, let us assume a situation of Switzerland being attacked through its mountain passes. Should it be illegal for Switzerland to have a capability and use a capability of making snow in those passes to cause avalanches to destroy those troops on its own territory? I submit that it shouldn't be.

UNKNOWN FACTORS

In conclusion, I recognize that what you have done in this effort, Senator—as you have stated in your report and on the floor—is not to attempt to write a definitive treaty. You are merely trying to stimulate discussion and analysis. There is certainly a lot more analysis that needs to be done. But to a large extent, once you get beyond fog dispersal or rainmaking, and I don't know what else is possible today, you get to an area where, as I have said previously, when speaking as an official witness of the Department of Defense, there is so much we don't know that we are not sure just how one should write this kind of a treaty, unless, as I said, you proceeded piecemeal and eliminated things which are clearly to be forbidden, such as climate modification.

Senator PELL. Thank you. I appreciate very much your personal remarks and find them very helpful.

TYPE OF AGREEMENT TO BE NEGOTIATED

Actually, as you know, as you pointed out yourself, in my report on this resolution, I said that the treaty was a model or example of the type of agreement that the Senate would like to see negotiated. I am not a lawyer. But exactly the same technique as I have pointed out was used in the law of the sea with actual specific results already accomplished, and results to come we hope in either Caracas or Venezuela in the future for the general law of the sea.

HOPE THAT U.S. WILL TAKE LEAD IN FIELD

If the Department of Defense would be specific in its comment, as you as an individual have been, I would be delighted, because then we would get into dialog. The problem here is there being so little dialog, I think some of the points you made are perfectly valid. Other points I think are not valid and shouldn't be covered, but at least there would be a dialog going. I very much hope that we will take the lead when the time comes in this field and not leave it up to Malta, which is really what happened with the law of the sea. Let the United States be the principal piece blazing the way toward peace and not the other nations in the world.

I thank you for this statement very much indeed. I would hope that your study will move ahead.

TIME FRAME FOR STUDY

What is your view as to the time frame when the study will be completed?

Mr. FORMAN. I just can't answer that question, Senator, because as I said earlier, we have not actually—at least as of the time I left the Pentagon to come up here—we had not actually received the physical document from the President directing the study. It may well be that that document does have a due date set forth in it. I just don't know.

Senator PELL. There is no reason it couldn't be done within a very few months, is there?

Mr. FORMAN. I would assume it would be called for to be produced within some months.

CHANGES IN DOD'S POSITION

Senator PELL. Since we last conversed, 18 months have gone by. DOD's position has changed in two respects. One, that you are willing to give us a classified briefing, which you were not then, and, second, you are willing to speak as an individual.

That is progress, I guess, but maybe less than 18 months from now there can be, I would hope, not only progress along these lines but agreement on a draft that we could actually push.

I thank you for being here very much indeed.

Mr. FORMAN. Thank you, Senator.

LACK OF SPECIFIC DOD COMMENT

Senator PELL. And I hope you will press hard and also take back with you to the Defense Department for the record my own still

profound disappointment at the lack of specific departmental comment that there is on this, and what I think is ignorance of the will of the Senate to move faster with response and my recollection is, as I mentioned to Mr. Pollack, that never before has a Senate resolution been forwarded to the President by the Secretary of the Senate asking for action, and the reason we went through this procedure was to underline the seriousness which some of us in the Senate felt the study should be given to this proposal.

Thank you very much.

WITNESS ORDER CHANGED

I am going to take our next witness a little out or order, but being struck with some of the informal points that were made by Mr. Forman, and having the chance to glance through the testimony of the witnesses last night, I would like to now ask Mr. James Leonard, vice president for Policy Studies of the United Nations Association, an individual who is very familiar with disarmament and played a substantial role in the achievement of the Seabed Disarmament Treaty, in fact was the negotiator for it, if he would come forward and not only put forth his testimony but he might care to comment on some of the personal views as to the drawbacks in this treaty on the part of Mr. Forman.

Mr. Leonard, Ambassador, once an Ambassador always an Ambassador.

STATEMENT OF JAMES LEONARD, VICE PRESIDENT FOR POLICY STUDIES, UNITED NATIONS ASSOCIATION

Mr. LEONARD. Thank you.

May I just preface my remarks, sir, by saying, as you know, I am here in my personal capacity and not any way representing the views of the organization that employs me.

I have a prepared statement, Mr. Chairman. I don't know whether you would like me to read it.

Senator PELL. I have had the opportunity to read it and since there are no colleagues here with me, maybe you would care to just digest it and move on to comment on Mr. Forman.

Mr. LEONARD. Thank you, sir.

Senator PELL. It is an excellent statement. I enjoyed it.

CONCEPT ADVOCATED IN S. RES. 71 SUPPORTED

Mr. LEONARD. Well, as you know from the statement, I do strongly support the concept that you are advocating in S. Res. 71 and outline in the statement the arguments that I feel weigh most strongly in favor of that course of action.

PROPOSED STUDY

I came here this morning hoping that it would be necessary to modify this statement as a result of the testimony that would be given by Mr. Pollack and by Mr. Forman, two extremely competent officials, and I am pleased to note that is in fact the case, that you have

had good news from your witnesses already this morning in that they can report that there is now a study underway.

I think that this committee can congratulate itself on having at least accelerated that study, although the rate of acceleration has been rather slow. Eighteen months is a long time to get to this operation.

I trust that it will move along briskly now and that when the time comes for the results of the study to be put in front of the public, which I would hope would be reasonably soon, I would particularly hope that the representatives of agencies other than the Department of Defense will be able to say that they had made available to them all the information necessary on all of the activities of the U.S. Government in this area.

I think it would not be possible for this study to be carried through effectively if only a part of those participating in it have access to classified information of various categories.

REPRESENTATION OF ACDA AT HEARING

Senator PELL. I point out that last time at our hearing ACDA, your former agency, was represented. This time they did not seem enthusiastic about coming forward, and so that is the only reason they are not here. They didn't feel under these circumstances they could contribute much.

I would hope next time we have a hearing on this subject they would be here, and I would hope, too, that the ACDA would once again take the lead in Government to balance the Defense Department position. So far there have been no signs of this, but we will wait and hope and pray.

Mr. LEONARD. I also, Mr. Chairman.

If I may just deal with one or two points that have come up in the testimony so far, I think that I might be useful.

HOW TREATY MAY BE DRAFTED

I am very encouraged by Mr. Forman's testimony in particular because I think the fact that he is turning his excellent mind to this question as to how a treaty may be drafted may perhaps indicate that this question is being taken seriously in the Defense Department as well as other parts of the Government.

With respect to the particular comments that he made I don't feel that I could simply off the top of my head, as the expression goes, deal with each of them. I do feel that in general the objections, criticisms, that he raised, although they do have a point, are the sort of elements that generally are taken care of either by redrafting the language of the treaty itself, as a process which goes on at great length, of course, during negotiations of a treaty, or in some cases simply by making clear in the negotiating record what is meant by particular language that is perhaps not totally clear or is in danger of meaning two different things to two different groups.

I would think that the basic position that we simply do not know enough to draft a treaty was in effect taken care of by your own comment when you pointed out that we do feel we know enough to eliminate climate modification and we know a great deal more about weather modification.

We always proceed in these things in the absence of total knowledge. I don't think there is any branch of science where the human race has come to know everything there is to know, and that certainly is going to be true for quite a long time to come about weather modification and climate modification, but as I indicate in my prepared statement, I don't think there is any doubt we know enough to go ahead and eliminate certain activities which are harmful or run the risk of being harmful.

INTENT OF RESEARCH

I could just mention briefly one particular point which a number of witnesses in the previous testimony before this committee also referred to, and it is the problem they see in the ability to distinguish between research which is peaceful in intent and research which might have a military application.

This is a problem which comes up again and again in arms control contexts but it is one which I believe I am correct in saying has been dealt with in arms control contexts through the application of the criterion of intent; that is, a treaty bans research or activities of various sorts which have a specified intent and permits other kinds of activities which have intent which is deemed to be desirable.

Unless I am mistaken, the Biological Weapons Treaty has this sort of distinction contained in it, but I haven't referred to the text in the last few minutes so I can't assert that with complete confidence.

Senator PELL. Which treaty?

Mr. LEONARD. The Biological Weapons Treaty.

INTERNATIONAL SUPPORT FOR PROPOSAL

I would like to comment also on the point of international support for a proposal such as you have been putting forward. I think there isn't much doubt that a U.S. initiative along these lines would be widely welcomed.

I do feel, however, that Mr. Forman has put his finger on one aspect of this. There are a number of other items on the arms control agenda also, and if the U.S. Government were to put forward an initiative along these lines, with the intention of distracting the international community from these other arms control issues, I think that this initiative would not be welcomed.

Specifically in the field of multilateral arms control, there is very strong desire on the part of most countries to have a comprehensive test ban to conclude the work begun in Moscow in 1963, by banning underground tests, and there is, I think, a strong desire to move forward in the field of chemical weapons, to do something about the production and stockpiling of chemical weapons, and if we simply attempt to divert people from those objectives by putting forward a proposal in the area of environmental warfare, I think they will tend to conclude that this is not an important area and not an important addition.

That could be a wrong conclusion but it would be a natural one for many other countries to reach.

I would hope, therefore, that anything we do in this field is accompanied by initiatives in other fields to show our good faith and desire to move forward in the arms control field generally.

Mr. Chairman, that is all I have.

EXECUTIVE BRANCH'S FAILURE TO DEVELOP AND ARTICULATE POSITION

Senator PELL. In your opinion, why has the executive branch failed to develop and articulate a position on this point? What was the reason why we have not been able to move ahead even though there has been considerable request and force from the Congress?

Mr. LEONARD. Well I think, Mr. Chairman, the problem has been largely that it was met with opposition within the military establishment and it was not given sufficiently high priority by other parts of the Government to overcome this opposition and to move the question onto the front burner, as the expression goes.

DESIRABILITY OF DOD TAKING LEAD IN STUDY

Senator PELL. Do you think that it is correct or desirable that the DOD take the lead in the coming study that has been assigned by the President?

Mr. LEONARD. I am sorry, I was not aware that was the case. Has that been the testimony?

Senator PELL. That is what Mr. Pollack said. The President has issued instruction that a study be done as to the merits of weather modification and the desirability of moving ahead along these lines of the treaty. The responsibility for carrying out this mission has been given to the Department of Defense.

Mr. LEONARD. Well, Mr. Chairman, if the task assigned is that of examining whether there should or should not be an arms control treaty, I would think the Arms Control Agency is the one that should be given the primary responsibility.

I recognize the basic knowledge on this subject lies within the Department of Defense and their cooperation is more than essential.

PARTICIPATION OF ACDA

Senator PELL. I would have thought so. As you know, the ACDA has taken a remarkably low profile in the last 18 months, and it is regrettable. That the study should have been given to them was my own reaction.

When you were working on the study before that was done within the U.S. Government, and Mr. Pollack was the chairman of the group, was ACDA participating in that study?

Mr. LEONARD. I believe it was, Mr. Chairman, although at that time I think I was in Geneva and not in Washington. I am quite confident in fact ACDA was a participant in the group.

Senator PELL. I believe it was, too.

U.S. RESPONSE IF ANOTHER NATION PROPOSED SIMILAR CONCEPT

Did you think the United States would respond in a constructive way if another nation proposed a concept similar to our own draft treaty proposal?

Mr. LEONARD. I think, Mr. Chairman, that the process would be essentially the same, that the interagency decisionmaking operation would get underway and would come to essentially the same conclusion whether it was a U.S. initiative or the initiative of some other government.

As you may recall, in the case of biological weapons, that was a British initiative which we then examined and came to a positive conclusion with regard to.

Senator PELL. I must say I personally am very disappointed that Mr. Ikle and the ACDA, to the best of my recollection, have not shown any interest or enthusiasm in connection with this concept in the last year or so.

I would hope, of course, they would become interested in it.

WITNESS' STATEMENT COMMENDED

As you know, your statement is going to be inserted in full in the record, and it is excellent testimony.

WAYS OF PUSHING AHEAD MORE VIGOROUSLY

Do you have any good advice to make where you sit as a civilian as to how I can push this ahead a little more vigorously? I don't want to reach the point where the weapons are all in hand because then it is usually more difficult to get a treaty in being than when the weapons are perhaps in the future.

Mr. LEONARD. Well, I would hope, Mr. Chairman, that you would, after a reasonable time has gone by, inquire vigorously of the executive branch what it has been up to and perhaps call hearings in order to ascertain what their responses are at that point.

I have also in my prepared statement suggested another approach, which is to include in the money bills of the Department of Defense a limitation that would, I think, encourage them to take seriously the position of the Congress in this respect.

COMMENDATION OF WITNESS

Senator PELL. Thank you. Thank you very much indeed and let me congratulate you on the role you played in the Seabed Disarmament Treaty and wish you well in your new job.

Mr. LEONARD. Thank you very much.

[Mr. Leonard's prepared statement follows:]

PREPARED STATEMENT OF JAMES F. LEONARD

I strongly support the concept advocated in Senate Resolution 71.

The arguments which I feel weigh most heavily in favor of a United States initiative along these lines are briefly the following:

(1) There is not, I belive, any valid military argument for our retaining the option to use environmental warfare;

(2) There already is and will continue to be a substantial cost to us in scientific terms if we continue to protect this option; and

(3) We are paying a substantial political price for our failure to take the leadership in closing off the possibility of environmental warfare.

In what follows I will focus on weather modification. The other forms of environmental warfare appear, from what I have been told, to be somewhat more remote and the arguments applying to them are in large part the same as those for weather modification.

Let me address briefly the military argument that weather modification may be developed into an effective weapon which the U.S. might some day want to use. To support this argument a variety of scenarios are advanced. With one exception, I find these scenarios either "incredible" or "marginal." The "incredible" scenarios postulate U.S. involvement in important wars in remote and underdeveloped

areas—wars which common sense tells us either will not occur or will not draw us in. These quite unconvincing scenarios are invented in an attempt to describe a situation where we would be facing adversaries who would not be able to use weather modification effectively against us. The Vietnam war has been, of course, the inspiration for these scenarios. I think it will be a long, long'time before we again get into any comparable situation.

The other, "marginal" scenarios are somewhat less unbelievable. But they necessarily involve opponents with a high technological capability. These opponents should prudently be expected to be able to use weather modification about as effectively as the United States, if in fact the possibility of effective use exists. Such scenarios therefore offer the United States only a marginal or even a negative military advantage. A war in Europe is one example. Such a war is not likely. But if one were to occur, it is extremely unlikely that the NATO countries would be able to use weather modification to great advantage in defending themselves against an attack from the East. I, at least, have never seen arguments to the contrary which were at all persuasive. Thus, in military terms weather modification looks to me like certain types of insurance which unscrupulous insurance agents sell to timorus individuals to "protect" them against utterly unlikely risks such as tidal waves in Utah. If such an individual is rich enough, the cost of the insurance may do him no great harm, but the United States is not infinitely rich and in my view the costs of this particular "insurance policy" are significant.

I said earlier that with one exception the scenarios for using weather modification were either incredible or marginal. The exception is, I believe, quite unlikely, but it is unhappily not to be completely ignored. I refer to the possibility that some form of weather modification might be developed into a truly effective weapon of mass destruction. I do not expect that this will happen, but even the remote possibility is a valid reason for doing everything that we can—along the lines recommended in your resolution—to ensure that no such weapon is developed. The reasoning here is obvious. The United States does not need any more weapons of mass destruction. Our nuclear arsenal is already far larger than any rational military or political requirement and it is sufficiently varied in its characteristics to meet any likely contingency. And, obvioulsy, neither our security nor world peace would be furthered if other nations should get possession of a new weapon of mass destruction. Rather the contrary. The development and even a limited dissemination of such a weapon could in a real sense negate the Non-Proliferation Treaty. It could lead to devastating wars whose effects could reach out far from their point of origin. This is the key consideration to bear in mind with regard to other forms of environmental warfare. It is, presumably, the argument which led the government to renounce climate modification, unilaterally and without even soliciting reciprocal action from other states.

In sum, an examination of the basic military considerations leads me to conclude that further development of weather modification or other forms of environmental warfare either would be, at best, of negligible utility to the U.S. or would be truly dangerous to our security.

What, on the other side of the ledger, are the costs of our failure to outlaw environmental warfare? One area in which we pay a price is the scientific development of the capability to use weather modification for peaceful, beneficial purposes. The magnitude of this cost is obviously difficult to assess and others are better qualified to do this than I, but common sense leads directly and plainly to the conclusion that other nations will be slow to cooperate with us, their scientists will be reluctant to work with ours, so long as they can fear that their contributions to the science of meteorology and to the technology of weather modification may boomerang in the form of U.S. military actions against their nation or their neighbors.

I hope that you will be developing from other experts a picture of what weather modification can do if pushed vigorously for legitimate ends. I would only note that what the experts are saying about the threatening character of the world food balance over the next few decades makes me hope that any possible help which the world might obtain from weather modification will in fact become available to us.

Our government's unwillingness or inability to decide that we don't want military weather modification is costly also in the political area. Over the past decade the United States led the way to a series of arms control treaties which brought real benefits to the world. Our leadership did not always measure up to the challenges it faced. Our initiatives were sometimes tardy and were often more limited than they should have been. But through 1972 one could say that the arms control process had a modest momentum. One could even hope that disarmament might some day overtake what has been called the mad momentum

of the arms race itself. Since mid-1972, however, arms control has slowed to a crawl. The informed public here and abroad is puzzled and concerned by this immobility. There are examples in each of the diverse areas of arms control. Some of these situations are, in fact, clearly more urgent than weather modification. But weather modification is a characteristic and rather striking case. I would draw particular attention to the failure of the Administration to level with Congress and the public; its failure to state its position clearly and frankly to the Congress or in international forums; and its failure to present the facts to the public so that we can assess all the arguments pro and con on a sound basis. The verbal smokescreens which Administration policy requires its witnesses to direct at inquiries such as this do not enhance the reputation of the United States and run counter to the basic principles of representative government.

I would like to close with a suggestion for consideration by the Committee.

Environmental warfare is, I believe, analogous to biological warfare in that it is in the U.S. interest to lead the way by renouncing it totally, as a matter of policy. We have already done exactly this with climate modification. We should then urge others to follow our example and negotiate a treaty to make this renunciation a permanent element of international law. Unhappily, for Congress simply to urge this or any similar course of action on the Administration may not be particularly effective. It has recently been rather difficult for the legislative branch to get the attention of the Executive branch. Congress can, however, still pass laws. I urge a provision in future defense money bills prohibiting the use of any funds for military weather modification activities. This would be analogous to the provisions which the Congress wisely inserted for several years in defense legislation banning the use of any funds for the production of chemical weapons. (That, by the way, is another arms control area in which there is an inexcusable and inexplicable failure on the part of the Administration to act or to explain its lack of action.) If this suggestion is adopted and the Congress makes clear in legislation that it will not permit activities aimed at environmental warfare, then the Administration may be more disposed to move along the lines of Senate Resolution 71.

Senator PELL. Our next witness is Mr. Pierre St. Amand, Earth and Planetary Sciences Division of the Naval Weapons Center, China Lake, Calif.

We are delighted you are here. I have heard of you through the years and we tried to have you at our last hearings. You were then out of the country, and I am very glad you are here, now.

I read your testimony last night. It is quite long, so I was wondering if you would care to have it inserted in the record and digest it for oral presentation.

STATEMENT OF PIERRE ST. AMAND, EARTH AND PLANETARY SCIENCES DIVISION, NAVAL WEAPONS CENTER, CHINA LAKE, CALIF.

Mr. ST. AMAND. I would be happy to have it entered and just to discuss the details, if you would like.

Senator PELL. I think it would be helpful to me and also I think to the people who are here if you would highlight it for us.

Mr. ST. AMAND. Very good.

Briefly, you had expressed interest in the sort of things we were doing, so I took some trouble to outline the general nature of the research work we had done in the past and I want to say right off the bat that I am appearing here at your invitation. I did not solicit the invitation, but I am happy to come and talk, and I am appearing not as a Navy representative but as a private citizen, and I must say that I am a little bit biased, perhaps, because I am rather proud to be associated with the Navy and to some extent I consider myself part of it, in my business life at least, but, some of my views are probably

at variance with those expressed by officials of the Navy and the Department of Defense and I am going to discuss this as it appears to me.

BENEFITS OF SCIENTIFIC DEVELOPMENTS BY NAVY

The Navy has long had a tradition that good science of benefit to the Nation and to humanity as a whole helps us all. Among the very first oceanographic efforts may be counted the works of Mathew Fontaine Maury. The massive compendium of navigational lore by Nathaniel Bowditch has been credited with the saving of millions of lives and having made navigation less hazardous than it was in the days before it was written.

Astronomy as a whole has benefited from Navy interest in positional astronomy. Many advances in medicine and in other sciences have been supported by the Navy and this information has been shared with us all.

It is not surprising therefore that the Navy, which has had to cope with the exigencies of the elements for its very survival at sea, should find weather modification a subject worthy of support. It is true that the Navy and the other Armed Forces stand to benefit from the science that they have developed. It is equally true that humanity at large has benefited from such work.

WORK AT NAVY WEAPONS CENTER

The story of our work at the Navy Weapons Center, formerly the Naval Ordance Test Station, is an outgrowth of this policy. It was not a deliberate venture on the part of the Navy at the outset, but instead was the outcome of a concatenation of circumstances and abilities to be found at no other single place in the country.

In 1957, Dr. William Finnegan and Dr. Lohr Burkart, of the chemistry division of the research department, were involved in the development of colored smokes that produced highly visible clouds to be used as markers at high altitudes.

One of the techniques to produce such a smoke consisted in using lead iodate to oxidize an organic fuel so that lead iodide and free iodine were produced. This scheme resulted in a brilliant, reddish-violet smoke.

Ancillary to this work they prepared a mixture that, upon combustion, produced silver iodide. They had heard of the use of silver iodide in cloud seeding, and living in an area where rain was a novelty, they were quite aware of the potential usefulness of their technique. They told me about it and we set about learning about cloud seeding.

As it turned out this approach was more important that we realized at first, because, theretofore, cloud seeders had been using a substance similar to, and derived from, silver iodide but which was not silver iodide. Silver iodide is used to cause supercooled water to freeze. If a substance is to catalyze the growth of ice, it must not dissolve in water before the water has time to freeze.

Silver iodide is relatively insoluble, and because it has a molecular structure similar to that of ice, it is a good material to cause liquid water to freeze. In those days, clouds were seeded by use of an acetone burner that produced, instead of silver iodide, a complex of silver iodide and one of several alkali iodides. It was not generally realized

that the product of this device was not silver iodide but another compound quite different in its physical properties.

The exhaust products were water soluble and did not function as silver iodide was expected to do. This meant that people who were seeding clouds with the older system did not do what they thought they were doing. Indeed, in many elaborate experiments, based on the premise that clouds were being seeded with silver iodide, the clouds were not being seeded at all, or were being seeded in a manner different from that postulated.

This single fact led to most of the confusion that has developed as to the effectiveness of cloud seeding.

Most of the disagreement that is still to be found in academic circles is based upon this difference. The matter is now pretty well cleared up and the way is open to conduct a new set of efforts that could clearly demonstrate the effectiveness of cloud seeding under different meteorological conditions. Indeed, this is now being done by several agencies but at a level of support that is inadequate to the problem.

We soon became aware of this problem, and with the understanding that silver iodide could be produced in relatively pure form, in the right particle sizes and in the correct amounts and that it could be emplaced in clouds at the right time, we went ahead and developed a cloud seeding system based on the use of pyrotechnics. We then tested a slightly different solution to be used in acetone burners that did indeed produce silver iodide. (This concept had been elucidated in 1949 by Dr. Bernard Vonnegut, the inventor of the acetone burner, but had been ignored.)

We were able to do this because the necessary talent for the research and development, indeed, a unique combination of chemists, physicists, engineers, pyrotechnic specialists, meteorologists, and aviators, the necessary equipment and an enlightened management were all to be found in one place. A good deal of this work was supported by the Bureau of Reclamation and much of it was done in connection with the Department of Commerce for Project Stormfury.

The task of optimizing the system was lengthy. It was necessary to review, and in part correct, the theory of catalysis as applied to the freezing of water. We had to determine the correct particle size of the nucleant. We had to determine the right amounts. The solubility of silver iodide and other nucleants had to be considered and their rates of solution taken into account. New nucleating materials that worked at higher temperatures were developed. The materials and devices were tested in clouds over our ranges and over the southern Sierra Nevada. Samples of our seeding devices were sent to university groups and to other Government agencies, so that tests might be conducted by others under realistic conditions.

EXPERIMENTS CONDUCTED

For 2 years, we carried out experiments in the southern Sierra for the Bureau of Reclamation. Later we cooperated with them in an effort conducted by Fresno State College, to increase the snowpack and the rainfall in the central Sierra Nevada.

For 7 years we have been conducting, through a contractor, North American Weather Consultants, and with help from the Bureau of

Reclamation, a rainfall augmentation experiment in the Santa Barbara area.

The works has gradually passed from experiments with single clouds to whole groups of clouds and to components of storm systems.

Senator PELL. I read it last night.

Mr. ST. AMAND. I will highlight it to show you the extent of the work we have been involved in.

No untoward incidents have occurred and none are expected because of the care with which we have set up the experiments to preclude excessive precipitation as a result of our efforts.

AREAS INVESTIGATED BY NAVY WEAPONS CENTER

We are now engaged in study of a technique for slowing down portions of winter storms and thus changing their trajectory so that the rain along the Pacific coast of California might be spread out a little more equitably thus reducing the perennial drought in southern California and perhaps reducing the rain in the northern part of the State where it is usually too wet.

This we have not attempted to do; this is probably outside of our range of interest. I sincerely hope some other agency of the State of California or the Federal Government will take up where we started.

Part of our work has been dedicated to the modification of clouds too warm to be modified by the freezing process. For 3 years, we conducted experiments in the Brownsville, Tex. area. This effort was intended to produce more rain from these marginal clouds and to suppress the growth of these clouds, should that prove desirable.

Fog clearance has received the lion's share of our attention in recent years because of the need to remove small patches of fog and to clear aircraft landing areas. The use of hygroscopic seeding agents was systematically tried and developed to the point where, under the conditions at Arcata, Calif., it is possible to produce instrument minimums in a 1,000-foot thick fog 80 percent of the time and to produce an actual opening about 60 percent of the time. The technique is expensive and messy but does work well enough to be used in emergency situations.

Recently we have begun an investigation of the use of electrically charged particles as fog-clearing agents and are having promising results that indicate that it might be possible to clear fog with a greatly reduced logistic burden.

Prevention of fog formation by coating bodies of water with evaporation suppressants was tried with success in the Panama Canal. Improved methods of applying the evaporation suppressants have been developed by our chemistry division.

We have done limited work in fog formation and intensification. This system uses an aerosol consisting of common salt made more hygroscopic by the addition of small amounts of potassium and lithium chlorides. With these it is possible to create an overcast condition and to make small cumulus clouds under the right meteorological conditions. In the amounts needed to stabilize or to create fog, the materials are not toxic, are less corrosive than sea spray and far less harmful than conventional screening smokes.

Our work has been to some utility to the rest of the world.

The fog prevention work in Panama is being tested to see if it is possible to relieve the obstruction to navigation that occurs at night during the rainy season in the Gaillard Cut of the Panama Canal. If the tests being undertaken continue as well as they have, this method will prove useful in permitting uninterrupted flow of traffic through the canal, thus aiding world commerce. The techniques of applying the evaporation suppressants will no doubt become widely used commercially and will prove of benefit in applications where ranchers and others have, for a long time, used evaporation suppressants to conserve water in small reservoirs and stock ponds.

DROUGHT RELIEF EFFORTS

On several occasions, the resources of the U.S. Military Establishment have been called upon to take action against droughts in various parts of the world. In 1967, a small group of private contractors directed by the Naval Ordinance Test Station was sent to India to help with a devastating drought in the Bihar and Uttar Pradesh Provinces.

Over a period of about 3 months, in the middle of the dry season about 100 clouds were seeded with air dropped pyrotechnic units. These clouds, most of which were not raining to begin with, yielded from one-quarter to one-half inch of rain. The drought was so far advanced, and the clouds so few, that this effort was not enough to materially affect the drought. It did show, however, that properly planned and conducted at the right time of the year, cloud seeding could beneficially aid that country in its agricultural efforts.

In 1969, a drought relief effort in the Philippines was conducted by the United States, using Air Force aircraft and crews and technical personnel from the Naval Weapons Center.

This effort was remarkably successful, because clouds, that were in general too small to rain by themselves, were caused to grow and rain abundantly. It was estimated by the Philippine government that at least $60 million in additional foreign exchange was developed by agricultural use of the rain resulting from the cloud seeding. In addition, another $25 million was saved because it was not necessary to import corn and rice.

The following year, the Philippine Sugar Institute led an effort using a U.S. contractor and Philippine pilots who had been trained the previous season by our personnel.

This effort met with the same sort of success and the capability to seed clouds has been retained and augmented.

In 1971, we were called upon to help the Island of Okinawa, then under U.S. military control. A protracted drought had reduced the water shortage on the island to inadequate proportions and the populace was subjected to severe water rationing.

The U.S. Navy made available the services of the antisubmarine patrol squadron at Naha and we furnished technical direction for a period of a few weeks. Here, the skills developed by the patrol squadron in tracking ships and submarines made it an easy matter to select clouds at sea whose trajectory would lead them over land and to estimate the time of landfall of the clouds. The clouds so selected were seeded at sea, caused to grow and kept alive until they came within 10 minutes of landfall.

Senator PELL. I don't mean to hurry you but it would be about 40 minutes if you read the whole statement.

I was wondering if you could highlight your points with regard to the treaty and also the potential use of this.

CENTER'S RESEARCH AND DEVELOPMENT SHARED

Mr. ST. AMAND. All right, I will do that. I am trying to make clear that our research and development has not been self-contained, that we shared it freely with the rest of the world as they have asked for it and with other agencies of the U.S. Government and with private concerns.

We receive correspondence every month from people in some foreign country who would like to get a little advice or learn something about how to do it, and we always carefully answer the letters and so forth. OK.

Senator PELL. Along this line, then, you share freely with other countries. Did your laboratory have any relationship with the weather modification in Southeast Asia that was reported in the press?

Mr. ST. AMAND. I am appearing here as a private citizen. I am not authorized to express any opinions whatsoever one way or the other on the subject, gentlemen. I must decline to answer.

Senator PELL. Thank you. I was just following up your statement that you shared your knowledge with all other nations; if that was so, I was wondering if we shared it in Laos and South Vietnam as well. But I know the restrictions under which you are operating, so we will move on to your comments.

USES OF ENVIRONMENTAL CONTROL

Mr. ST. AMAND. OK. It has been suggested the control of the environment would constitute a truly horrible weapon of war. If one could do all the things that the proponents of restricting the use of geophysical weapons imagine could be done, this might be true.

As it is, one can only make rain, clear fog, and reduce hail at the present time. On a tactical scale, this technology—I am talking about a small scale where you have your groups committed, and small areas, you must do something to help them—could be very useful to the United States and would not constitute a threat to the climate of the world.

The potential exists that over the years, the applications of geophysics to warfare could become a very important military tool. I am considering this primarily in a tactical sense.

No one can, at present, influence earthquakes in any appreciable way. It is true that small earthquakes have occurred as reservoirs were being filled, and in a few instances appear to have been caused by underground pumping. These techniques hold no promise for any deliberate use in controlling such phenomena, nor can I envision any techniques for producing or influencing earthquakes one way or the other.

EARTHQUAKE CONTROL

Senator PELL. Is that as of now or do you visualize the technique cannot be developed?

Mr. ST. AMAND. If you want to get an answer that is wrong ask a scientist what can't be done, but I don't think that within our century any progress can be made in controlling earthquakes. By understanding the nature and mode of occurrence of earthquakes and the application of sound engineering and good construction practices, the threat of earthquakes can in a few decades be abated.

Tsunamis are caused by large earthquakes. There is no way to produce true tsunamis. Even if there were, a tsunami would not affect installations more than a few hundred yards of the shoreline. Tsunamis would not be a useful weapon because they radiate over the whole ocean and would cause extensive damage to friendly coasts as well.

Changes in ocean currents are possible to attain with protean efforts. One could perhaps dam the Bering Straits or divert the Gulf Stream. Such an effort would require the cooperation of a large part of the world and would present such unforeseen consequences that it is unlikely that it would, or could, be done unilaterally by any civilized nation.

WHY TREATY IS NOT NEEDED

I, therefore, feel that such a treaty addresses things that cannot be done now, are extremely unlikely in the next century, probably wouldn't be done in any case, and are therefore premature.

A treaty to preclude generic use of geophysical weaponry as could be used to cause damage in excess of that necessary for the attainment of the objective is not needed, because we are already morally and, in effect, legally bound to do as the treaty would say.

We would, if no such treaty existed, not be bound to forego the use of an advantageous system were that system to be used effectively in the protection of our own forces, people, and property. One must consider, in proposing such a treaty, whether the use of any weapon or device whatsoever to protect a fighting force does in itself constitute an act of war.

DISTINGUISHING BETWEEN PEACEFUL AND WARLIKE USES OF WEATHER MODIFICATION

To my mind anyone who does anything in support of his government, or economy, in a time of war is a member of the fighting team and is participating in war. If this be so, how can we distinguish when an act is performed if it will be in violation of the treaty?

The complete barrier to all such work as proposed in the treaty could moreover work unnecessary hardship on our defense forces. For example: Would it be proper to clear fog so that our warplanes could safely return from combat? Would it be proper to clear fog so that they could launch a mission? Would it be proper to clear a target area so that they could strike the enemy?

All of these would appear to be proscribed. It might also be improper to clear fog for any purpose whatsoever, if the persons whose work was facilitated by such clearance could more effectively aid the military effort of their country.

Some distinction should be made that is not now made in the proposed treaty, or the United States may have to deprive itself of the enjoyment of such advantages as might flow from peaceful use of

weather modification, if it were done in time of war to augment food or energy supplies so that the war could be more effectively fought.

TECHNOLOGY TO AID OUR TROOPS, NOT HURT ENEMY

Weather is a terrible problem to the Navy and to a lesser extent the Air Force. To the Army and the Marines the weather is a serious factor that must always be contended with and which often decides the outcome of military contests. There are situations wherein the technology would not be used in actual combat to hurt the enemy but might greatly aid our own troops while engaged in a war.

Excessive fog could prevent resupply as it did in the Battle of the Bulge. The American troops were short on food, ammunition, and fuel, and were unable to advance. This advance was critical to obtaining the fall of Germany while the Wehrmacht was still reeling from earlier reverses.

A portion of the time this fog was supercooled. Available techniques can now, with a very high reliability, clear supercooled fog in a matter of 30 or 40 minutes. It would have shortened World War II by several weeks if the technology had then been available. Would it have been wrong to use the technology? I think not.

Tank and infantry warfare is dependent upon a fairly hard surface for the mobility of troops and equipment. Were a situation to arise in which by increasing rainfall, one could decrease the trafficability to such a point that the efforts of the enemy to attain an objective were thwarted or delayed until we could prepare for a confrontation, would we be justified in using weather modification? I think so.

WHETHER GEOPHYSICAL WARFARE WOULD CONSTITUTE CRUELTY

On the other hand, if there were no clearcut military target and the only outcome of one's action were to cause misery for the civilian population, and there were other ways of preventing men and material from reaching the front, then the use of such tactics would clearly be irresponsible in that damage would be caused without gaining any real advantage for oneself.

One must also address the question of whether or not geophysical warfare would constitute cruelty. All war is bad and counterproductive. Usually wars are fought with high explosives, projectiles and other products that have a deleterious effect on personnel. Would it be less cruel to immobilize an infantry company with excessive rainfall than it would be to burn them with napalm or destroy them with bombs? If they would be kept out of the fight and not be permitted to hurt themselves or others, would it not be better than killing them?

Another type of geophysical welfare that has two sides to it might be the manufacture of a long-term change in climate. Two sides, because it could be used to harm or to aid a potential enemy. Assume for the minute that a large country exists in which a nonirrigable crop must be planted and matured so that the country has adequate food and foreign exchange. It might, to take a negative viewpoint, be advantageous to cause heavy rain during planting season to preclude sprouting and growth and then to cause severe and protracted drought during the growing season.

This could conceivably cause a crop failure and bring our hypothetical enemy to his economic knees. First, we would have to be able to do it and we now cannot. Second, we would have to get them to hold still for it—this might not be possible. Third, world opinion, if the effort were discovered, and it almost certainly would be, would force the aggressor to desist, perhaps too late for that season, but the impact of world opinion might be such as to make such action unprofitable.

On the other hand it might just be possible to beneficiate the climate—this is the sort of thing I would like to be able to do—of the place to the point where the potential enemy could have such an adequate economic base that he would have too much to lose by engaging in war.

Let us assume that a large country was, because of overpopulation, poor soils and protracted drought, in such a position that it was a wasteland populated by starving hordes. With what is now known in agriculture, land management, water management, and weather modification, it might well be possible to help that country obtain a viable economic status and supply its own needs. In the end this might well result in improved world relations.

Whether to do this or not is a matter for that country involved to decide. On the other hand we might wish to help them. With their consent and cooperation one might call upon U.S. military forces to undertake a large share of the weather modification work because they would have the capability and equipment to do so.

The trained and disciplined personnel could do it more capably than an ad hoc collection of resources. Thus, the military could be used constructively in foreign affairs, doing the very things that the proposed treaty would not let them prepare for.

In a well run country the armed forces are a tool of the makers of foreign policy; we should keep this tool sharp and available.

DETECTION OF SMALL-SCALE VIOLATIONS AND ENFORCING TREATY

I should now like to address another aspect of such a treaty. Would small-scale violations be detectable? Would the treaty be enforceable? The answer to both questions is in doubt at the present time.

Unless adequate intelligence were available so that we could learn of the preparations and plans for such an adventure it is unlikely that a violation could be detected until it was too late. There is now no way to tell if a storm has been seeded.

It is true that the seeding agent might possibly be detected and identified. With what technology now exists, it is extremely difficult to do so because the air all over the world is so polluted by heavy metals that the augmentation of heavy metal content of rain caused by cloud seeding could not be told from that already present. The science of weather prediction is not yet so exact that small changes produced by weather modification could be detected. Were such changes on a subcontinental scale they would probably attract attention.

Were they to attract attention we should be faced with the problem of calling the malefactors on it. Would this be settled easily by diplomatic negotiation or would we be obligated to make them quit?

In order to prevent violation of such a treaty we would have to spend a fortune finding means of detecting such activity and proving that the treaty was not being obeyed.

An example comes to mind in the field of seismology where in order to detect violations of a treaty involving testing of nuclear weapons millions of dollars were spent developing a seismic detection system.

The technology developed to detect atomic explosions is in part applicable to earthquake work but the science of sesimology dedicated to study of earthquakes received much less attention, and still does to a very large extent, in spite of the fact that a large earthquake anywhere in the country would be a civic and economic disaster of outrageous proportions.

WORK OF WITNESS' ORGANIZATION

In closing, I would like to thank you for the chance to make my ideas known and to acquaint you with the work of my organization. I feel that the things we have done have been good and have been a worthwhile expenditure of the Government's money and our time.

That we are in a Navy laboratory has facilitated the work we have done and I really feel that it probably would not have been done as soon had not the Naval Ordnance Test Station decided to go ahead in a new field that at the time was clearly of more general and humanitarian interest than military utility.

Eventually others would have done the same things and perhaps done them better. We have, however, been a force in shaping the direction in which weather modification in this country has gone and I believe that it was a good direction.

It has been a pleasure for us to work with the other Federal agencies in the development of their own programs, to use the things they turned out and to see them use ours. I believe you will agree with me that the humanitarian uses of the things we have done in a naval laboratory have been worthwhile. I would rather than take a negative attitude toward human activity of any sort to try to find a way to take advantage of it and I concur in your wisdom in that you have expressed a desire to use things for peaceful purposes and I would like to see a treaty, if such were written, where we could make optimum use of the resources of the country to carry out these worthwhile ends.

SUGGESTED CHANGES IN PROPOSED TREATY

Let me say that if we must have a treaty let us write another one eschewing all forms of violence as a means of settling disputes. If we can't do that, and if we must have the proposed treaty, let us so write it that—

1. Tactical use of geophysical weapons be permitted for the benefit and protection of our fighting forces.
2. Strategic use be limited, when and if it becomes a reality, to peaceful application by mutual agreement of the countries concerned and the concurrence of such neighbors as may also be affected.
3. That military forces be used in such constructive efforts if it is to advantage to do so.

Thank you.

Senator PELL. Thank you very much.

DIFFERENCE BETWEEN TACTICAL AND STRATEGIC USES OF GEOPHYSICAL WEAPONS

What is the difference in your mind between the tactical use of geophysical weapons and strategic use?

Mr. St. Amand. Strategic use would be use that tended to upset the economy of another country for a long period of time, or to cause extensive damage to the crops of that country. Tactical use would be a situation where under battlefield conditions or in training exercises you could beneficiate the weather so you could operate better, you could make it a little bit worse so that the other side couldn't operate as well.

Senator Pell. Speaking to you as a scientist, what would be the watershed between the two?

Mr. St. Amand. It is a hard distinction to make.

Senator Pell. Is it possible to make it, do you think?

Mr. St. Amand. I would say that you could not draw a clearcut distinction. You might have to make the distinction on the basis of the size of the military operation and the consequences of failure and availability of other methods that you could use.

In general, tactical to a military person is that the tactical mission is something you use in day-to-day work with small groups and strategic things involve the use of larger areas.

Senator Pell. Would it be a question of relativity and interpretation, would it be very hard to be specific?

Mr. St. Amand. That will be indeed a challenge to the writers of the treaty.

WITNESS' VIEWS ON WEATHER MODIFICATION

Senator Pell. About a dozen years ago you testified before the Senate Commerce Committee and at that point I gathered you are quite consistent in your views. You said and I quote—"A good deal of the work of the Naval Ordnance Test Station is aimed at giving the U.S. Navy and other Armed Forces, if they should care to use it, the capability of modifying the environment to their own advantage, or to the disadvantage of the enemy. We would regard the weather as a weapon and weather is as good a one as any."

This is basically your view?

Mr. St. Amand. This was basically my view and still is. The things we have done for the world at large have been spinoffs from our work and we were happier with those than we were with any other aspect of it.

CAN WEATHER MODIFICATION BE USED AS WEAPON NOW?

Senator Pell. Has weather modification, in your view, reached the stage where it could be utilized as a weapon?

Mr. St. Amand. Say that again, please.

Senator Pell. Has weather modification already reached the stage where it could be used as a weapon?

Mr. St. Amand. Only in a tactical scale.

KINDS OF MODIFICATION NAVAL ORDNANCE TEST STATION CONCERNED WITH

Senator PELL. Is your naval ordnance test station concerned with any other kinds of environmental or geophysical modification besides the instances you cited in your testimony of rainmaking, rain suppression and fog dispersal and hail?

Mr. ST. AMAND. Nothing.

Senator PELL. That is it?

Mr. ST. AMAND. That is it. We have people working in air pollution and things of that sort but there is no modification or any other use involved.

PRODUCING ACIDIC RAINFALL

Senator PELL. Have you been able to develop a method of treating clouds with chemicals that could produce an acidic rainfall capable of fouling mechanical gear and equipment and radars and things of that sort?

Mr. ST. AMAND. We haven't even thought of this.

Senator PELL. This is the first time you have thought of it?

Mr. ST. AMAND. I read it in the newspapers but we haven't done anything at all like that.

Senator PELL. You have done no research along those lines?

Mr. ST. AMAND. No; it would be grossly uneconomical anyway.

SUIT AGAINST U.S. GOVERNMENT FOR PATENT INFRINGEMENT

Senator PELL. As you know, the U.S. Government is being sued for a patent infringement on its rights by a private contractor. Do you have any views with regard to the merits of his suit?

Mr. ST. AMAND. This is a matter that is under litigation and it would be improper for me to discuss it but the Justice Department would probably be able to answer that question for you, sir.

Senator PELL. I thank you very much indeed. It is very good of you to be with us.

Thank you. The whole testimony will be in the record, as I say.

Mr. ST. AMAND. Thank you, sir.

[Mr. St. Amand's prepared statement follows:]

PREPARED STATEMENT OF PIERRE ST. AMAND, EARTH AND PLANETARY SCIENCES DIVISION, NAVAL WEAPONS CENTER, CHINA LAKE, CALIF.

Mr. Chairman, distinguished Senators and guests: My name is Pierre St. Amand, I live at 112 Blueridge, China Lake, California. I am employed at the Naval Weapons Center to direct work in environmental sciences. My background is that of a geologist-geophysicist with a broad interest in all aspects of earth science. I graduated from the University of Alaska and the California Institute of Technology. I was a Fulbright Research Scholar to France and I have worked with the International Cooperation Agency in South America. The main thrust of my professional work has been oriented toward the safe and profitable use of the environment for human benefit. You may find it odd that one interested in such things is employed at the Naval Weapons Center. The answer is that it has been the policy of the Navy to encourage and support science of use to the country as a whole as well as to the Navy itself. The opportunity to do good and useful work there is at least as great and probably greater than anywhere else in the Federal System.

I am appearing here at your invitation, not as a Navy representative but as a private citizen and as a scientist who has worked in the field of weather modification. Although I am proud to work with the Navy, and to some extent consider myself a part of it, some or all of my views may be at variance with those expressed by Officials of the Navy and of the Department of Defense. I am pleased to have the opportunity to express my own views on this important subject and to have them heard and considered.

The Navy has long had a tradition that good science of benefit to the nation and to humanity as a whole helps us all. Among the very first oceanographic efforts may be counted the works of Mathew Fontaine Maury. The massive compendium of navigational lore by Nathaniel Bowditch has been credited with the saving of millions of lives and having made navigation less hazardous than it was in the days before it was written. Astronomy as a whole has benefited from Navy interest in positional astronomy. Many advances in medicine and in other sciences have been supported by the Navy and this information has been shared with us all. It is not surprising therefore that the Navy, which has had to cope with the exigencies of the elements for its very survival at sea, should find weather modification a subject worthy of support. It is true that the Navy and the other armed forces stand to benefit from the science that they have developed. It is equally true that humanity at large has benefited from such work.

The story of our work at the Naval Weapons Center, formerly the Naval Ordnance Test Station, is an outgrowth of this policy. It was not a deliberate venture on the part of the Navy at the outset, but instead was the outcome of a concatenation of circumstances and abilities to be found at no other single place in the country. In 1957 Dr. William Finnegan and Dr. Lohr Burkardt of the Chemistry Division of the Research Department, were involved in the development of colored smokes that produced highly visible clouds to be used as markers at high altitudes. One of the techniques to produce such a smoke consisted in using lead iodate to oxidize an organic fuel so that lead iodide and free iodine were produced. This scheme resulted in a brilliant, reddish-violet smoke. Ancillary to this work they prepared a mixture that, upon combustion, produced silver iodide. They had heard of the use of silver iodide in cloud seeding, and living in an area where rain was a novelty, they were quite aware of the potential usefulness of their technique. They told me about it and we set about learning about cloud seeding.

As it turned out this approach was more important than we realized at first, because, theretofore, cloud seeders had been using a substance similar to, and derived from, silver iodide but which was not silver iodide. Silver iodide is used to cause supercooled water to freeze. If a substance is to catalyze the growth of ice, it must not dissolve in water before the water has time to freeze. Silver iodide is relatively insoluble, and because it has a molecular structure similar to that of ice, it is a good material to cause liquid water to freeze. In those days, clouds were seeded by use of an acetone burner that produced instead of silver iodide, a complex of silver iodide and one of several alkali iodides. It was not generally realized that the product of this device was not silver iodide but another compound quite different in its physical properties.

The exhaust products were water soluble and did not function as silver iodide was expected to do. This meant that people who were seeding clouds with the older system did not do what they thought they were doing. Indeed, in many elaborate experiments, based on the premise that clouds were being seeded with silver iodide, the clouds were not being seeded at all, or were being seeded in a manner different from that postulated. This single fact led to most of the confusion that has developed as to the effectiveness of cloud seeding, in that otherwise rigorously conducted experiments were producing indeterminate results. Most of the disagreement that is still to be found in academic circles is based upon this difference, The matter is now pretty well cleared up and the way is open to conduct a new set of efforts that could clearly demonstrate the effectiveness of cloud seeding under different meteorological conditions. Indeed, this is now being done by several agencies but at a level of support that is inadequate to the problem.

We soon became aware of this problem, and with the understanding that silver iodide could be produced in relatively pure form, in the right particle sizes and in the correct amounts, and that it could be emplaced in clouds at the right time, we went ahead and developed a cloud seeding system based on the use of pyrotechnics. We then tested a slightly different solution to be used in acetone burners that did indeed produce silver iodide. (This concept had been elucidated in 1949 by Dr. Bernard Vonnegut, the inventor of the acetone burner, but had been ignored.)

We were able to do this because the necessary talent for the research and development, indeed, a unique combination of chemists, physicists, engineers, pyrotechnic specialists, meteorologists and aviators, the necessary equipment and an enlightened management were all to be found in one place. A good deal of this work was supported by the Bureau of Reclamation and much of it was done in connection with the Department of Commerce for Project Stormfury.

The task of optimizing the system was lengthy. It was necessary to review, and in part correct, the theory of catalysis as applied to the freezing of water. We had to determine the correct particle size of the nucleant. We had to determine the right amounts. The solubility of silver iodide and other nucleants had to be considered and their rates of solution taken into account. New nucleating materials that worked at higher temperatures were developed. The materials and devices were tested in clouds over our ranges and over the southern Sierra Nevada. Samples of our seeding devices were sent to University groups and to other government agencies, so that tests might be conducted by others under realistic conditions.

For two years, we carried out experiments in the Southern Sierra for the Bureau of Reclamation. Later we cooperated with them in an effort conducted by Fresno State College, to increase the snow pack and the rainfall in the Central Sierra Nevada. For seven years we have been conducting, through a contractor, North American Weather Consultants, and with help from the Bureau of Reclamation, a rainfall augmentation experiment in the Santa Barbara area.

The work has gradually passed from experiments with single clouds to whole groups of clouds and to components of storm systems. No untoward incidents have occurred and none are expected because of the care with which we have set up the experiments to preclude excessive precipitation as a result of our efforts. We are now engaged in study of a technique for slowing down portions of winter storms and thus changing their trajectory so that the rain along the Pacific coast of California might be spread out a little more equitably thus reducing the perennial drought in Southern California and perhaps reducing the rain in the northern part of the state where it is usually too wet.

Part of our work has been dedicated to the modification of clouds too warm to be modified by the freezing process. For three years, we conducted experiments in the Brownsville, Texas area. This effort was intended to produce more rain from these marginal clouds and to suppress the growth of these clouds, should that prove desirable.

Fog clearance has received the lion's share of our attention in recent years because of the need to remove small patches of fog and to clear aircraft landing areas. The use of hygroscopic seeding agents was systematically tried and developed to the point where, under the conditions at Arcata, California, it is possible to produce instrument minimums in a 1,000-foot thick fog 80% of the time and to produce an actual opening about 60% of the time. The technique is expensive and messy but does work well enough to be used in emergency situations.

Recently we have begun an investigation of the use of electrically charged particles as fog clearing agents and are having promising results that indicate that it might be possible to clear fog with a greatly reduced logistic burden.

Prevention of fog formation by coating bodies of water with evaporation suppressants was tried with success in the Panama Canal. Improved methods of applying the evaporation suppressants have been developed by our Chemistry Division.

We have done limited work in fog formation and intensification. This system uses an aerosol consisting of common salt made more hydroscopic by the addition of small amounts of potassium and lithium chlorides. With these it is possible to create an overcast condition and to make small cumulus clouds under the right meteorological conditions. In the amounts needed to stablize or to create fog, the materials are not toxic, are less corrosive than sea spray and far less harmful than conventional screening smokes.

The fog prevention work in Panama is being tested to see if it is possible to relieve the obstruction to navigation that occurs at night during the rainy season in the Gaillard Cut of the Panama Canal. If the tests being undertaken continue as well as they have, this method will prove useful in permitting uninterrupted flow of traffic through the canal, thus aiding world commerce. The techniques of applying the evaporation suppressants will no doubt become widely used commercially and will prove of benefit in applications where ranchers and others have, for a long time, used evaporation suppressants to conserve water in small reservoirs and stock ponds. Under extreme conditions of temperature and drought, such as are found in the arid southwest, this system can prevent the evaporation of from five to ten feet of water during a typical year. The materials are not ecologically harmful and offer no hazard to persons or animals.

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On several occasions, the resources of the United States Military establishment have been called upon to take action against droughts in various parts of the world. In 1967, a small group of private contractors directed by the Naval Ordnance Test Station was sent to India to help with a devastating drought in the Bihar and Uttar Pradesh Provinces. Over a period of about three months, in the middle of the dry season about 100 clouds were seeded with air dropped pyrotechnic units. These clouds, most of which were not raining to begin with, yielded from ¼ to ½ inch of rain. The drought was so far advanced, and the clouds so few, that this effort was not enough to materially affect the drought. It did show, however, that properly planned and conducted at the right time of the year, cloud seeding could beneficially aid that country in its agricultural efforts.

In 1969, a drought relief effort in the Philippines was conducted by the United States, using Air Force aircraft and crews and technical personnel from the Naval Weapons Center. This effort was remarkably successful, because clouds, that were in general too small to rain by themselves, were caused to grow and rain abundantly. It was estimated by the Philippine government that at least $60,000,000 in additional foreign exchange was developed by agricultural use of the rain resulting from the cloud seeding. In addition, another $25,000,000 was saved because it was not necessary to import corn and rice. The following year, the Philippine Sugar Institute led an effort using a United States contractor and Philippine pilots who had been trained the previous season by our personnel. This effort met with the same sort of success and the capability to seed clouds has been retained and augmented. It was not necessary to use it in 1971 and 1972, but some work was done in 1973 and it appears that the Filipinos will continue to make wise use of the capability as it is needed.

In 1971, we were called upon to help the Island of Okinawa, then under U.S. military control. A protracted drought had reduced the water shortage on the Island to inadequate proportions and the populace was subjected to severe water rationing. The Islands had about a million people trying to use the water falling on the approximately 600 square miles of land available, most of which drains directly into the sea. The United States Navy made available the services of the anti-submarine patrol squadron at Naha and we furnished technical direction for a period of a few weeks. Here, the skills developed by the patrol squadron in tracking ships and submarines made it an easy matter to select clouds at sea whose trajectory would lead them over land and to estimate the time of landfall of the cloud. The clouds so selected were seeded at sea, caused to grow and kept alive until they came within 10 minutes of landfall, at which time they were seeded for maximum growth, and in the course of blowing across the Island, beneficial amounts of rainfall were produced. The task was doubly difficult because it was necessary to avoid having rain on certain parts of the island at some times. In spite of the difficulties, and because of the skill of the Patrol Squadron, it was possible to increase the rainfall to the point where water rationing could be suspended. The work started in July and was terminated in December, when enough typhoons passed by to assure the island of an adequate water supply for the time being. In addition, most of the rest of the Ruyukuan Islands were also artifically irrigated during the expedition.

In 1971, Air Force crews that had been trained in the Philippines, were called upon for a short time to relieve a drought in Texas. Once again, NWC furnished seeding materials and equipment and aided in the training of the aircrews, but did not participate directly in the effort. After a short time, the Air Force withdrew and commercial operators were called upon to take over the work.

In 1972, the Naval Weapons Center and the Hurricane Hunter Squadron, VW–4, were asked to help with a drought in the Azores. With one weather reconnaissance aircraft, technical advice from NWC and help from the Air Weather Service, it was possible to wet down all of the islands in the Azores several times. After two weeks, the weather reconnaissance aircraft was replaced by aircraft from the local patrol squadron and the work continued until the drought situation had passed. Once again, the skill of the Navy crews in tracking clouds made possible a successful effort that would have been extremely difficult, if not impossible, otherwise.

It would have been possible, and still is possible, to apply these techniques in many parts of the world where life itself depends on additional rainfall. It appears that this practice has been stopped and the good precedent dropped. The reason is not clear, for the efforts were effective and no untoward incidents, such as excessive rainfall, occurred.

The seeding techniques that we have in large part developed are now in use in almost every country in the world. The devices that we developed for seeding are widely copied and manufactured. We have made such information as we had freely available to people here, and abroad, who chose to carry on development on their own. In connection with rainfall augmentation we have worked with or advised the following groups of people and domestic agencies.

Department of the Interior, Bureau of Reclamation
Department of Commerce; Stormfury Project, Great Lakes Project, Florida Cumulus Project
National Committee on Atmospheric Research; Hail Projects
Department of Agriculture
State of South Dakota
U.S. Forest Service
State of Washington
State of California
South Dakota School of Mines and Technology
Colorado State University
University of Montana
University of Washington
University of Wyoming
Numerous private corporations

We have had contact with individuals interested in this matter in the following countries: India, Philippines, Taiwan, Chile, Israel, Rhodesia, Mexico, Portugal, England, France, Italy, Argentina and Australia.

A substantial portion of the critical scientific theory was developed at NWC. Our contributions include clarification of nucleation theory for the formation of ice in clouds, solution of Smoluchowski's equation in general form. Methods for calculation of the time required for a solid of a given size to dissolve in a solvent were developed. Improved values of collection coefficients were calculated. Theory applying to the use of electrically charged particles to capture other particles was extended. The theory of condensation was improved. A number of new nucleating compounds were developed, for use at temperatures warmer than that at which silver iodide functions, and were tested. Improved acetone burners for ground based and for airborne use were developed.

It has been suggested that control of the environment would constitute a truly horrible weapon of war. If all the things that the proponents of restricting the use of geophysical weapons imagine could be done were doable, this might be true. As it is, one can only make rain, clear fog and reduce hail at the present time. On a tactical scale, this technology could be very useful to the United States and would not constitute a threat to the climate of the world. The potential exists that over the years, the applications of geophysics to warfare could become a very important military tool.

No one can, at present, influence earthquakes in any appreciable way. It is true that small earthquakes have occurred as reservoirs were being filled and in a few instances appear to have been caused by underground pumping. These techniques hold no promise for any deliberate use in controlling such phenomena, nor can I envision any techniques for producing or influencing earthquakes one way or the other. By understanding the nature and mode of occurrence of earthquakes and the application of sound engineering and good construction practices, the threat of earthquakes can in a few tens of years be abated.

Tsunamis are caused by large earthquakes. There is no way to produce true tsunamis. Even if there were, a tsunami would not affect installations more than a few hundred yards of the shoreline. Tsunamis would not be a useful weapon because they radiate over the whole ocean and would cause extensive damage to friendly coasts as well.

Changes in ocean currents are possible to attain with protean efforts. One could perhaps dam the Berring Straits or divert the Gulf Stream. Such an effort would require the cooperation of a large part of the world and would present such unforeseen consequences that it is unlikely that it would, or could, be done unilaterally by any civilized nation.

I, therefore, feel that such a treaty addresses things that cannot be done now, are extremely unlikely in the next century, and probably wouldn't be done in any case and is therefore premature.

A treaty to preclude generic use of geophysical weaponry as could be used to cause damage in excess of that necessary for the attainment of the objective is not needed, because we are already morally and, in effect, legally bound to do as

the treaty would say. We would, if no such treaty existed, not be bound to forego the use of an advantageous system were that system to be used effectively in the protection of our own forces, people and property. One must consider in proposing such a treaty, whether the use of any weapon or device whatsoever to protect a fighting force does in itself constitute an act of war.

To my mind anyone who does anything in support of his government, or economy, in a time of war is a member of the fighting team and is participating in war. If this be so, how can we distinguish when an act is performed if it will be in violation of the treaty? The complete barrier to all such work as proposed in the treaty could moreover work unnecessary hardship on our defense forces. For example: Would it be proper to clear fog so that our war planes could safely return from combat? Would it be proper to clear fog so that they could launch a mission? Would it be proper to clear a target area so that they could strike the enemy? All of these would appear to be proscribed. It might also be improper to clear fog for any purpose whatsoever, if the persons whose work was facilitated by such clearance could more effectively aid the military effort of their country.

Some distinction should be made that is not now made in the proposed treaty, or the United States may have to deprive itself from the enjoyment of such advantages as might flow from peaceful use of weather modification, if it were done in time of war, to augment food or energy supplies so that the war could be more effectively fought.

Weather is a terrible problem to the Navy and to a lesser extent the Air Force. To the Army and the Marines the weather is a serious factor that must always be contended with and which often decides the outcome of military contests. There are situations wherein the technology would not be used in actual combat to hurt the enemy but might greatly aid our own troops while engaged in a war. Excessive fog could prevent resupply as it did in the Battle of the Bulge. The American troops were short on food, ammunition and fuel and were unable to advance. This advance was critical to obtaining the fall of Germany while the Wehrmacht was still reeling from earlier reverses. A portion of the time, this fog was supercooled. Available techniques can now, with a very high reliability, clear supercooled fog in a matter of 30 or 40 minutes. It would have shortened World War II by several weeks if the technology had then been available. Would it have been wrong to use the technology? I think not.

Tank and infantry warfare is dependent upon a fairly hard surface for the mobility of troops and equipment. Were a situation to arise in which by increasing rainfall, one could decrease the trafficability to such a point that the efforts of the enemy to attain an objective were thwarted or delayed until we could prepare for a confrontation, would we be justified in using weather modification? I think so.

On the other hand, if there were no clearcut military target and the only outcome of one's action were to cause misery for the civilian population, and there were other ways of preventing men and material from reaching the front, then the use of such tactics would clearly be irresponsible in that damage would be caused without gaining any real advantage for oneself.

Force should be limited to that necessary to obtain the objective. It is equally true that to use less force than necessary is wrong in that it prolongs the conflict and in the end causes more loss of life, suffering and property damage and incurs the risk of losing. The use of force must be delicately balanced; to use too much is irresponsible, to use too little is wrong. We should reserve to our fighting forces, and to our Commander in Chief, the right to make such use as is necessary of such tactical weapons as they may need to win a war in which we might be engaged; or at least, to keep the war going at a controlled level until such time as they have, by other means, obtained the objectives of the confrontation.

One must also address the question of whether or not geophysical warfare would constitute cruelty. All war is bad and counterproductive. Usually wars are fought with high explosives, projectiles and other products that have a deleterious effect on personnel. Would it be less cruel to immobilize an infantry company with excessive rainfall than it would be to burn them with Napalm or destroy them with bombs? If they would be kept out of the fight and not be permitted to hurt themselves or others, would it not be better than killing them? These people will certainly come in handy during the reconstruction when the damage caused by conventional weapons must be repaired and their country rebuilt.

Another type of geophysical warfare that has two sides to it might be the manufacture of a long term change in climate. Two sides, because it could be used to harm or to aid a potential enemy. Assume for the minute that a large country exists in which a non-irrigable crop must be planted and matured so that the coun-

try has adequate food and foreign exchange. It might, to take a negative viewpoint, be advantageous to cause heavy rain during planting season to preclude sprouting and growth and then to cause severe and protracted drought during the growing season. This could conceivably cause a crop failure and bring our hypothetical enemy to his economic knees. First we would have to be able to do it and we now cannot. Secondly, we would have to get them to hold still for it—this might not be possible. Thirdly, world opinion, if the effort were discovered, and it almost certainly would be, would force the aggressor to desist, perhaps too late for that season, but the impact of world opinion might be such as to make such action unprofitable.

On the other hand, it might just be possible to beneficiate the climate of the place to the point where the potential enemy could have such an adequate economic base that he would have too much to lose by engaging in war. Let us assume that a large country was, because of overpopulation, poor soils and protracted drought, in such a position that it was a wasteland populated by starving hordes. With what is now known in agriculture, land management, water management and weather modification, it might well be possible to help that country obtain a viable economic status and supply its own needs. In the end, this might well result in improved world relations. Whether to do this or not is a matter for that country involved to decide. On the other hand we might wish to help them. With their consent and cooperation one might call upon U.S. military forces to undertake a large share of the weather modification work because they would have the capability and equipment to do so. The trained and disciplined personnel could do it more capably than an ad hoc collection of resources. Thus the military could be used constructively in foreign affairs, doing the very things that the proposed treaty would not let them prepare for. In a well run country, the armed forces are a tool of the makers of foreign policy; we should keep this tool sharp and available.

I should now like to address another aspect of such a treaty. Would small scale violations be detectable? Would the treaty be enforceable? The answer to both questions is in doubt at the present time. Unless adequate intelligence were available so that we could learn of the preparations and plans for such an adventure it is unlikely that a violation could be detected until it was too late. There is now no way to tell if a storm has been seeded. It is true that the seeding agent might possibly be detected and identified. With what technology now exists, it is extremely difficult to do so because the air all over the world is so polluted by heavy metals that the augmentation of heavy metal content of rain caused by cloud seeding could not be told from that already present. The science of weather prediction is not yet so exact that small changes produced by weather modification could be detected. Were such changes on a subcontinental scale they would probably attract attention.

Were they to attract attention we should be faced with the problem of calling the malefactors on it. Would this be settled easily by diplomatic negotiation or would we be obligated to make them quit?

In order to prevent violation of such a treaty, we would have to spend a fortune finding means of detecting such activity and proving that the treaty was not being obeyed. An example comes to mind in the field of seismology, where in order to detect violations of a treaty involving testing of nuclear weapons, millions of dollars were spent developing a seismic detection system. The technology developed to detect atomic explosions is in part applicable to earthquake work but the science of seismology dedicated to study of earthquakes received much less attention, and still does to a very large extent, in spite of the fact that a large earthquake anywhere in the country would be a civic and economic disaster of outrageous proportions.

In closing, I would like to thank you for the chance to make my ideas known and to acquaint you with the work of my organization. I feel that the things we have done have been good and have been a worthwhile expenditure of the government's money and our time. That we are in a Navy laboratory has facilitated the work we have done and I really feel that it probably would not have been done as soon had not the Naval Ordnance Test Station decided to go ahead in a new field that at the time was clearly of more general and humanitarian interest than military utility. Eventually, others would have done the same things and perhaps done them better. We have, however, been a force in shaping the direction in which weather modification in this country has gone and I believe that it was a good direction. It has been a pleasure for us to work with the other federal agencies in the development of their own programs, to use the things they turned out and to see them use ours. I believe you will agree with me that the humanitarian uses of the things we have done in a Naval Laboratory have been worthwhile.

Let me say that if we must have a treaty, let us write another one eschewing all forms of violence as a means of settling disputes. If we can't do that, and if we must have the proposed treaty, let us so write it that:

(1) Tactical use of geophysical weapons be permitted for the benefit and protection of our fighting forces.

(2) Strategic use be limited, when and if it becomes a reality, to peaceful application by mutual agreement of the countries concerned and the concurrence of such neighbors as may also be affected.

(3) That military forces be used in such constructive efforts if it is to advantage to do so.

Thank you.

Senator PELL. Our next witness is Dr. Gordon MacDonald, the Henry Luce Professor of Environmental Policy and Study of Dartmouth College, a former member of the Council on Environmental Quality, and I must say he looks much more refreshed and invigorated and younger than when I last saw him.

STATEMENT OF DR. GORDON J. F. MacDONALD, DARTMOUTH COLLEGE, HANOVER, N.H.

Mr. MACDONALD. University life today is far different than it was a few years ago and certainly much more pleasant than life in Government, I can assure you.

NEED FOR INTERNATIONAL AGREEMENT

I welcome this opportunity to discuss with you certain aspects of weather modification and in particular the need for an international agreement prohibiting the use of weather modification as a weapon of war.

The action taken by the Senate on July 11, 1973, passing Senate Resolution 71, was a much-needed first step toward achieving such an agreement. It is in my view most unfortunate that the administration has not sought to initiate those steps required to implement the resolution.

INDICATIONS UNITED STATES WOULD BE JOINED BY OTHER COUNTRIES

I believe the time is particularly appropriate for the United States to take a new initiative in this area. A number of contacts over the past year have convinced me that we would be joined in this undertaking by a large number of countries, including the U.S.S.R.

One example where such contacts were made was the VII Dartmouth Conference. This unofficial meeting was held during the week of December 3, 1972, and a number of high-level Soviet officials participated. The Soviet co-chairmen were E. K. Federov, a member of the U.S.S.R. Academy of Sciences and Chief of the Main Directorate of the Hydrometeorological Service of the U.S.S.R., and G. A. Zhukof, Pravda commentator and Deputy to the Supreme Soviet of the U.S.S.R.

The U.S. delegation included a number of your colleagues from the other House, William Ruckelshaus, then Administrator of the Environmental Protection Agency but not acting in his official capacity, and a group of distinguished private citizens from the industrial,

financial, and scientific worlds. The joint communique makes specific reference to geophysical warfare and I quote from the communique:

> The participants in this meeting completely reject the use of chemical, biological, or nuclear means of mass destruction. They also reject attempts to make use of man-made environmental change as a means of waging war, and urge that an international agreement be sought renouncing the development and use of such weapons.

This, I believe, is a strong endorsement of the principles contained in Senate Resolution 71. Since that meeting I have on several occasions met with Soviet Academician Federov and am certain that he holds today the views expressed in that communique of over a year ago.

Senator PELL. I must add I raised this question also with Mr. Brezhnev when we had our meeting at the Blair House. He did not make any substantive reply but it is a subject I am glad that you did discuss with the Soviets.

Mr. MACDONALD. My last meetings with Academician Federov were at the end of June, and then again early this fall when he was here chairing the Soviet delegation on the United States-U.S.S.R. Environmental Agreement. On both occasions he expressed the views to which I have referred.

In view of these informal contacts and others, it would seem a most propitious time for the United States, together with other nations, to advance a treaty much along the lines of that contained within Senate Resolution 71.

ROUTES TO ACHIEVING TREATY

A number of routes could be followed to achieve such a treaty. For example, action could be initiated through a U.N. resolution such as has been passed on other arms control issues. Alternatively, the United States and U.S.S.R. could call a conference under U.N. auspices to negotiate the details of the treaty. Or the latter course could follow on the passage of an appropriate U.N. resolution.

REASONS TO SEEK UNIVERSAL BAN

There are a number of reasons to seek a universal ban on this new method of warfare. While these reasons have been discussed in detail in previous hearings, I believe it important to reiterate them.

Science and engineering of weather modification have not advanced to such an extent that all effects are predictable. Actions, such as rainmaking, which are taken to achieve a localized advantage, may have far-reaching and unforeseen effects.

Second, weather modification, whether it is simple rainmaking or the much more complex and poorly understood steering of storms or disbursing climates, would certainly involve civilians and nonmilitary facilities in addition to the presumed military targets.

The generally accepted, although often violated, rules of war prohibit making civilians an avowed or obvious object of an attack.

A third and very significant point is that the widespread acceptance of techniques of geophysical warfare as legitimate would further blur the distinction between conventional and unconventional means of warfare.

Deficiencies both in the basic understanding of the physical processes of the environment and the technology of environmental change, to which I have referred, make it highly unlikely that environmental modification will be an attractive weapon system in any direct military confrontation, at least in the near future.

Man already possesses highly effective tools to achieve destruction. Eventually, however, means other than open warfare may be used to secure national advantage. Widespread, unconventional guerrilla attacks such as we have witnessed over the past few years illustrate how the definition of war is changing. As economic competition among many advanced nations heightens, it may be to a country's advantage to insure a peaceful, natural environment for itself and a disturbed environment for its competitors.

Operations producing such conditions might be carried out covertly since nature's great irregularities permit storms, floods, droughts, earthquakes, and tidal waves to be viewed as unusual but not unexpected. Such a secret war need never be declared or known by the affected populations. It could go on for years with only the security forces involved being aware of it. The years of drought and storm could be attributed to unkindly nature and only after a nation was thoroughly drained would an armed takeover be attempted.

Finally, even the possibility that nation-states might view environmental modification as a weapon of war casts suspicion on the legitimate development and use of environmental modification for peaceful and beneficial purposes.

Indeed, the appearance that a country or countries are undertaking research that could lead to weapons of war might very well lead to the breakdown of the century-old tradition and practice of sharing meteorological data. Through agreements between nations and through the activities of the World Meteorological Organization, a specialized United Nations' agency, virtually all countries of the world freely exchange atmospheric data. This makes it possible for the weather services of individual nations to provide the much needed forecasts.

If the United States were to be cut off from observations taken by other nations, particularly from those in the northern hemisphere, there would be severe economic consequences, the magnitude of which is difficult to estimate.

JUSTIFICATION FOR INTERNATIONAL DISCUSSIONS OF WEATHER MODIFICATIONS

In addition to reasons directly connected with warfare, I believe international discussions of weather modifications are justified in two other important ways.

Today countries are undertaking weather modification operations as opposed to experiments. The issue may well arise as to whether or not such operations are advantageous or disadvantageous to neighboring countries.

Seeding in the high Cascades in order to increase snowpack may be perceived by our Canadian neighbors as possibly affecting their weather or climate. You can imagine countless other scenarios in which activities in one country might possibly affect the environment in another.

Unless satisfactory international instruments exist, misunderstandings and tensions could arise.

Second, certain proposed weather modification experiments such as a continuation of Project Stormfury in the Pacific would require the cooperative efforts of several countries. Again, early discussions among countries which could possibly be affected by such operations, or discussions with other countries that would wish to participate in the development of that technology, would be of great assistance in carrying such programs forward.

QUESTIONS RAISED BY SENATE RESOLUTION 71

Senate Resolution 71 does raise a number of questions. For example, it is likely to generate controversy over whether the ban on the use of weather modification should cover fog dispersal. Fog dispersal can and has been used to permit landings and takeoffs of warplanes under conditions where such operations would not be possible.

From time to time, there have been comments in the press that the United States has used fog dispersal to rescue downed pilots during the Vietnamese conflict. There are those who would argue that the use of fog dispersal opens up the possibility for the use of more damaging techniques.

I would argue for the opposite view, primarily because many of the techniques for fog dispersal are dissimilar to those used to enhance precipitation or bring about other changes in weather. For example, the use of propane for cold fog dispersal and the use of other chemical agents for warm fog dispersal is quite unlike the use of silver iodide in increasing rainfall.

A second problem is the ever-present question of verification. Certainly, weather modification experiments on a small scale can be carried out covertly. However, even on a relatively small scale, a cloud-seeding experiment might be detected at distances as great as 100 kilometers or so because extremely sensitive techniques have been developed that could measure fluctuations in silver content of rain or air.

Furthermore, acceptable arms control agreements do not require the ability to detect every violation—only major ones. A variety of techniques, including currently accepted national techniques of verification, could be applied to determine whether or not a nation has underway a covert weather or climate modification research and development program.

In moving toward such a treaty as advocated by the Senate, we should remember that the political, legal, economic, and sociological consequences of deliberate environmental modification, even for peaceful purposes, will be of such complexity that perhaps all our present involvement in nuclear affairs will seem simple by comparison.

Our understanding of basic environmental science and technology is primitive. Still more primitive are our notions of the proper political forms and procedures to deal with consequences of modification.

The experiences before and at the Stockholm U.N. Conference on the Human Environment demonstrated the problems of dealing with inadvertent modification of the environment. All experience shows that less significant technological changes than purposeful environmental control finally transform political and social relationships. Experience

also shows that these transformations are not necessarily predictable and that the guesses we might make now based on precedent are likely to be wrong.

It would seem, however, that these nonscientific, nontechnological problems are of such magnitude that they deserve consideration by nations throughout the world if society is to live comfortably in a more controlled environment.

SENATE RESOLUTION 71 IMPORTANT CONTRIBUTION

It is in this sense that I believe Senate Resolution 71 is such an important contribution to that goal. I strongly hope that these hearings provide the necessary encouragement for the administration to proceed in a major diplomatic effort to bring about a treaty banning the use of methods of environmental modification for hostile purposes.

Thank you, Mr. Chairman, and I would be glad to respond to any questions.

Senator PELL. Thank you very much, indeed.

SENATE PASSED SENATE RESOLUTION 71 BY 82 TO 10

Apropos the support for the Senate resolution, I think it should be borne in mind that the administration is opposed, as we both know, to the enactment of it and had an ample chance to make its views known to the Foreign Relations Committee and to the Senate. There was substantial debate in which the administration made its contribution, and yet the Senate, which is not a stupid body, after actually considering the pros and cons of it, as sensible men, some wearing the American flag in their buttonholes, others just as good Americans not wearing the flag in the buttonhole, together collectively we decided 82 to 10 that we should move ahead in this direction. That is a pretty good jury and pretty good decision when you have exposure to both sides and both viewpoints.

POTENTIAL ENVIRONMENTAL AND GEOPHYSICAL WEAPONS

I was wondering if you would give us a little laundry list, check them off, one, two, three, four, five, of what are potential environmental and geophysical weapons. I remember reading an article you wrote that had such a laundry list, and I was wondering if you would refresh my memory with that list and if there had been any additional weapons added in.

Mr. MACDONALD. We could certainly start with modification of precipitation. I think the enhancement of precipitation is a technology that is at hand, and we can use it today if we so wish for practical purposes. Whether or not it could be used over a long term for strategic purposes is a matter of debate.

Unlike the previous witness, I do believe that there have been advances in the understanding of the mechanics as to how earthquakes come about, how earthquakes might be initiated, and how they might be avoided.

The experience in the Rocky Mountain Arsenal, in which fluids were injected, demonstrates how man can trigger earthquakes. Experiences with the Rasilliston experiment further demonstrate a very close connection with fluid injection and the setting off of earthquakes.

I believe that once we achieve this better understanding of earthquake, it would be possible to generate large tsunami waves that could be used as weapons of war. We have a much better understanding of the high atmosphere and of the role that the very important molecule ozone plays in the high atmosphere.

I can imagine ways that we could remove the compound from the atmosphere, increase the intensity of ultraviolet radiation, and through covert means select the parts of the world where enhanced ultraviolet radiation would have adverse effects on all biological life.

In fact, I think if you look at any aspect of the environment anywhere, you can see we are beginning to develop a technology that can influence that part of the environment. You have a potential weapon of war, and that is why I think it is so important to stop right now before those technologies develop. They are not developed now except to the limited extent of precipitation modification.

If we agree on an international basis, however, that we should not go ahead and develop these techniques for hostile purposes, then I think we have made an enormous advance.

Senator PELL. To add to your laundry list of potential weapons, you would also have the melting of icecaps. What other ones might you be able to tick off as being possible development in the future?

Mr. MACDONALD. I think the icecap potentially could bring about worldwide changes of climate. Another possibility is to melt the bottom of the Antarctic icecap and cause tidal waves of one sort or another by having the ice slide more rapidly out into the ocean than it otherwise would by providing a heat source at the botton of the ice.

One can imagine certain kinds of modifications of the electrical behavior of the atmosphere that might possibly influence the activities of individuals through interaction with what is called the alpha activity of the brain.

There are just countless examples, as you said, a laundry list. I give you five or six kinds of ways one can think but basically what I am saying is that any time you alter the environment, whether it be air, water, or the electric magnetic conditions under which you live, you have a potential weapon.

WITNESS' ARTICLE

Senator PELL. Without objection, I shall insert in the record the article that you wrote, of which maybe you would send us an extra copy.

Mr. MACDONALD. I would be delighted to do so. This goes back to 1966.

[The information referred to follows:]

[From "Unless Peace Comes," Nigel Calder, Ed., The Viking Press, N.Y., 1968]

HOW TO WRECK THE ENVIRONMENT

(By Gordon J. F. MacDonald, United States)

Professor MacDonald is associate director of the Institute of Geophysics and Planetary Physics at the University of California, Los Angeles. His researches have embraced a remarkable diversity of natural phenomena, and his professional interests are further extended by his participation in national science policy-making. He is a member of President Johnson's Science Advisory Committee.

Among future means of obtaining national objectives by force, one possibility hinges on man's ability to control and manipulate the environment of his planet. When achieved, this power over his environment will provide man with a new force capable of doing great and indiscriminate damage. Our present primitive understanding of deliberate environmental change makes it difficult to imagine a world in which geophysical warfare is practiced. Such a world might be one in which nuclear weapons were effectively banned and the weapons of mass destruction were those of environmental catastrophe. Alternatively, I can envisage a world of nuclear stability resulting from parity in such weapons, rendered unstable by the development by one nation of an advanced technology capable of modifying the earth's environment. Or geophysical weapons may be part of each nation's armory. As I will argue, these weapons are peculiarly suited for covert or secret wars.

Science-fiction literature contains many suggestions of how wars would progress if man indeed possessed the ability to change weather, climate, or ocean currents. Many of these fictional suggestions, and other more serious discussions, fail to take into account the limitations of nature. Jules Verne gave a detailed discussion of displacing the earth's polar caps, thus making the world's climatic zones more equitable (*Les Voyages Extraordinaires; Sans Dessus Dessous*, Metzel, 1889). Verne's proposal was to eliminate the twenty-three-degree tilt in the earth's axis, putting it at right angles to the sun-earth plane. However, as Verne correctly pointed out in a subsequent discussion, the earth's equatorial bulge stabilizes our planet, and even the launching of a 180,000-ton projectile would produce a displacement of only one-tenth of a micron. Senator Estes Kefauver, Vice-Presidential candidate in the 1956 American election, rediscovered Verne's original proposal and was seriously concerned with the tipping of the earth's axis. He reported that the earth's axis could, as the result of an H-bomb explosion, be displaced by ten degrees. Either Senator Kefauver or his scientific advisers neglected the stabilizing influence of the earth's bulge. The maximum displacement that can be expected from the explosion of a one-hundred-megaton H-weapon is less than one micron, as Walter Munk and I pointed out in our book, *Rotation of the Earth* (Cambridge University Press, New York, 1960).

Substantial progress within the environmental sciences is slowly overcoming the gap between fact and fiction regarding manipulations of the earth's physical environment. As these manipulations become possible, history shows that attempts may be made to use them in support of national ambitions. To consider the consequences of environmental modification in struggles among nations, we need to consider the present state of the subject and how postulated developments in the field could lead, ten to fifty years from now, to weapons systems that would use nature in new and perhaps unexpected ways.

The key to geophysical warfare is the identification of the environmental instabilities to which the addition of a small amount of energy would release vastly greater amounts of energy. Environmental instability is a situation in which nature has stored energy in some part of the earth or its surroundings far in excess of that which is usual. To trigger this instability the required energy might be introduced violently by explosions or gently by small bits of material able to induce rapid changes by acting as catalysts or nucleating agents. The mechanism for energy storage might be the accumulation of strain over hundreds of millions of years in the solid earth, or the supercooling of water vapor in the atmosphere by updrafts taking place over a few tens of minutes. Effects of releasing this energy could be worldwide, as in the case of altering climate, or regional, as in the case of locally excited earthquakes or enhanced precipitation.

WEATHER MODIFICATION

The earth's atmosphere is an envelope of air that rotates, for the most part, at the same speed as the underlying continents and oceans. The relative motion between the atmosphere and the earth arises from sources and sinks of energy that vary in location and strength but which have, as their ultimate source, the sun's radiation. The quantities of energy involved in weather systems exceed by a substantial margin the quantity of energy under man's direct control. For instance, the typical amount of energy expended in a single tornado funnel is equivalent to about fifty kilotons of explosives; a single thunderstorm tower exchanges about ten times this much energy during its lifetime; an Atlantic hurricane of moderate size may draw from the sea more than 1000 megatons of energy. These vast quantities of energy make it unlikely that brute-force techniques will lead to sensible weather modification. Results could be achieved, however, by working on the instabilities in the atmosphere.

We are now beginning to understand several kinds of instabilities in the atmosphere. Supercooled water droplets in cold clouds are unstable, but they remain liquid for substantial periods of time unless supplied with nuclei on which they can freeze. Conversion of water droplets to ice through the introduction of artificial nuclei can provide a local source of energy. This released heat can cause rising air currents which in turn lead to further formation of supercooled water. This process may lead to rainfull at the ground greater than that which would have been produced without the artificial nucleation. A second instability may arise, in which water vapor condenses into water, again affecting the distribution of sensible energy. On a larger scale, there is the so-called baroclinic instability of atmospheric waves that girdle the planet. Through the imbalance of heat between equator and pole, energy in this instability is stored, to be released in the creation of large cyclonic storms in the temperate zones. There are other, less well understood instabilities capable of affecting climate, I shall return to them later.

What is the present situation with respect to weather modification and what might be reasonably expected in the future? Experiments over the past eighteen years have demonstrated unequivocally that clouds composed of supercooled water droplets can be transformed into ice-crystal clouds by seeding them with silver iodide, "dry ice" (frozen carbon dioxide), and other suitable chemical agents. This discovery has been applied operationally in the clearance of airports covered by supercooled ground fog. No analogous technique has yet evolved for clearing warm fog, although several promising leads are now being investigated. In the case of warm fog, the atmospheric instability is that water vapor distributed in small drops contains more surface energy than the same water distributed in large drops. The trick for clearance of this warm fog will be to discover some way of getting the small drops to organize themselves into larger ones and then fall to the ground.

There is increasing, though inconclusive, evidence that rainfall from some types of clouds and storm systems in temperate regions can be increased by ten to fifteen per cent by seeding. Somewhat more controversial evidence indicates that precipitation can be increased from tropical cumulus by techniques similar to those employed in temperate regions. Preliminary experiments on hurricanes have the aim of dissipating the clouds surrounding the eye of the storm in order to spread the energy of the hurricane and reduce its force. The results are controversial but indicate that seeding can, in certain circumstances, lead to a marked growth in the seeded cloud. This possibility may have merit in hurricane modification, but experimentation has not yet resulted in a definitive statement.

Regarding the suppression of lightning there is mixed but largely promising evidence that the frequency of cloud-to-ground strokes can be reduced by the introduction of "chaff" strips of metallic foil of the kind used for creating spurious echoes in enemy radars.

In looking to the future, it is quite clear that substantial advances will be made in all of these areas of weather modification. Today, both military and civilian air transport benefit from progress in the clearance of ground fog. Further progress in the technology of introducing the seeding agent into the fog makes it likely that this type of fog dispersal will become routine. In a sense, fog clearing is the first military application of deliberate manipulation of weather, but it is, of course, very limited.

Large field programs are being undertaken in the United States to explore further the possibility of enhancing precipitation, particularly in the western and northeastern states. On the high ground of the western states, snow from winter storms provides much of the country's moisture. Investigations are under way to see if seeding can lead to an increased snowpack and thus enhance the water resources. Intense interest in this form of weather modification, coupled with an increased investigation of the physics of clouds, is likely to lead to effective cloud modification within the next five to fifteen years. At present the effects are measured only statistically, and too little has been done in cloud observation before and after seeding in the way of precisely pinpointing which clouds are most likely to be affected.

As far as military applications are concerned, I conjecture that precipitation enhancement would have a limited value in classical tactical situations, and then only in the future when controls are more thoroughly understood. One could, for example, imagine field commanders calling for local enhancement of precipitation to cover or impede various ground operations. An alternative use of cloud seeding might be applied strategically. We are presently uncertain about the effect of seeding on precipitation down wind from the seeded clouds. Preliminary analysis suggests that there is no effect 200–300 miles down wind, but that continued seeding over a long stretch of dry land clearly could remove sufficient moisture to pre-

vent rain 1000 miles down wind. This extended effect leads to the possibility of covertly removing moisture from the atmosphere so that a nation dependent on water vapor crossing a competitor country could be subjected to years of drought. The operation could be concealed by the statistical irregularity of the atmosphere. A nation possessing superior technology in environmental manipulation could damage an adversary without revealing its intent.

Modification of storms, too, could have major strategic implications. As I have mentioned, preliminary experiments have been carried out on the seeding of hurricanes. The dynamics of hurricanes and the mechanism by which energy is transferred from the ocean into the atmosphere supporting the hurricane are poorly understood. Yet various schemes for both dissipation and steering can be imagined. Although hurricanes originate in tropical regions, they can travel into temperate latitudes, as the residents of New England know only too well. A controlled hurricane could be used as a weapon to terrorize opponents over substantial parts of the populated world.

It is generally supposed that a hurricane draws most of its energy from the sea over which it passes. The necessary process of heat transfer depends on wave action that permits the air to come in contact with a volume of water. This interaction between the air and water also stirs the upper layers of the atmosphere and permits the hurricane to draw on a substantially larger reservoir of heat than just the warm surface water. There may be ways, using monomolecular films of materials like those developed for covering reservoirs to reduce evaporation, for decreasing the local interaction between sea and air and thus preventing the ocean from providing energy to the hurricane in an accelerated fashion. Such a procedure, coupled with selective seeding, might provide hurricane guidance mechanisms. At present we are a long way from having the basic data and understanding necessary to carry out such experiments; nevertheless, the long-term possibility of developing and applying such techniques under the cover of nature's irregularities presents a disquieting prospect.

CLIMATE MODIFICATION

In considering whether or not climate modification is possible, it is useful to examine climate variations under natural conditions. Firm geological evidence exists of a long sequence of Ice Ages, in the relatively recent past, which shows that the world's climate has been in a state of slow evolution. There is also good geological, archeological, and historical evidence for a pattern of smaller, more rapid fluctuations superimposed on the slow evolutionary change. For example, in Europe the climate of the early period following the last Ice Age was continental, with hot summers and cold winters. In the sixth millennium B.C., there was a change to a warm humid climate with a mean temperature of five degrees Fahrenheit higher than at present and a heavy rainfall that caused considerable growth of peat. This period, known as a climatic optimum, was accentuated in Scandinavia by a land subsidence that permitted a greater influx of warm Atlantic water into the large Baltic Sea.

The climatic optimum was peculiar. While on the whole there was a very gradual decrease of rainfall, the decrease was interrupted by long droughts during which the surface peat dried. This fluctuation occurred several times, the main dry periods being from 2000 to 1900, 1200 to 1000, and 700 to 500 B.C. The last, a dry heat wave lasting approximately 200 years, was the best developed. The drought, though not sufficiently intense to interrupt the steady development of forests, did cause extensive migrations of peoples from drier to wetter regions.

A change to colder and wetter conditions occurred in Europe about 500 B.C. and was by far the greatest and most abrupt alteration in climate since the end of the last Ice Age. It had a catastrophic effect on the early civilization of Europe: large areas of forest were killed by the rapid growth of peat, and the levels of the Alpine lakes rose suddenly, flooding many of the lake settlements. This climatic change did not last long; by the beginning of the Christian era, conditions did not differ greatly from current ones. Since then climatic variations have continued to occur, and although none has been as dramatic as that of 500 B.C., a perturbation known as the little ice age of the seventeenth century is a recent noteworthy example. The cause of these historical changes in climate remains shrouded in mystery. The rapid changes of climate in the past suggest to many that there exist instabilities affecting the balance of solar radiation.

Indeed, climate is primarily determined by the balance between the incoming short wave from the sun (principally light) and the loss of outgoing long-wave radiation (principally heat).

Three factors dominate the balance: the energy of the sun, the surface character of terrestrial regions (water, ice, vegetation, desert, etc.), and the transparency of the earth's atmosphere to different forms of radiated energy. In the last connection, the effect of clouds in making cool days and relatively warm nights is a matter of familiar experience. But clouds are a manifestation rather than an original determinant of weather and climate; of more fundamental significance is the effect of gases in the atmosphere, which absorb much of the radiation in transit from the sun to the earth or from the earth into space. Intense X-rays and ultraviolet from the sun, toegether with high-energy atomic particles, are arrested in the upper atmosphere. Only the narrow band of visible light and some short radio waves traverse the atmosphere without serious interruption.

There has been much controversy in recent years about conjectured over-all effects on the world's climate of emissions of carbon dioxide to the atmosphere from furnaces and engines burning fossil fuels, and some about possible influences of the exhaust from large rockets on the transparency of the upper atmosphere. Carbon dioxide placed in the atmosphere since the start of the industrial revolution has produced an increase in the average temperature of the lower atmosphere of a few tenths of a degree Fahrenheit. The water vapor that may be introduced into the stratosphere by the supersonic transport may also result in a similar temperature rise. In principle it would be feasible to introduce material into the upper atmosphere that would absorb either incoming light (thereby cooling the surface) or outgoing heat (thereby warming the surface). In practice, in the rarefied and windswept upper atmosphere, the material would disperse rather quickly, so that military use of such a technique would probably rely upon global rather than local effects. Moreover, molecular material will tend to decompose, and even elemental materials will eventually be lost by diffusion into space or precipitation to the surface. At intermediate levels, in the stratosphere, materials may tend to accumulate, though the mixing time for this part of the atmosphere is certainly less than ten years and may be a few months. If a nation's meteorologists calculated that a general warming or cooling of the earth was in their national interest, improving their climate while worsening others, the temptation to release materials from high-altitude rockets might exist. At present we know too little about the paradoxical effects of warming and cooling, however, to tell what the outcome might be.

More sudden, perhaps much briefer but nevertheless disastrous, effects are predictable if chemical or physical means were developed for attacking one of the natural constituents of the atmosphere—ozone. A low concentration of ozone (O_3, a rare molecular form of oxygen) in a layer between fifteen and fifty kilometers altitude has the utmost significance for life on land. It is responsible for absorbing the greater part of the ultraviolet from the sun. In mild doses, this radiation causes sunburn; if the full force of it were experienced at the surface, it would be fatal to all life—including farm crops and herds—that could not take shelter. The ozone is replenished daily, but a temporary "hole" in the ozone layer over a target area might be created by physical or chemical action. For example, ultraviolet at 250 millimicrons wave length decomposes ozone molecules, and ozone reacts readily with a wide range of materials.

At present, we can only tentatively speculate about modifying the short-wave radiation at its source, the sun. We have discovered major instabilities on the sun's surface that might be manipulated many years hence. In a solar flare, for example, 10^{10} megatons of energy are stored in distorted magnetic fields. With advanced techniques of launching rockets and setting off large explosions, we may sometime in the future learn to trigger these instabilities. For the near future, however, modification will not be in the short-wave incoming radiation but in the long-wave outgoing radiation.

The usual schemes for modifying climate involve the manipulation of large ice fields. The persistence of these large ice fields is due to the cooling effects of the ice itself, both in reflecting (rather than abosrbing) incoming shortwave radiation and in radiating heat at a higher rate than the usual ground cover. A commonly suggested means of climate modification involves thin layers of colored material spread on an icy surface, thus inhibiting both the reflection and radiation processes, melting the ice, and thereby altering the climate. Such a procedure presents obvious technical and logistic difficulties. For example, if one wished to create a surface coating of as little as one micron thickness to cover a square 1000 kilometers in size, the total material for this extremely thin coating would weigh a million tons or more, depending upon its density. So the proposals to dust from the air some of the globe's extended ice sheets are unrealistic and reflect a brute-force technique, taking no advantage of instabilities within the environment.

Although it may be technologically difficult to change an ice cap's surface character, and thus its thermal properties, it may be possible to move the ice, taking into account the gravitational instability of ice caps. The gravitational potential energy of water as a thick, high ice cap is much greater than it would be at sea level. This fact makes it possible, at least in principle, to devise schemes for bringing about a redistribution in the ice. Indeed, A.T. Wilson has proposed a cyclical theory for the Ice Ages, based on this instability.

The main points of Wilson's theory are as follows:

1. Antarctica is covered by an ice sheet several kilometers thick. Pressure at the bottom of the ice is great enough to keep the ice at or near its melting point; water is an unusual material in that a pressure increase lowers rather than raises its melting point. An increase in thickness of the ice sheet could result in melting at the bottom. The resulting ice-water mixture along the sole of the glacier would permit flow by a process of freezing and melting—a flow process much more effective than ordinary plastic flow.

2. If such an instability occurs, the ice sheet will flow out onto the surrounding sea, and a large shelf will be formed between Antarctica and the ocean around it. As a consequence, short-wave solar radiation will be reflected, and there will be enhanced loss of heat by radiation at the long wave lengths, causing cooling and the inducement of world-wide glaciation.

3. Once the ice shelf is in the ocean, it will begin to melt and eventually will be removed. The ice remaining on land will be much thinner than before. As the reflectivity of the southern hemisphere decreases with the melting of the Antarctic ice cap, the global climate will grow warmer again, corresponding to the start of an interglacial period. The ice cap will slowly form again.

Commenting on Wilson's theory, J. T. Hollin has noted the possibility of a catastrophic surge or advance of the ice sheet, such as has been recorded from small glaciers on numerous occasions. The largest surge yet reported is probably that of the ice cap in Spitsbergen, which advanced up to twenty-one kilometers on a front of thirty kilometers sometime between 1935 and 1938. There are also reports of glacial advances at speeds up to one hundred meters per day. Hollin speculates that, once the bottom-melting phase of a gravitationally unstable ice cap is reached, it will move quickly. In addition to trapped geothermal heat melting the ice at the bottom, there are additional contributions from frictional heat generated as the glacier scrapes along the solid ground.

If the speculative theory of Wilson is correct (and there are many attractive features to it), then a mechanism does exist for catastrophically altering the earth's climate. The release of thermal energy, perhaps through nuclear explosions along the base of an ice sheet, could initiate outward sliding of the ice sheet which would then be sustained by gravitational energy. One megaton of energy is sufficient to melt about 100 million tons of ice. One hundred megatons of energy would convert 0.1 cm. of ice into a thin layer of water covering the entire Antarctic cap. Lesser amounts of energy suitably placed could undoubtedly initiate the outward flow of the ice.

What would be the consequences of such an operation? The immediate effect of this vast quantity of ice surging into the water, if velocities of one hundred meters per day are appropriate, would be to create massive tsunamis (tidal waves) that would completely wreck coastal regions even in the Northern Hemisphere. There would then follow marked changes in climate brought about by the suddenly changed reflectivity of the earth. At a rate of one hundred meters per day, the center of the ice sheet would reach the land's edge in forty years.

Who would stand to benefit from such application? The logical candidate would be a landlocked equatorial country. An extended glacial period would insure near-Arctic conditions over much of the temperate zone, but temperate climate with abundant rainfall would be the rule in the present tropical regions.

FUTURE OF WEATHER AND CLIMATE MODIFICATION

The foregoing perhaps represents a more positive view of weather and climate modification than that held by many earth scientists. I believe this view is justified as it is based on three scientific and technological advances. First, understanding of basic meteorology has advanced to such an extent that mathematical models of the atmosphere here have been developed incorporating the most important elements. Physical processes in clouds, in turbulent exchanges at the surface, and in transmission of radiation through the atmosphere are no longer as mysterious as they once were. The volumes simulated by the models range from the size of a single cloud to the entire atmosphere: these models are no longer primitive representations.

Secondly, the advent of high-speed computers enables atmospheric models to be studied in greater detail. These computers have a peculiar importance to weather modification, since they will enable scientists to carry out extended experiments to test whether or not various schemes for manipulating the atmosphere are indeed possible and what the outcome should be.

The third advance lending support to expectations for weather and climate modification is the new array of instruments developed to observe and detect changes in the atmosphere. The most dramatic and perhaps the most powerful is the meterological satellite, which provides a platform whence the atmosphere can be observed, not only in geographically inaccessible regions, but also with entirely new physical measurements. For example, meteorological satellites of the future will permit the determination of humidity, temperature, and pressure as averaged over substantial volumes of the atmosphere, providing quantities that are needed to develop the mathematical models. Sophisticated surface instrumentation, for observing detailed processes within smaller parts of the atmosphere, provides us with far more powerful tools with which to look at clouds and at the interaction of the atmosphere with its boundaries than those which were available ten or twenty years ago.

EARTHQUAKE MODIFICATION

What causes earthquakes? Over geological time, the irregular distribution of heat-producing radioactive elements in the rock layers gives rise to subsurface temperature differences between various parts of the earth. In the continents, granites and similar rocks have concentrated radioactive elements near the surface; no similar concentration has taken place in the suboceanic regions, which may as a result be more than one hundred degrees centigrade cooler than the corresponding subcontinental regions. Such variations in temperature along a horizontal line, due to the differences in the vertical distribution of heat-producing elements, give rise to large thermal stresses, causing strain analogous to that which cracks a glass tumbler filled with hot water. The strain tends to be greatest in regions of abrupt temperature change along a horizontal line through the earth's crust. The strain may be partially relieved by the slow convective flow of material in the deep earth which is thought by some geophysicists to push continents about. But the strain can also be relieved by sharp fractures or by movements along previous faults in rocks near the surface. Movement along a fault radiates energy outward, which results in an earthquake. Each year approximately 200 megatons of strain energy is released in this fashion, the largest earthquakes corresponding to energy of the order of 100 megatons. The energy released depends on the volume of material affected. The largest earthquakes take place along faults having a linear dimension of 1000 kilometers, whereas smaller ones take place along faults of one kilometer or less.

Major earthquakes tend to be located along two main belts. One belt, along which about eighty-five per cent of the total energy is released, passes around the Pacific and affects countries whose coastlines border this ocean, for example Japan and the west coast of North America. The second belt passes through the Mediterranean regions eastward through Asia and joins the first belt in Indonesia. Along these two belts, large earthquakes occur with varying frequencies. In California a large earthquake might be expected once every fifty to one hundred years, while Chile might expect such a disturbance once every ten to twenty years. Sometimes major earthquakes have occurred in regions ordinarily thought of as being free from risk. For example, the New Madrid earthquake of 1811–1812 devastated a large area of central North America but had only slight cultural effects because of the area's sparce population.

Today, our detailed understanding of the mechanism that causes an earthquake and of how the related instability can be triggered is limited. Only within the last few years have serious discussions of earthquake prediction begun, whereas moderately reliable weather forecasts have been available for about the last thirty to fifty years. Currently, substantial effort is being made, primarily by Japan and the United States, to develop techniques for forecasting earthquakes. These techniques are based to a large extent on the determination of changing strain conditions of materials in the rocks surrounding recognized fault zones. Of possible value is the observation that before an earthquake the accumulating strain accelerates.

Control of earthquakes is a prospect even more distant than that of forecasting, although two techniques have been suggested through recent experience.

1. In the course of the underground testing of nuclear weapons at the Nevada test site, it was observed that an explosion apparently released local strain in the

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earth. The hypothesis is that the swift build-up of strain due to the sudden release of energy in an explosion discharges strain energy over a large volume of material.

2. Another method of releasing strain energy has appeared from pumping of underground water in the vicinity of Denver, Colorado, which has led to a series of small earthquakes. The hypothesis here is that underground water has provided local lubrication permitting adjacent blocks to slip by one another.

The use as a weapon system of the strain energy instability within the solid earth requires an effective triggering mechanism. A scheme for pumping water seems clumsy and easily detectable. On the other hand, if the strain pattern in the crust can be accuratly determined, the phased or timed release of energy from smaller faults, designed to trigger a large fault at some distance, could be contemplated. This timed release could be activated through small explosions and thus it might be possible to use this release of energy stored in small faults at some distance from a major fault to trigger that major fault. For example, the San Andreas fault zone, passing near Los Angeles and San Francisco, is part of the great earthquake belt surrounding the Pacific. Good knowledge of the strain within this belt might permit the setting off of the San Andreas zone by timed explosions in the China Sea and Philippine Sea. In contrast with certain meteorological operations, it would seem rather unlikely that such an attack could be carried out covertly under the guise of natural earthquakes.

MODIFICATION OF OCEANS

We are still in the very early stages of developing the theory and techniques for predicting the state of the oceans. In the past two decades methods have been devised for the prediction of surface waves and surface wind distribution. A warning system for the tsunamis (tidal waves) produced by earthquakes has also been developed.

Certain currents within the oceans have been identified, but we do not yet know what the variable components are; that is, what the weather within the ocean is. Thus we have not been able to identify any instabilities within the oceanic circulation that might be easily manipulated. As in the case of the solid earth, we can only speculate tentatively about how oceanic processes might be controlled.

One instability offering potential as a future weapon system is that associated with tsunamis. These frequently originate from the slumping into the deep ocean of loosely consolidated sediments and rocks perched on the continental shelf. Movement of these sediments can trigger the release of vast quantities of gravitational energy, part of which is converted in the motion of the tsunami. For example if, along a 1000-kilometer edge of a continental shelf, a block 100 meters deep and ten kilometers wide were dropped a distance of 100 meters, about 100 megatons of energy would be released. This release would be catastrophic to any coastal nation. How could it be achieved? A series of phased explosions, perhaps setting off natural earthquakes, would be a most effective way. I could even speculate on planning a guided tidal wave, where guidance is achieved by correctly shaping the source which releases energy.

BRAIN WAVES AROUND THE WORLD?

At heights of forty to fifty kilometers above the earth's surface substantial numbers of charged particles are found which made this part of the atmosphere, the ionosphere, a good conductor of electricity. The rocks and oceans are also more conducting than the lower atmosphere. Thus, we live in an insulating atmosphere between two spherical conducting shells or, as the radio engineer would put it, in an earth-ionosphere cavity, or wave guide. Radio waves striking either conducting shell tend to be reflected back into the cavity, and this phenomenon is what makes conventional long-distance radio communication possible. Only recently, however, has there been any interest in natural electrical resonances within the earth-ionosphere wave guide. Like any such cavity, the earth-ionosphere wave guide will tend to sustain radio oscillation at certain frequencies in preference to others. These resonant frequencies are primarily determined by the size of the earth and the speed of light, but the properties of the ionosphere modify them to a certain extent. The lowest resonances begin at about eight cycles per second, far below the frequencies ordinarily used for radio communnication. Because of their long wave length and small field strength, they are difficult to detect. Moreover, they die down quickly, within one sixteenth of a second or so; in engineering terms, the cavity has a short time constant.

The natural resonant oscillations are excited by lightning strokes, cloud-to-ground strokes being a much more efficient source than horizontal cloud-to-cloud discharges. On the average, about one hundred lightning strokes occur each second (primarily concentrated in the equatorial regions), so that about six lightning flashes are available to introduce energy before a particular oscillation dies down. A typical oscillation's field strength is of the order of 0.3 millivolts per meter.

The power of the oscillations varies geographically. For example, for a source located on the equator in Brazil the maximum intensity of the oscillation is near the source and at the opposite side of the earth (around Indonesia). The intensity is lower in intermediate regions and toward the poles.

One can imagine several ways in which to increase the intensity of such electrical oscillations. The number of lightning strokes per second could be enhanced by artificially increasing their original number. Substantial progress has been made in the understanding of the physics of lightning and of how it might be controlled. The natural oscillations are excited by randomly occurring strokes. The excitation of timed strokes would enhance the efficiency with which energy is injected into an oscillation. Furthermore, the time constant of the oscillation would be doubled by a fourfold increase in the electrical conductivity of the ionosphere, so that any scheme for enhancing that conductivity (for example, by injecting readily ionized vapor) lowers the energy losses and lengthens the time constant, which would permit a greater number of phased lightning strokes before the decay of an oscillation.

The enhanced low-frequency electrical oscillations in the earth-ionosphere cavity relate to possible weapons systems through a little-understood aspect of brain physiology. Electrical activity in the brain is concentrated at certain frequencies, some of it extremely slow, a little around five cycles per second, and very conspicuous activity (the so-called alpha rhythm) around ten cycles per second. Some experiments have been done in the use of a flickering light to pull the brain's alpha rhythm into unnatural synchrony with it; the visual stimulation leads to electrical stimulation. There has also been work on direct electrical driving of the brain. In experiments discussed by Norbert Wiener, a sheet of tin is suspended from the ceiling and connected to a generator working at ten cycles per second. With large field strengths of one or two volts per centimeter oscillating at the alpha-rhythm frequency, decidedly unpleasant sensations are noted by human subjects.

The Brain Research Institute of the University of California is investigating the effect of weak oscillating fields on human behavior. The field strengths in these experiments are of the order of a few hundredths of a volt per centimeter. Subjects show small but measurable degradation in performance when exposed to oscillating fields for periods of up to fifteen minutes.

The field strengths in these experiments are still much stronger, by a factor of about 1000, than the observed natural oscillations in the earth-ionosphere cavity. However, as previously noted, the intensity of the natural fluctuations could be increased substantially and in principle could be maintained for a long time, as tropical thunderstorms are always available for manipulation. The proper geographical location of the source of lightning, coupled with accurately timed, artificially excited strokes, could lead to a pattern of oscillations that produced relatively high power levels over certain regions of the earth and substantially lower levels over other regions. In this way, one could develop a system that would seriously impair brain performance in very large populations in selected regions over an extended period.

The scheme I have suggested is admittedly far-fetched, but I have used it to indicate the rather subtle connections between variations in man's environmental conditions and his behavior. Perturbation of the environment can produce changes in behavior patterns. Since our understanding of both behavioral and environmental manipulation is rudimentary, schemes of behavioral alteration on the surface seem unrealistic. No matter how deeply disturbing the thought of using the environment to manipulate behavior for national advantage is to some, the technology permitting such use will very probably develop within the next few decades.

SECRET WAR AND CHANGING RELATIONSHIPS

Deficiencies both in the basic understanding of the physical processes in the environment and in the technology of environmental change make it highly unlikely that environmental modification will be an attractive weapon system in any direct military confrontation in the near future. Man already possesses highly effective

tools for destruction. Eventually, however, means other than open warfare may be used to secure national advantage. As economic competition among many advanced nations heightens, it may be to a country's advantage to ensure a peaceful natural environment for itself and a disturbed environment for its competitors. Operations producing such conditions might be carried out covertly, since nature's great irregularity permits storms, floods, droughts, earthquakes, and tidal waves to be viewed as unusual but not unexpected. Such a "secret war" need never be declared or even known by the affected population. It could go on for years with only the security forces involved being aware of it. The years of drought and storm would be attributed to unkindly nature, and only after a nation was thoroughly drained would an armed takeover be attempted.

In addition to their covert nature, a feature common to several modification schemes is their ability to affect the earth as a whole. The environment knows no political boundaries; it is independent of the institutions based on geography, and the effects of modification can be projected from any one point to any other on the earth. Because environmental modification may be a dominant feature of future world decades, there is concern that this incipient technology is in total conflict with many of the traditional geographical and political units and concepts.

Political, legal, economic, and sociological consequences of deliberate environmental modification, even for peaceful purposes, will be of such complexity that perhaps all our present involvements in nuclear affairs will seem simple. Our understanding of basic environmental science and technology is primitive, but still more primitive are our notions of the proper political forms and procedures to deal with the consequences of modification. All experience shows that less significant technological changes than environmental control finally transform political and social relationships. Experience also shows that these transformations are not necessarily predictable, and that guesses we might make now, based on precedent, are likely to be quite wrong. It would seem, however, that these nonscientific, nontechnological problems are of such magnitude that they deserve consideration by serious students throughout the world if society is to live comfortably in a controlled environment.

AUTHOR'S NOTE: In the section on weather modification I have drawn heavily on Weather and Climate Modification (National Academy of Sciences, National Research Council, Washington, 1966). A.T. Wilson's paper on "Origin of Ice Ages" appeared in Nature, vol. 201, pp. 147–49 (1964), and J.T. Hollin's comments in vol. 208, pp. 12–16 (1965). Release of tectonic strain by underground nuclear explosion was reported by F. Press and C. Archambeau in Journal of Geophysical Research, vol. 67, pp. 337–43 (1962), and man-made earthquakes in Denver by D. Evans in Geotimes, vol. 10, pp. 11–17. I am grateful to J. Homer and W. Ross Adey, of the Brain Research Institute of the University of California at Los Angeles, for information on the experimental investigation of the influence of magnetic fields on human behavior.

Senator PELL. And there are no new potential weapons that could be added to that list, are there?

Mr. MACDONALD. Many of the ideas expressed in that article have progressed in the sense that those technologies I discussed have been developed to a much greater extent today than they were in 1966.

Senator PELL. But there are no new technologies that did not appear in that, are there?

Mr. MACDONALD. Not to my knowledge.

Senator PELL. Thank you.

COUNCIL ON ENVIRONMENTAL QUALITY

As a former member of the Council on Environmental Quality, were you part of Mr. Pollack's study committee they had about a year and a half ago on this subject?

Mr. MACDONALD. No, the council on Environmental Quality was not included in the Under Secretary's committee looking at this problem.

Senator PELL. Did the Council on Environmental Quality ever have any problem obtaining the information concerning DOD operations in the field of weather modification?

Mr. MACDONALD. The Council on Environmental Quality as I think applies to other agencies, did not have that information made available to it.

OTHER POINTS IN MR. ST. AMAND'S STATEMENT

Senator PELL. Do you have any particular comments besides the question of the potential use of earthquakes with regard to Mr. St. Amand's statement? Were there any other points particularly that piqued you one way or the other?

Mr. MACDONALD. I would have to look at the statement in detail. I prefer not to comment at this time.

EXECUTIVE BRANCH'S REFUSAL TO ARTICULATE NATIONAL POLICY

Senator PELL. What in your personal view and opinion is the primary reason for the executive branch's refusal to articulate a national policy on this issue?

Mr. MACDONALD. I think the reason in part is a bureaucratic one in the sense that there are conflicting interests. In part it is—it's my feeling, I have no direct knowledge—that other than the references contained within the Pentagon Papers, we did use certain techniques in Southeast Asia and that making the public aware of the use of these techniques might be damaging in a variety of ways.

In part I think there is serious concern as to whether restricting or prohibiting by international agreement the development of these methods as weapons will discourage the development of environmental modification techniques for peaceful purposes. I don't think there is a simple answer. It is one that bothered me a great deal when I was in the Council and so bothers me today.

U.S. POSITION AT STOCKHOLM CONFERENCE

Senator PELL. You were a member and I was adviser to the U.S. delegation to the Stockholm Conference. Looking back on that, I remember I was surprised at the sensitivity of our delegation to the questions of environmental modification of warfare that were being posed at the time. I recall also being the only member of the delegation who objected to our knee jerk reaction to Palme's speech which said frankly what was in everybody's mind who was there.

What was your view in retrospect? What is the reason for the ultrasensitivity, you remember, when we insisted on somewhat gutting the recommendation saying "where feasible" in recommendation 218. I was curious about what you thought of our reaction to Palme, the oversensitivity.

Mr. MACDONALD. Basically, the delegation was, of course, under instructions. The instructions were formulated in this area principally by the National Security Council at that time. I think the situation exists today where there is no overall policy as to whether or not weather modification should be used or weather modification techniques be developed as weapons of war.

When we were in Stockholm I would say that there was no agreed-upon policy.

OPERATION ROME PLOW

Senator PELL. There is no secret about Operation Rome Plow where they knocked down the trees in Vietnam. It seems to me that falls in the environmental modification and yet our sensitivity to it being even discussed was an extreme.

My own theory about it was that Mr. Ehrlichman, who at the time I think had certain bully-boy characteristics, was at the Stockholm Conference in the early part and back and forth. I don't know if you care to hypothesize on an opinion.

Mr. MACDONALD. I think that it extended to direct instructions from the White House and the National Security Council and that was the reason. It was not just the members of the delegation, including Mr. Ehrlichman.

APPROPRIATE AGENCY TO CONDUCT NEW STUDY

Senator PELL. Do you believe that the Defense Department should be the agency to conduct the new study mentioned in Mr. Pollack's statement? I think we have moved quite far ahead in that a study is being ordered by the President.

As you know, in Government you have to go through a series of studies before any action is ever taken, and you never know whether it is going to be one study or several studies, but each study is at least one slow step forward.

Mr. MACDONALD. Yes; I was delighted to hear this morning from Mr. Pollack that such a study has been ordered. I will only recall that this is an issue that has been before this administration for a number of years. You have raised it with the administration. It came up in connection with the Secretary of State's confirmation hearings. It has been there.

And only now is a particular agency requested to carry out such a study. I think that the Department of Defense is completely inappropriate to carry out such an investigation. It has a vested interest in it. I think it would be more appropriate, for example, to ask the Arms Control and Disarmament Agency to take on such a study. And you might argue that it also has a vested interest.

You might ask an independent body from outside the Government to look into this question. To ask the Defense Department to look into it is not the way to proceed.

Senator PELL. It reminds me of what a present colleague and former member of the executive branch once said about having a coalition government—it is like putting the fox into the hen coop.

Mr. MACDONALD. Yes; the hen coop or whatever, but this is clearly a case in which you are asking the principal participants of a certain activity to judge whether that activity is good for the country as a whole and I just think that is bad.

Senator PELL. I would agree.

I thank you very much indeed for coming down from New Hampshire and we are glad you were with us today.

Mr. MACDONALD. Thank you very much.

Senator PELL. The next witness is Dr. Thomas Malone, director of the Holcomb Research Institute, Butler University, Indianapolis, Ind., and formerly of the University of Connecticut.

STATEMENT OF DR. THOMAS F. MALONE, DIRECTOR, HOLCOMB RESEARCH INSTITUTE, BUTLER UNIVERSITY, INDIANAPOLIS, IND.

Mr. MALONE. Thank you very much.

My name is Thomas F. Malone. I am speaking as a private citizen, but from a background of onetime Chairman of the National Academy of Sciences' Panel on Weather and Climate Modification and Vice President of the International Council of Scientific Unions and Secretary General of its Committees on Atmospheric Sciences, and currently a member of the President's National Advisory Committee on Oceans and Atmosphere where I have special responsibility for their position on weather modification.

Mr. Chairman, in view of the advanced hour, it might be helpful if I simply submitted my statement and presented my views on what I think you identified as the key issues in this hearing.

Senator PELL. That would be most agreeable and the statement will be inserted in the record as if read.

Mr. MALONE. Thank you, sir.

WHY EXECUTIVE BRANCH POLICYMAKERS ARE SLOW TO RESPOND

I think the issues are, first, why are the policymakers in our executive branch so slow to respond to this issue, which, as you know, I raised 8 years ago before hearings of the Senate Commerce Committee pointing out the "nightmare" versus the "vision" of the atmospheric scientists in this vexing field.

And I think there are two reasons. One is that I don't believe that the dimension of the issues involved in environmental problems have really been sensed by these people who have shown great courage and imagination in establishing detente with potential adversaries. It has been too narrowly viewed as a warfare weapon rather than the larger implications of an emerging capacity to exercise meaningful control over our environment.

I think it is a lack of awareness of what we are really talking about.

Second, I think that in view of the secrecy which veils the Southeast Asia operation, one is led to question whether or not the claims of effectiveness have not been extravagant. This has been true of weather modification in general and since one doesn't have access to these reviews—these assessments—one is not able to evaluate them.

But I have a small still voice within me which says that it is not unthinkable that the claims of military effectiveness have been exaggerated just as the claims of civilian effectiveness in this field have frequently been exaggerated by well-meaning honest people whose enthusiasm exceeds their perception.

So that would be my views on this key question that you have raised.

ADEQUACY OF MEASURES PROPOSED

The second key question I believe is the adequacy of the measures which are proposed. I share Professor MacDonald's keen disappointment at the selection of DOD as the agency to carry out the study. I have fine, competent friends, colleagues, in DOD who I admire. This is just the wrong place. This kind of responsibility in the executive department belongs in the State Department.

Senator PELL. Or ACDA. Wouldn't that be the logical place?

Mr. MALONE. ACDA would be appropriate. I believe that the implications here—that is, of this matter escalated to its proper importance—transcends the responsibility of ACDA and becomes a matter of international science policy which I believe would fall within the purview of the State Department.

And I might say, sir, that another institution which might be helpful is the newly established Office of Technology Assessments [OTA] that is attached to the Congress.

There are two mechanisms.

In addition, there is a precedent for establishing special commissions to look into these matters, and I think that this would be a very appropriate way to examine some of these larger broader issues and to bring this down from the realm of hyperbole to the practical.

Let me just mention a few of the great societal issues which I think are related to the whole question of environmental modification.

One is the energy problem which is vexing us today. It is clear that with a doubling time of the order of a decade or two in the production of energy, we are really racing pell-mell toward that time when we may be forced to choose between more people or limitations on the energy per capita, because of the concentration of waste heat dumped into the atmosphere and the possibility that it would induce unacceptable perturbations and affect our climate.

A second area is the food issue where the potential doubling or quadrupling over the food requirements between now and the end of the century are going to strain our food producing capacities and they are going to make extremely important the utilization of the water and air resources and are going to result in desalination to provide irrigation, interruption of the hydrologic cycle with consequences of inadvertently modifying the climate that we should begin to address now.

The third area that I am concerned about is the natural catastrophe area. Last week I was in Miami listening to the head of the hurricane unit down there speaking of the frightful, frightening potential for casualties running into the tens of thousands in connection with storm surges moving on to the coastal zone where the population density has soared in the last decade or so.

Several options are available to ameliorate that hazard. One certainly is the diminution of the intensity of hurricanes. If that is to proceed, the whole operation will have to move to the Pacific Ocean, and in that case, we immediately get into an international operation.

So that what I am suggesting, sir, is that if we look at the whole matter of either conscious or inadvertent environmental modification and its relation to some of the great societal issues and the frightening policy decisions which are going to confront us within a matter of

decades, then our Government, our Nation, has a great opportunity to take a constructive attitude to frame the proper questions and to subsume within this context the military utilization of this capability.

And it is in that direction that I would hope that you could with your very effective persistence move the thinking of our policymakers in both the executive and legislative branches of the Government.

I would hope that these Commissions, the State Department, or OTA would pick out the societal issues which I have mentioned, assess the adequacy of our scientific knowledge to resolve the policy questions involved, identify the research needs, and propose the kind of global strategies which would help us all to address them.

SECRECY OF SEEDING IN SOUTHEAST ASIA

Finally, sir, I would say that there is the question of the rather sordid secrecy of the seeding in Southeast Asia. I have given my little apprehensions there that must remain as to whether or not national security has become intermingled with a veil which sort of covers up or shrouds extravagant claims. This could all be resolved very quickly if the relevant documents were declassified and put in the public domain and exposed to the kind of scrutiny which we, in the scientific community, have found very helpful in either reducing extravagant claims or conversely, as a matter of fact, identifying things not recognized within the scientific establishment.

Mr. Chairman, I think I might stop here in view of the hour and be responsive to your questions.

Senator PELL. Thank you very much.

ADMINISTRATION WILLING TO HAVE CLASSIFIED DISCUSSION

I think we moved a little bit ahead today. For the first time the administration has been willing, on a classified basis, to discuss this subject. Until now, even with the Senate Foreign Relations Committee in closed session, there was no openness whatsoever—no candor at all.

That is a long cry from declassification, and I agree with you that it should be done.

STUDIES ON WEATHER, GEOPHYSICAL MODIFICATION

Are you aware in the scientific community of any detailed studies on this general subject of weather and geophysical modification?

Mr. MALONE. Within the scientific community, of course, the National Academy of Science has addressed the weather modification. It has not addressed the broader geophysical modification issue—not that I am familiar with.

PUTTING ENVIRONMENTAL MODIFICATION INTO CONTEXT

Senator PELL. I agree with you, too, in your statement that these problems transcend national borders; they are really global, and I know I have become a member of and become very interested in the Club of Rome. The Club of Rome believes these problems concerning energy and food and the oceans and population transcend national borders. I would hope we might add into our thinking this idea of

scientific weather modifications, scientific actions of this sort, because increasingly actions that are taken within one nation's border will have an impact on another.

Mr. MALONE. I wish you could persuade the policymakers in the Government that world society is at a sort of crossroads. Our ability to manipulate information, to manipulate materials, to interfere with life processes, to hand them information, have all brought us to the stage where our per capita capacity to transform natural resources into goods and services is doubling every few decades.

This means there is a better life downstream.

On the other hand, we are increasing at about 5 percent per year our demand on natural resources and we are in danger of overstressing the carrying capacity of Planet Earth. It is, precisely for this reason that we need to explore these because which road we pick will not be decided by some large plebiscite but by what Johnny Von Neumann told us many years ago, by a long series of small correct decisions.

It is in that context I would hope our Government could put this whole matter of environmental modification.

COMMENDATION OF WITNESS

Senator PELL. I thank you and I thank you very much indeed, Dr. Malone, for coming to this hearing.

[Dr. Malone's prepared statement follows:]

PREPARED STATEMENT OF DR. THOMAS F. MALONE, DIRECTOR, HOLCOMB RESEARCH INSTITUTE, BUTLER UNIVERSITY, INDIANAPOLIS, IND.

Mr. Chairman: In preparing for these timely hearings, I read—and reread—the report of the Hearings on Senate Resolution 281 held in July of 1972 before your Committee. Three impressions remain with me following that review:

The remarkable unanimity of the scientific community in supporting the proposal that the United States Government exercise initiative and leadership in seeking international agreement to eschew the hostile use of environmental modification and, in particular. military weather modification—yet the seeming ineffectiveness of these views in making something happen.

The commendable initiative of your Committee in holding hearings that led to a recorded Senate vote in favor of the Resolution—and yet the lethargy of Congress in acting on a matter that was brought before them during the course of extensive hearings in 1966.

The sordid secrecy that shrouded the alleged weather modification operations in Southeast Asia—leaving the thoughtful reader wondering whether national security was *really* involved or whether the veil of classification was drawn over these activities to shield shoddy science and extravagant claims from the scruntiny of peer review by which the soundness, integrity, and effectiveness of scientific programs are maintained.

It is with the persuasiveness and the effectiveness of the arguments advanced by the scientists in favor of eschewing the hostile use of weather modification that I would like to dwell briefly this morning. My convictions are strong and they have remained unchanged since February 24, 1966, when I testified before the Committee on Commerce of the United States Senate and drew a sharp contrast between "the vision" of atmospheric scientists of a world in which "the benefits of weather and climate control are allocated equitably among nations by methods that will have been developed (through) * * * 'a long sequence of small correct decisions' " * * * and "the nightmare" of atmospheric scientists of a world in which conflict * * * has been aggravated by dispute over the rights to one of the most international of our natural resources—the atmosphere * * * a world in which * * * the problem of nuclear proliferation (is) replaced by the proliferation of an environmental modification capability."

Many of the arguments that have been advanced by the scientists have been based on moral imperatives, that is, on the course of action that would follow from an ethical framework attuned to circumstances of the contemporary world. Others recognize the jeopardy in which large scientific programs of a necessarily international character might be placed by contaminating scientific efforts directed toward beneficial ends with other scientific efforts directed toward military ends. These arguments are fundamentally valid, but a new dimension is beginning to emerge that intensifies the urgency of the matter and provides a rationale of pragmatic self-interest that might turn out to be compelling when idealism fails to carry the day. This new dimension is concerned with societal issues that require courageous and imaginative public policy decisions if we are to avert a series of crises over the decade immediately ahead and is also concerned with the dependence on international agreement and cooperation to establish the knowledge base upon which these policy decisions rest.

Mr. Chairman, I would like to touch on three of these issues in the hope that you and your committee can cast them in a form that will be persuasive to both Houses of Congress.

The first has to do with the world "food crisis" which is so clearly impending, and so inextricably related to weather and climate that its intensity may be exacerbated or ameliorated by the manner in which we 'manage" our atmospheric resources. It is a simple statement of fact that *agricultural technology* seeks to maximize productivity while *nature* seeks to maximize ecological stability—two goals which are incompatible. To satisfy the soaring world food demands, we have pushed productivity to such high levels that we have fostered a high degree of instability in our agricultural ecosystems. This instability interacts with natural fluctuations in weather and climate and could be grievously aggravated by inadvertant climate modifications associated with human activities. The thousands of deaths through stravation in the Sahelian region of Africa are a shocking testimony to this dangerous state of affairs. With world food demands increasing two to four fold by the end of this century, it is clear that our global agricultural system will be strained to the limit. We have seen during 1973, that *world* food problems interact intimately with our own national system of food production. I want to make two points:

World food production is sharply dependent on weather and climate and its fluctuations.

We must learn to anticipate climatic changes, whether occuring naturally or as a result of human and industrial activities. This problem can *not be* solved by a single nation. It must be and is being addressed by international efforts. Next summer there will be convened in Stockholm a special summer study addressed to the kind of programs that need to be mounted during the First GARP Global Experiment in 1977–78 in order to illuminate the physical bases of natural and man-made climatic changes. The success of these diliberations and the programs emanating from them would be markedly enhanced were they to be carried out within a milieu in which international agreements had been reached eschewing the hostile uses of weather modifications. There is much more than the success of a scientific program involved. What *is* involved is an effort to provide the body of knowledge upon which policy decisions vital to our national self-interest depend.

The second issue has to do with a "sleeper" in the energy crisis. It is crystal clear that our current energy shortages simply reflect imperfections and artificial barriers in the extraction, transportation, refining and distribution of fossil fuels. These are socio-economic-political problems which can be resolved. If one looks beyond the current set of difficulties, it is equally clear that we are going to have adequate energy for the next hundred years. In fact, with a doubling time of something like 15 years in the world consumption of energy, long before our fossil fuels are exhausted we may well be confronted with one of the most major policy decisions the world has yet confronted. I refer to the limited capacity of the biosphere to absorb heat without inducing unacceptable pertubations in global wind patterns and hence world climate. This matter is now under active study by the presidentially appointed National Advisory Committee on Oceans and Atmosphere which communicates directly with both the executive and legislative branches of our government. Simply put, the concentration of heat discharged into the atmosphere may turn out to reach a high enough value within the next hundred years that we will have to place constraints on the population, on the population distribution, or on the energy consumption per person. The policy

implications for the world, and in particular for our nation which has such a high consumption of energy per capita, are obvious. To assess the seriousness of this matter in a sound and thoughtful manner, to fashion the tools and techniques to analyze the relevant issues and to go about the task of acquiring the necessary knowledge to undergrid the policy decisions is an effort which no single nation could possibly undertake. Once again I am trying to make the point that the treatment of atmospheric problems *must* be internationalized in our own national self-interest.

The third issue concerns the matter of catastrophic hurricanes. If one simultaneously looks at the accelerating concentration of population along coastal zones and the seventy-year record of hurricane entries into these coastal zones, one is led to the sobering conclusion that we seem to be locked in on a course which will lead us inevitably to a catastrophic event in which many *tens of thousands* of lives will be lost in a single weather episode. In fact, one can make a categorical prediction that such an event will occur sooner or later unless land-use policies are drastically altered, construction codes are brought into consonance with the kind of storm surges that mathematical modelling of wind, waves and coastal topography indicate, or alternatively, we develop the capacity to influence the intensity of hurricanes or change their direction. Other options for dealing with this hazard may be identified as the problem achieves public visibility. In the meantime, prudence suggests that we move ahead with research of the kind carried on in the program called "Storm Fury" in order to shed some light on the possibilities of modifying hurricanes. Here again, however, we are faced with a compelling need for internationalization of the effort. A strong case can be made for moving the research activities from the Atlantic into the Pacific Ocean because of the higher frequency of hurricane type storms in that region of the world. But tinkering with hurricanes, however soundly the scientific experiment is designed, is an extremely sensitive matter. Hurricanes are notoriously capricious and there is a natural tendency to ascribe any erratic behavior to human intervention during the course of scientific investigations into the possibility of modifying either intensity or direction. Once again I hope I made clear that more than the scientific integrity or the successful conduct of an intrinsically interesting scientific experiment is at stake. If there were any thought that a capability to tamper with hurricanes might be used as an hostile measure against another nation, the development of the knowledge base of the research would be seriously crippled. I hope we will not wait until catastrophe *does* strike and tens of thousands of our fellow citizens are drowned, to take the action that seems to be so clearly indicated.

Mr. Chairman, in these brief remarks I have tried to differentiate between the point of view that international agreement on environmental modification should be sought because it is "good" and the point of view that at least several grave societal issues that directly affect the self interest of the United States require for their resolution the formalization of international understanding and agreement. Somehow it seems inconceivable to me that the policy makers in this great nation of ours who have shown such wisdom and imagination in opening up lines of communication with potential adversaries can not be persuaded that the course you propose is not only statesmanlike but pragmatically in our self interest. After eight years of frustration over the failure of our nation to exercise initiative in this matter, my hopes have been rekindled by these hearings.

Two items by way of conclusion:

Since the hearings in 1972 the Committee on Atmospheric Sciences of the National Academy of Sciences has published another report on *Problems and Progress in Weather and Climate Modification* and re-emphasized and reiterated a position taken earlier that: "In order to safeguard the life-sustaining properties of the atmosphere for the common benefit of mankind, *the U.S. Government is urged to present for adoption by the United Nations General Assembly a resolution dedicating all weather-modification efforts to peaceful purposes and establishing, preferably within the framework of international nongovernmental scientific organizations, an advisory mechanism for consideration of weather-modification problems of potential international concern before they reach critical levels.*

Finally, it is time that we put this murky matter of the military use of weather modifications in Southeast Asia behind us. Now that we have disengaged from active combat there is no reason, in my mind, that the documentation describing those operations and the evaluation of their effectiveness can now be declassified and made available to the scientific community. I am persuaded that this would have a salutory effect on the troublesome issues that revolve around this questionable course of action.

Senator PELL. Our final witness today is Prof. Howard Taubenfeld, of the Institute of Aerospace Law, Southern Methodist University of Dallas, Tex.

I notice you have a fairly lengthy statement, and I wonder if we could have this inserted in the record.

STATEMENT OF DR. HOWARD J. TAUBENFELD, INSTITUTE OF AEROSPACE LAW, SOUTHERN METHODIST UNIVERSITY, DALLAS, TEX.

Mr. TAUBENFELD. Well, sir, I am of Germanic descent, and it usually takes me about 2 hours to get to the verb. I do apologize to you for not having been able to furnish the statement before today. My wife, who is a political economist, and I work in these areas together, and sometimes the negotiations on an agreed draft are something like what I think must go on between the Senate and DOD.

In any event, I, in view of the hour and of your patience in sitting this long with all of us, would like to call attention just to a very few points and hope that you may have the chance to look at the document at some other time.

Senator PELL. And it will be inserted in full in the record.

THE 1967 STUDY ON INTERNATIONAL IMPLICATIONS OF WEATHER MODIFICATION

Mr. TAUBENFELD. Thank you. To begin with, our work is concerned only with the weather modification aspects of the proposed treaty. We have been working in the field of international implications of weather modification since 1967 when the State Department asked us to do a study for them on international implications.

That study was published in the External Research series of 1968, and I think has met the fate of many such studies. Just a few years ago I was happy to present to Prof. Dean Rusk a copy of the paper which he had asked for several years ago as Secretary of State and which obviously had never before wended its way up that far.

AGREEMENT WITH LIMITING LARGE-SCALE HOSTILE MODIFICATION USE

It is quite clear that we all agree with the idea of limiting large-scale hostile modification use. We agree with "dedicating all environmental work to peaceful purposes," just as we are all, most of us, still in favor of motherhood and apple pie.

The remarks that are contained in the paper, to some degree have been expressed by others here, and I would like to, in a sense, reverse what we did in the paper. We did try to comment on this draft treaty, but then to go on to some other matters that we are very concerned with, which are a takeoff from it.

LANGUAGE OF TREATY

I would like to suggest, as other have here, that the treaty as presented and as you yourself have suggested, sir, is in some ways too broad as far as language goes. I, myself, as an international lawyer looking at the world today, would not be particularly favorable to eliminating in this way what I would like to call small-scale use without getting into the question what "small scale" means. Weather modifica-

tion in its "local" aspects may be at least as humane as weapons that are currently permitted.

I would like, myself, to see a much broader approach to the use of weapons, and of course, in the use of war itself.

I would also, having been in the field for almost a decade, have to give a nod of appreciation to the work that has been done by groups like Naval Research people because they have advanced the general art of weather modification in a field where funding has experienced a decline. There might be some real problems in taking them out of the field if this is what it amounted to.

Moreover, and a point which perhaps could only be cautiously made by people in defense, but which I think really does need consideration, if it does become possible somewhere, sometime, by somebody to make or to initiate major climatic shifts, it would be my hope they would be reversible, and one needs knowledge in order to know what one would do if faced by this nearly total weapon.

I think some research which in a sense has this kind of military orientation, though it would be the same research as for other purposes, should be continued. However, as you said, it is not so much wording and particular small points of the treaty that are important.

Our main problem with the treaty is that in a way indirectly expressed by some of my predecessors here, the treaty is too narrow for what I see as the major problems which the world may very well confront in the not too distant future.

We have been talking about the shifting of climate as a major weapon and as a horror story. It might certainly, if it were possible and could not be countered by other weather weapons, be countered by the threat of use of nuclear retaliation.

You are talking about national survival. But when Dr. Teller a decade ago talked about weather as a possible source of the last World War, or the cause of it, I don't think he was talking about weaponry; he was talking about how important weather is to countries and the real threat that it would pose to any country to see substantial shifts, whatever their reasons, in its weather, and hence its resource base.

It is perfectly clear that climate shifting, or climate modification, if it developed in anybody's hands, would be bound to be destabilizing to the international system and would very probably be in one context or another a cause of war.

Our problem though is that any wide scale effects may very well be just as devastating to many countries, to many persons, to the earth itself. They come about from a use of climate modification in war or from experiments on a broad scale by some scientists. "Let us see if the Arctic ice really will go out if we try one of these things."

There has also been talk of at least two kinds of modification done entirely for local purposes. The Russians talk about reversing rivers in Siberia to provide more water in central Russia, which is definitely needed. It would also presumably mildly affect, if it did no more than that, their northern coast by warming it, and that would be useful to them.

There is talk about removing the Brazilian forest. Each of these might in turn cause a catastrophe on earth. Neither one is being done or is being contemplated as a weapon or even in any sense to seriously dislocate any other country, yet the effects are of concern to all of us.

INTERNATIONAL PUSH BY UNITED STATES NEEDED

Our suggestion is that what is needed is an international push by the United States. I don't think anyone else will do it—an international approach to large-scale modifications. In this sense, the treaty suggestion may be unfortunate in focusing on weather modification as a weapon, although it is certainly a dandy way to get attention to the need of the field.

It isn't, I think, large-scale use of weapons that is the major concern, because it seems to be doubtful they would be used. They can be countered in other ways. Weather modification in turn; nuclear bombs, if necessary.

It seems to me we need to focus attention already on things which are going on, that is, the potential large-scale shifts caused by large-scale scientific experiments, large-scale changes for other purposes, and perhaps most particularly, large-scale industrialization.

It is perfectly clear, as the Stockholm Conference showed that you can't simply say to a developing country: "Don't industrialize." Development is a very complex question which has had attention focused on it and which I don't think you want to pay attention to here.

RIGHTS OF EACH COUNTRY

We suggest in our 1968 study, and I didn't see any particular reason for shifting, that an overall approach even now to the problems of large-scale climatic shift (which would, of course, include large-scale shifts used as weapons) would have to start with the notion of the inviolability of any nation's resource base, including its right to its "normal" weather, whatever that was, so that all countries would be protected.

There is then the additional right of each country to permit or conduct controlled experiments to control and improve the national weather, so long as this is not undertaken aggressively, and is undertaken with due care for requisite over-all safety and for peaceful purposes, and does not affect other nations' parallel rights.

NEED FOR MASSIVE INTERNATIONAL COOPERATION

You would need for all of this massive international cooperation through information sharing, consultation, joint programs, joint controls, perhaps licensing, to achieve beneficial use. You would need to provide against economic disaster and this might very well slow the developments. It is true you would also need international political consensus in a region, or worldwide, before any major modification efforts could be permitted and this too would slow the development.

TREATY SOLVES ONLY PART OF CLIMATIC-CHANGES PROBLEM

My small fear, sir, is that even if there were a treaty in this form, if a treaty limited to the banning of large-scale use of modification techniques in war were accepted (and I think if it were limited to those large-scale uses it might be acceptable to our DOD) it is my fear that we might then believe that we would then have solved the problem of large-scale climatic changes. I think that we would have approached only a very small part of it.

We have much more argument in the paper but I think that is sufficient for this moment.

Senator PELL. Thank you very much.

HURRICANE MODIFICATION

Hurricanes may be a point I should have struck on before among the various weapons that have been mentioned. I noticed that you are professor of aerospace at Southern Methodist University.

Not now, but as the years go by, would we be able to create and direct and point a hurricane?

Mr. TAUBENFELD. I always answer questions like that by speaking as a professor of law. My advice on technological matters would be as follows:

It seems to me that there is scanty but good evidence that some effects on hurricanes is, are, whatever the word is, possible. The work will shift to the Pacific, as you know, in 1976 without participation of the Department of Defense for a number of reasons, and I would assume that it might be possible in time to steer major storms.

I don't know whether there is a notion within the state of the art foreseeably how one would create a stupendous storm of the type that a hurricane represents and steering is a word that the people in the field don't want to use.

In fact, one of the dilemmas now, I suppose is that it would be easier if there was feeling you could steer a hurricane. Right now what you can do, perhaps, is to spread it out a little bit and that leads to a question I now ask our scientist friends each time we meet as a study group on implication of weather modification. Which would you prefer, a hurricane that was coming in and would probably hit a shoreline 50 miles long at 100 knots, or one that was coming in at 85 and would hit the coast for 75 miles?

That is a terrible dilemma and I almost hope that science doesn't find the answers to hurricane modification.

I have no technical information as to whether this would be feasible. I would like to make one point on scientific information.

EFFECTS OF MAJOR INTERNATIONAL PROGRAMS

Dr. MacDonald, in his eloquent statement, spoke about halting this kind of research; that is, the potential of using weather modification or other environmental techniques for war.

We make a comment, maybe a suggestion if you choose to take it that way, that one might very well argue that GARP [Global Atmospheric Research Program] and all of the other major scientific programs in atmosphere should be halted because those are the kinds of programs that are going to demonstrate and give us the knowledge and perhaps give the basis for eventually doing this sort of thing, controlling the weather.

I don't think that most of the scientists have any feeling that these major international programs should cease and yet those are the ones I rather think, not the limited work in national defense laboratories, which are going to form the basis for ultimate weather modification on a very large scale conceivably.

Senator PELL. Thank you.

INTERNATIONAL LAW AND WEATHER MODIFICATION

What international discussions have been taking place concerning the possible extension over weather modification of the body of international law that is being developed in connection with nuclear testing and chemical and biological warfare?

Have there been any international discussions on this subject we are talking about?

Mr. TAUBENFELD. Not formal that I know of; very little on the informal side. There are, as far as I know, and again speaking as a professor of law, there are certainly no formal international agreements that the United States and other countries participate in with respect to weather modifications.

The United States has talked informally to Canada when we wanted to seed over the Great Lakes. We have talked informally to Cuba and to the British about the Bahamas, about the hurricane work. We certainly talked to the Philippines about potential hurricane modification. The Japanese we are talking to informally because they are very upset about the possibility of our doing hurricane work and typhoon work in the Pacific and I don't know if anyone has talked to the Chinese Communist Government about modification. I would be interested in their reaction.

Senator PELL. If it was correct that the United States employed weather modification techniques in the Vietnam war, specifically the insertion of silver iodine in cloud formation, does such an operation violate any present existing principle of international law?

Mr. TAUBENFELD. As far as I am concerned and as far as my studies have gone (I have had two teams of students trying to work this up, too), the answer in my judgment is no.

JUSTIFYING WEATHER MODIFICATION UNDER INTERNATIONAL PRINCIPLES OF SELF-DEFENSE

Senator PELL. Do you believe the United States can jusify the use of weather modification as a weapon under the international principles of self-defense?

Mr. TAUBENFELD. If you are talking about rights that involve also consideration of United Nations Charter, that is, no use of armed force except in self-defense, then we can only justify any use of force in that context. I would have to, at this stage of international relations, and considering what I judge to be the very limited capabilities of weather modification techniques, answer a little bit as Pierre St. Amand did in the quotation you read.

Weather is, if you like, a potential weapon, and I see no reason why it should not be used, legally speaking. I cannot in fact myself see any reason why it should not, in the present state of the arms control legal framework, be used from the moral point of view. If it is possible to prevent the enemy from getting to the battlefield with guns and equipment by making a road muddy, it is very hard for me to see why that should be illegal when it is permissible to blow him up once he gets there. I find that a dichotomy that is very hard to understand.

Now, if you are talking about some future worth, in which we have much sounder controls over all kinds of weapons in fighting, I would like to reconsider that.

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COMMENDATION OF WITNESS

Senator PELL. Well, I thank you very much indeed, Professor Taubenfeld, and thank your wife for her contribution to your statement which we look forward to enjoying. And this concludes this hearing of the subcommittee which will now adjourn subject to the call of the Chair.

[Dr. Taubenfeld's prepared statement follows:

PREPARED STATEMENT OF DR. HOWARD J. TAUBENFELD, INSTITUTE OF AEROSPACE LAW, SOUTHERN METHODIST UNIVERSITY, DALLAS, TEX.

While the evidence that the United States was probably engaging in some form of weather modification activities in Southeast Asia seems to be one of the most important generators of current efforts to bar, by treaty, environmental intervention by the military,[1] some commentators have been concerned with the possibly disastrous effects of conscious and unintended large-scale weather modification activities for many years now.[2] For a number of reasons, developed hereafter, while we remain very much disturbed by the major political conflicts and serious systemic destabilizations which can be expected if certain large-scale weather modification techniques become operational we can only support the creation of a treaty of the type contained in "the Pell resolution" after modifications and then with some remaining reservations.

We do not propose to rehearse in detail here matters which earlier subcommittee hearings and several other publications have examined extensively. In brief, these earlier materials, as well as many discussions over the years among concerned individuals [3] suggest that support for the Pell Resolution comes from diverse sources and concerns, most of which contain the kernel of an important consideration for society. In varying degrees, these include concern over (a) the potential risk of major and/or permanent damage to the world environment or to that of a country from unrestrained intentional large-scale wartime modification activities; (b) the possibility that modification as a weapon may be indiscriminate in its effects, and/or its results may be very difficult to control or even to predict; it would thus tend to damage the civilian, as well as the military component of an enemy, and, indeed, it might damage non-enemy regions as well, perhaps significantly, for it might trigger much larger climatic changes than were intended. In general, these two can be summed as the fear of a deliberately induced poorly-controlled natural catastrophe; (c) it might be most useful primarily against "civilian" targets; (d) the possibly destablizing effects of weather-switching knowledge in the hands of one or more nations which could use it as a threat of huge scale damages in wartime and therefore as a type of "total weapon," or simply as a means of improving their own weather, in a way which might damage the weather of others significantly; (e) the feeling among scientists and others that "science" and the work of well-meaning "scientists" should not be used for such purposes as weaponry and certainly not for the elaboration of new "total weapons" of this type; (f) the feeling that (1) *any* move or (2) any credible, safe move towards "arms control" is useful—a "step in the right direction" towards establishing, eventually, an overall system of arms limitation, and control, and binding international conflict resolutions institutions; (g) the feeling that one is here intervening in God's handiwork and that this is, of necessity, wrong and dangerous. Of these, it is primarily the first three and most especially concern over the possible emergence of what might well be a new total weapon even less controllable than the existent ones which are alluded to in the Resolution and the draft treaty as bases for concerned action. We will return briefly to all but the last of these other concerns as well.

To accomplish its ends, the treaty proposes a ban, "at any place," on "any environmental or geophysical modification activity as a weapon of war" and on "any research or experimentation" directed to that end, while formally excluding "any research, experimentation, or use for peaceful purposes." Weather modifica-

[1] See, generally Davis, "Weather Warfare: Law and Policy," 14 Ariz. L. Rev. 659-688 (1973), and sources cited.

[2] See Taubenfeld & Taubenfeld, External Research Series, U.S. Dept. of State, 1968: "The International Implications of Weather Modification Activities," "Some International Implications of Weather Modification Activities," XXIII *Intl. Org.* 808 (1969), and sources cited in these two items.

[3] For example, at the all day meeting on weather modification at the AAAS meeting here in Washington in December, 1972.

tion is defined as including any activity designed to, or in fact effecting precipitation change, hail, lightning and fog change, storm system change and long range atmospheric effects anywhere.

While we have long shared this Subcommittee's concern about major environmental alterations and have often cited Dr. Edward Teller's prediction that "weather" might be the cause of the "last" world war, the present draft treaty seems both too broad and too narrow to adequately improve human security on "spaceship earth," once we can deliberately make major, widespread and/or irreversible modifications in the weather and even the climate.

1. The proposal is too narrow:

(a) While weather modification technology is, today, concerned with at best modest, short-run changes in relatively small geographic areas, it is the possibility that large-scale changes in climate may occur which should be the focus of concern. Whether such changes come about as acts of war, from unwise large-scale peaceful experiments, from intentional acts designed for other purposes, such as to improve a country's own weather or clear its forests for other productive uses or, indeed, from such events as the industrialization of a new area, the effects on mankind could be devastating. We do not now know enough scientifically to know which attempts to modify nature are likely to be very damaging or even disastrous. If a treaty is attainable at all now, it seems most important to focus on a proposal like that suggested by SMIC which would prevent "large-scale" (they suggest over one million square kilometers) or persistent or long-term modifications; at least until the scientific community achieved consensus on the consequences of the activity.[4] We would, of course, certainly want to broaden this to add other crucially important criteria from society's point of view before commencing any environmental modifying experiments or operations in which long-run and/or ultimately significant effects on others are implied even if these considerations may at times delay the scientific quest. Most important we would like to require that *political consensus* be achieved amongst all potentially significantly affected states. It seems possible to argue that each affected party has a right in international law to be consulted and quite possibly to deny its acquiescence to actions by others entailing significant damages to itself.[5] Presumably no state would freely give its consent to experiments or operations unless it were convinced that it would not be harmed thereby. This in practice is likely to mean that it feels it will ultimately gain therefrom—at least from the new knowledge sought.[6]

Note, however, that this traditional approach to limiting potentially deleteriour international actions that might damage another state incorporates a strong traditional bias endogenous in the international system. That bias is clearly in favor of the status quo, including in this case the present distribution of good weather, and other desiderata, for example, a livable environment, with industrial development. This immediately exposes the political difficulty in the long run in

[4] This also seems similar to the suggestions supported by Dr. MacDonald at the "Pell Hearings" in July 1972 (p. 73, note 4).

[5] See Taubenfeld and Taubenfeld, op. cit. suptra, p. 1, note 2.

[6] See Taubenfeld and Taubenfeld. In some cases it might well be difficult to secure this kind of international agreement to allow an experiment of potentially widespread impacts to be undertaken, as for example, in "the Needles" case. The problem then was that no scientific consensus as to the implications of and safety of the experiments had been achieved. The Needles did not prove to be hazardous. But the risk was taken for all by the U.S. Surely some better controls over possibly hazardous experiments in nature are desirable. But this remains a complex problem. For example, it appears likely that some nations not ready to exploit new scientific or technological information may not be anxious to have it developed, not until they are ready to obtain their share of the benefits therefrom. This matter was discussed in the Ocean Affairs context in Mexico at the AAAS meeting of June-July, 1973. So far, however, it appears that scientists have normally been able to "work things out" when they aim to undertake an international experiment (or one which would significantly impact the territory or seas or people of another state). One popular pragmatic system has been to interest their parallel counterparts in other nations in persuading their governments to allow the scientific research in which they could participate to take place. For this international system in which states can bar entry to scientists this seems a politically practical approach. But as we have been suggesting, a scientific consensus on the scientific safety and the scientific promise of an experiment is not necessarily sufficient to assure its political safety and the desirability of an experiment in the current international system. This in turn should be assured, it would seem. Unfortunately, even if each nation looks after itself and political devices for exciting the interest of all needed participants are negotiated, it is not necessarily true that experimentation pregnant with international dangers—such as implicit dangers to the peace, will not be agreed to by the experimenting parties. For example, two states might agree on an experiment, the deleteriousness of which would fall primarily on a third or others. Some general norms on the safety standards and on the burdens of experimentation-imposed damages seems desirable. It goes without saying that if it is not sufficient for such considerations to have a consensus among the experimenting states that it is certainly not sufficient for the safety of humanity, or for security of the peace, to seek to secure only a consensus amongst the scientific community. Of course the scientific community's input as to the safety, promise and scientific implications of and impacts implied by the experimentation in question would normally be heavily weighted in the decision processes of most societies. And including some agreed provision for encouraging the freedom of the scientific quest, at the international level, so long as it does not endanger other very important human values (only one of which is physical safety, another, for example, being peace) seems highly desirable. International study as to how this can be implemented—the institutional alternatives for promoting science safely seems likewise desirable.

adopting a conflict resolution strategy relying primarily on such a self-negating agreement as that no state will harm another by inducing environmental or weather changes without its consent. Such a self-denying system has not worked in the past and cannot be expected to work in the long run to control international conflict over resources and the weather as a major resource. The problems are obvious. What about those states initially poorly endowed with good weather like the Soviet Union? Once they learn how to improve their situation and become strong enough to challenge the status quo, they can be expected to make efforts to recarve the status quo distribution of good weather even if that should happen to impose some losses on other states. They may try to get consent by threat or threaten war for retaliation. Hard bargaining and repetitive international crises and escapades of brinksmanship can be expected if improving one nation's weather dramatically must entail serious losses to another—unless these potentialities are somehow successfully neutralized by better conflict resolution machinery than has been adumbrated at the international level in the past.

This can be thought of as another version of the ancient problem of maintaining the peace: how to accomplish and accommodate peaceful changes of a redistributionary nature in a system in which the consent of the damaged parties has to be obtained, not primarily for legal reasons but because otherwise they may be expected to fight for the status quo if they believe that will help them improve the outcome. Various ways of imposing changes in favor of the strong at least, which are short of war, do exist, for example, by diplomacy, including promises, threats and various expressions of superior bargaining power based on various sources of power, economic, geographic, psychological-legal, as well as political, etc. all compounded together in some international forum like the U.N. (A court won't do for the Power demanding more than its status quo rights.) But all too often war has become the ultimate engine of redistributionary change in the international system. In conclusion then, though we do suggest that any treaty on weather and environmental modification adopt this normal legal and political strategy for allowing a sovereign the freedom to act to improve his knowledge or welfare, to modify the weather, for example, only with the consent of other damaged parties in cases where these activities are likely to affect other nations' weather and resource bases in ways they do not consider desirable, we do not consider this would be likely to be in the long run a sufficient design of a political-institutional setting for accommodating major international weather modification possibilities peacefully into the international system, particularly if redistributions are unavoidable—if some weather must be worsened, as seems likely. As a beginning, as a part of a strategy for which there is good historic precedent—for keeping the peace until a more adequate institutional design can be negotiated, we propose such an approach, with the caveat that it does have a conservative status quo bias and therefore is likely to be challenged eventually on this ground by nations which might gain disproportionately.[7]

At least initially it is likely to constrain somewhat the pursuit of scientifically or politically dangerous experimentation to require that all likely significantly affected parties be (1) identified and (2) consulted for their agreement. Note at present levels of scientific knowledge even the first of these, the identification of all parties likely to be impacted in the long run by a modification experiment or program requires much more information than is presently available.[8] To get this would necessitate normally much more "experimentation in computers" or if it is absolutely necessary to use a human environment as a laboratory, this would in logic require both careful precautions to limit the effects on humans and their environment of experiments to find out about impacts—and far more comprehensive efforts to compensate those damaged in this pursuit of essential scientific knowledge than has been traditional even in the traditional U.S. approach to the liability of those who affect others deleteriously in the pursuit of knowledge for the benefit of all by scientific experimentation. Thus, in sum, we suggest that, to protect humanity, its weather and ecosystem and the resource bases of the nations of the world community from deliberate or unexpected but in principle foreseeable damage due to scientific experimentation or, later, implementation in weather modification, seismic manipulations, etc. that a treaty be sought on the broader lines suggested above rather than on the narrower Pell approach.

[7] And by some scientists who are likely to dislike any long run constraints, no matter how politically or even biologically sound, on their freedom to explore.

[8] For example alternative methods of intentionally or unintentionally melting the Arctic ice cap is one major experiment in nature, frequently mentioned in the literature which quite possibly might effect changes in major weather patterns globally in ways that are debated. Scientists seem agreed already that anything like this, with potentially world-wide consequences should not be undertaken until better understood, or should be undertaken only after careful worldwide scientific scrutiny. We have suggested that worldwide political scrutiny should likewise be required despite the implied delays in experimentation.

If major conflicts over the environment or over the distribution of good weather are allowed to develop because some states are likely to be damaged, whether or not deleterious effects are intended by those states seeking to modify the status quo of nature to their own advantage, major world power confrontations in which the use of "total weapons" of one kind or another are considered, seem likely. In such a case (1) it seems on the face of it very likely that it would be difficult to enforce a Pell-style treaty of self-denial of "the weather weapon" and (2) at first blush, at least, it would appear in these circumstances, not necessarily desirable to do so. Major weather-switching might under some circumstances be the most preferable "total weapon," allowing, for instance, human life to persist and, in the good climes after the peace (presumably occupied by the winners) even to prosper. Unless, of course, as also appears likely in the case of nuclear powers, the would-be losers would respond with other even less humane total weapons, i.e. with nuclear devices—or at least pose a credible threat to do so.

It seems worth briefly exploring these lines of reasoning, even despite the widespread distastefulness of such analyses. Judging from past experiences with disarmament commitments the credibility of a self-denying treaty obligation to eschew using major weather modification as a weapon is likely to be poor in times of major war. Should these technologies be achieved, as suggested, it can be expected they will be used whenever, after all the circumstances are considered, it appears likely to be profitable for a state to use them. In this case, the most probable techniques involved seem unlikely to be secret or to require significant conversion to be switched from peaceful to wartime purposes. Since they are also likely to be generally very broadly sought after and available as a relatively cheap, potential source of economic self-help, most nations, large and small, are likely to have credible access to this class of potent ally devastating weapons. Also, this could be expected to be an "n-country" world in the case of the "weather weapon" very soon after scientific discovery. How then could any nation really rely on a Pell-type self-denying treaty to protect it from this potentially total weapon?[9] Indeed, especially for small non-nuclear states this would appear to be the optimal total weapon readily available, cheap and less likely to lead to accidental total irreversible damage or annihilation. In sum, it seems quite reasonable to guess that, since the technology of weather switching is likely to be widely available and to result in a less devastating "total" weapon than nuclear devices, that threat to resort to it, if such threats were not made illegal, might become relatively frequent in the present international system. This might, indeed, also increase the risk of a nuclear counter threat or even a nuclear riposte by the nuclear powers.

Thus it seems worth attempting to put at least a legal ban on aggressive use of major weather switching or environmental modification. Also ultimately it seems likely that it would be this—this likelihood that if major deleterious weather modification became possible, it would become part of the menu of terrors which the nuclear power of the nuclear powers, the most total weapon, is balancing, which can be expected to be the real enforcement behind a Pell type self-denying proclamation prohibiting the resort to weather and environmental modifications.[10] But again this promises to work most securely against non nuclear powers. How to effectively deter Soviet or Chinese aggressive self-improvement of their initial weather endowment remains unclear and crucially important. Again a general ban on the weather weapon, plus a ban on damaging others without consent by environmental modifications would at least establish a tenable legal posture for the rest of the world, which would, no doubt, have to be supplemented by some creative machinery for international weather-environment redistributionary conflict resolution.

In sum, it appears crucial to design a system for managing all important international conflicts over weather and the environment, which are implicit in an unrestrained scientific free-for-all to discover these techniques of manipulation of nature, followed by an unconstrained economic competition to grab off the best modification of the original natural distribution. It is these competitions among major powers which are likely to be radically destabilizing in this international system; and which therefore attention should focus upon primarily.

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[9] Indeed, the weather weapon may never be used, as gas has not generally been since the First World War, because it is too difficult or costly to control and might boomerang.

[10] Should the international system some day succeed in removing this nuclear deterrent to aggressive weather switching for peaceful or war purposes then the self-denying obligation not to use weather-environment aggressively or to damage other nations even for peaceful purposes could again lack enforceability and credibility. Even so, since most nations could quite likely be expected to be able to resort to the weather weapon, it is less likely that this would lead to a unilaterally destabilizing disarmament. And more important, a world that could achieve a credible nuclear disarmament would presumably provide as well a much safer, less volatile world system than the primitive community we have been assuming which relies heavily for stability on this balance of terrors.

In addition, it seems evident that it has to be the world's business since it is likely to be a cause of major international conflict if a new ice age—or some other major environmental perturbation is precipitated by nation A's use of wide-scale modification in a war with nation B, or by the industrialization of Africa,[11] or the clearing of the Brazilian forests, or by the scientists of country C in experimenting with climatic shifts, or by the actions of the Russian state in seeking to change the direction of rivers to bring irrigation water to central Russia or to warm an Arctic port. We do not suggest that all issues be lumped together or that they can be treated identically, but some potentially productive approach to all of them is now called for.

Furthermore, since we can assume that no nation would like any other nation to be able to, or to have a legal right to, initiate major weather changes which would affect it deleteriously, and since at present no nation has achieved that capacity, this would seem a reasonably promising time to seek a generally beneficial treaty arrangement for the control of damaging intervention in the weather, climate or environment. Perhaps a treaty (or even a UN declaration), of the type we suggested in 1968, is in order on the Peaceful Uses of Weather Modification Capabilities. In contrast with the present Pell proposal we feel this should include an attempt to forsee and neutralize as far as possible all the important dangers to the peace potentially implicit in these new technologies. Such an effort would include pledges on

(1) The inviolability of all nations' resource bases, including the rights to their normal moisture and their weather.[12]

(2) The right of each nation to permit or conduct controlled experiments to control and improve the national weather so long as this is not undertaken aggressively but undertaken with due care for the requisites of safety and for peaceful purposes and does not affect other nations' parallel rights and rights under (1) unless the express or tacit consent of the latter is obtained.

(3) The need for international cooperation through information sharing, consultation, joint programs and/or controls, possibly with licensing, to achieve beneficial use of the possibilities of controlling weather modification for the greatest benefit of all mankind and for sharing the costs and gains fairly. The forms cooperation will take should keep pace with knowledge and unfolding technological capabilities.

(4) The need for international cooperation among the affected states for effectively controlling pollution and the damages from inadvertent weather modification while assuring the right to pursue industrial development to all.

It is surely time now to think further about defining and achieving the optimal international institutional strategy for regulating the whole potential range of environmental modification activities to assure they are normally undertaken only in the common interests.

Some years ago we suggested, not hopefully, but not entirely facetiously, that, since the development of any capabilities to create major weather changes might be extraordinarily destabilizing in the current world system of order, that all such major international research projects in climate and weather as GARP, which are designed and intended to yield the information which would make a "weather weapon" much more of a real possibility, be postponed or halted until such time as the necessary actions to cope peacefully with these possibilities also seemed likely.

We can not realistically expect the scientific community to willingly give up such major quests for understanding. We therefore agree with the Subcommittee that international action of some sort to safeguard humanity from the dangerous potentials of such new knowledge is already appropriate. We feel, however, that the approach to large-scale weather modification should be more inclusive than that of the proposed treaty in ways already mentioned. We also feel that the treaty goes too far in other respects.

2. The proposal is too broad:

(a) There are several possible modification techniques which seem inappropriate for banning in part for humanitarian reasons at least so long as armed conflict by traditional weapons remains internationally lawful. The most obvious case is

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[11] The "industrialization-pollution" set is clearly very untractable without some modification of the currently typical actions of the actors in the international system. It is by no means impossible to think of approaches which would induce the developing states to cooperate to minimize world problems so long as they do not have to pay for this luxury.

[12] Since it may be scientifically the case that any modification effort may have some effect, however slight, on another (or on every other) country's weather resources, it should be made clear that this principle does not bar all activities. If an effect is minor and unintended, and can be readily and fully compensated for, it presumably should be tolerated. This principle makes it clear that damage must be avoided where possible and paid for where minor and inadvertent.

clearing fog at airports, now done routinely for "cold" fog at some places by the military and at civilian airports. No long run or wide area effects have ever been reported. While aircraft are legally permissible in warfare, no country would presumably accept a ban on modifying airport weather to make flying safer, even though this might facilitate an increased number of missions. If one moves up from this one step further, should clearing the weather over the English Channel on Jule 4, 1944, had it been possible and of only temporary local effect, be conceived of as a crime? While use of high explosives, flame, smoke for screens, and other unpleasant techniques for controlling a battlefield are permissible, it seems difficult to justify banning the use, if it existed, of a modification technique for creating or clearing a battlefield fog or for wetting or drying out the contested terrain. Battlefield techniques which primarily improve the functioning and safety and efficiency of traditional combat weapons are likely to be used by the nations. And perhaps even on balance they are likely to cut down the toll of warfare, to save lives. There seems little obvious reason to attempt to ban them; and little hope of doing so effectively. Even where typical environmental modification techniques are designed for use primarily or exclusively against civilian populations, they do not appear to be potentially as dangerous or as irreversibly damaging as other similarly utilized weapons of mass total war. It has become traditional in this century to attack the supply lines of an army, right back to the factories and populations. Effective limitation of the use of all such weapons of mass destruction should be attempted. A revision of the rules of warfare seems overdue. However, it should be remembered that present rules do purport to protect civilian populations. If they are ineffectual that itself is a lesson, a warning to seek for causes. And it must be further recognized that the twentieth century high technology all-out war has brought the distinction between civilian farm and factory worker and fightingman itself into question. Unless and until conventional warfare itself can be credibly limited to the military contestants it does not seem inherently more criminal to induce rain to fall on civilians rather than bombs. Indeed it seems more humane.

On the other hand, mass privation caused by enemy induced drought might well be more widespread than privation even by such more traditional weapons as blockade, pillage or seige. Even in such cases it seems probable that any such attempts to induce drought or otherwise destroy crops would be counteracted by responsive weather modifications or other counter measures so far as possible. For, as noted, the technology, even as it improves in reliability, seems likely to remain relatively simple, broadly understood, and generally available to poor as well as rich states. Nevertheless it seems reasonable to draw the necessarily arbitrary line somewhere near here between environmental modification techniques which can be classed realistically as new versions of traditional, limited weapons of war and which insofar as they yield temporary, reversible, limited modifications can be expected to remain quite legal; and those new weapons of irreversible or large scale environmental change which often can be used to indiscriminately damage whole populations and which might well be outlawed, in principle at least, by treaty.

(b) To the extent that the treaty would take the military completely out of research in weather modification, it seems too broad. First of all we have suggested that some environmental modifications be permitted as possibly more humanitarian—and no worse than other conventional means of warfare. These would have to be developed and tested by the military. In addition it seems doubtful that, with its present broad wording, the treaty could be accepted by the Soviet Union, where the military fire the shells and rockets in civilian hail suppression programs for example, or in the United States, for that matter where the military have been called on to lend planes and equipment to drought relief programs (in Texas), and have provided support for other primarily civilian research programs such as Project Stormfury. They have in general worked with civilians of this and other countries in learning about severe storms, fogs, etc., they have developed new modification technology of general utility, for example, silver iodide delivery systems which others can use, in addition, one supposes, to pursuing some forms of "classified" research.

Weather modification is indeed another area in which it is difficult or impossible to segregate "militarily useful" from "civilian" research. Cloud studies, seeding techniques, everything, seem equally useful to weather prediction or flying and to both military and civilian pursuits. Thus, unless equivalent funding sources were made available to "civilian" modification research, and research in this field has in fact been cut back recently, removing the military from all research would probably slow the development of techniques for peaceful uses. Moreover, in the

absence of a secure enforcement system, even if a treaty banning use of any major "weather weapon" were adopted, it might well appear essential to those concerned with national security and international stability to continue to permit carefully devised military or civilian research on the development elsewhere of modification and/or counter-modification techniques. Even these programs should be designed to avoid major wide-scale research in nature until it is clearly safe and acceptable to all importantly affected parties. Thus some system of organized consultations and reporting seems in order even for nations which feel they must continue research to keep abreast of the technological possibilities and to maintain a capacity to detect and to counter potential major modifications or weather switches threatened by a non-party or a treaty violator, if such maneuvers became feasible. At minimum any damages caused to others from operations or experimentation without their consent should regularly be compensated for efficiency reasons as well as for equity. How to assure that military research units conform to acceptable group standards of environmental safety and responsibility, etc., however, remains a significant problem—not well resolved even within states like the United States and even more difficult at the international level. We do not mean to gloss that over. Surely it should be explored more than it has been before an indiscriminate "ban everything new" strategy is adopted.

Thus while supporting an approach now to preventing weather modification from becoming a new source of major conflict, we believe that the presently proposed draft treaty goes too far in an effort to bar military usage of potentially life saving, or at least inherently no more deadly, substitutes for other legal weapons in limited and small wars. At the same time it does not cope with the major problems these technologies raise—weather switching—intended or not—for peaceful uses which damage others and which would tend to be at least as harmful to the world's environment and more destabilizing to the peace than a major use in wartime. The proposed treaty needs major revisions, in our judgment, both to be more creatively useful to the security of the human community, even in its present state of development, and to have some chance of acceptance by the nations.

This brings us to the position of those who support all small steps to disarmament as "steps in the right direction." Our position is to pursue this strategy only when it appears on balance to yield a net move in the right direction, after considerations of self-defense and systemic balance are elucidated. Our nation and our world must not be exposed to substantial risks or the suggestion is probably a step in the wrong direction. Two dangers of such a "ban everything as soon as you can" strategy are (1) that even if successful, it does not eliminate war or the causes of war, nor does it limit the use of historically the most popular lethal weaponry—even of mass impact. It may therefore regularly be expected to eliminate the more humane new weapons along with the more deadly ones, in favor of continued use of those which have historically the most successful wartime applications. (2) Even more important such a strategy may repeatedly delude people into thinking they have definitively denatured the dangerous implications of a new technology, when they have not at all even attempted to cope with the major problems which it poses for society. We hope our discussion has pointed out some of both types of fallacy.

We do not think this is a bad thing if properly redrafted to permit restricted humanitarian-weather modifications and conventionally limited uses in wartime of these techniques. It even has the traditional escape clause so that states can always seek self-defense as they always have, by loosening any restrictions which seriously inconveneince them on balance in their pursuit of survival on their own terms. We think this is not enough, and because it is so very little, it therefore poses a substantial danger of being a fraud-of fooling people-of lulling them into believing that the major political dangers potentially implicit in the development of useful weather modification technology, for instance, for changing the status quo of nature in ways that traditionally have led to wars, have been coped with when they have not. Not at all. This proposal then is only a small partial step towards assuming that these new technologies will not induce Armageddon. This little step is likely to be far from enough, though on balance, if improved, it is not likely to be a step in the wrong direction.

We could endorse a proposal of this type, modified as suggested herein, as generally in the self interest of the United States so long as this is understood, since it should, among other things, facilitate the control by the Big Powers of the numerous countries, large and small, which will share these new technologies with

their potential for dangerous conflict. This promises on balance to be a legal convenience, but it is not likely to be an important achievement in neutralizing the major potential hazards to world peace and survival potentially implicit in these new technological achievements. How to do this optimally still deserves our primary attention.

[Whereupon, at 1 p.m., the subcommittee adjourned, subject to the call of the Chair.]

[Top Secret hearing held on March 20, 1974; made public on May 19, 1974]

WEATHER MODIFICATION

WEDNESDAY, MARCH 20, 1974

UNITED STATES SENATE,
SUBCOMMITTEE ON OCEANS AND
INTERNATIONAL ENVIRONMENT OF THE
COMMITTEE ON FOREIGN RELATIONS,
Washington, D.C.

The subcommittee met, pursuant to notice, at 2:30 p.m., in room S–116, Capitol Building, Senator Claiborne Pell [chairman of the subcommittee] presiding.

Present: Senators Pell and Case.

Also present: Dr. Pierce S. Cordan, U.S. Arms Control and Disarmament Agency.

Senator PELL. Gentlemen, I think we might as well get started.

Some of my colleagues will be coming in, but I think it is important to get on with this meeting today and lay out the record.

Why don't you introduce yourselves and then proceed as you will, after which I have a series of questions.

STATEMENT OF DENNIS J. DOOLIN, DEPUTY ASSISTANT SECRETARY OF DEFENSE (EAST ASIA AND PACIFIC AFFAIRS); ACCOMPANIED BY MAJ. GEN. RAY FURLONG, USAF, DEPUTY ASSISTANT SECRETARY OF DEFENSE (LEGISLATIVE AFFAIRS); LT. COL. ED SOYSTER, USA, ORGANIZATION OF THE JOINT CHIEFS OF STAFF; COL. ALBERT J. KAEHN, JR., O.D.D.R. & E.; AND WILLIAM CHAPIN, BUREAU OF INTERNATIONAL SCIENTIFIC AND TECHNOLOGICAL AFFAIRS, DEPARTMENT OF STATE

Mr. DOOLIN. Thank you, Mr. Chairman.

I am Dennis Doolin, Deputy Assistant Secretary of Defense for East Asia and Pacific Affairs. This is Maj. Gen. Ray Furlong, Deputy Assistant Secretary of Defense for Legislative Affairs, and Lt. Col. Ed Soyster of the Office of the Joint Chiefs of Staff, who will be your briefer today. If it meets with your approval, I propose that Colonel Soyster will give the briefing.

Colonel Soyster.

Colonel SOYSTER. The purpose of this briefing is to provide information on the only DOD classified weather modification activity—this being our rainmaking in Southeast Asia.

[Chart 1 follows:]

CHART 1

SEASIA RAINMAKING

[SUPPLIED BY DEPARTMENT OF DEFENSE]

A CLASSIFIED RAINMAKING PROGRAM WAS CONDUCTED IN SEASIA FROM 1967 TO 1972 WHICH EMPLOYED AIR DROPPED SILVER AND LEAD IODIDE SEEDING UNITS TO INCREASE NORMAL MONSOON RAINFALL.

PURPOSE OF OPERATIONS

Colonel SOYSTER. The purpose of this operation was to make difficult the North Vietnamese infiltration through the Laotian panhandle and Plain Des Jarres.

EFFECTS OF NORTHEAST AND SOUTHWEST MONSOON SEASONS

This area of Southeast Asia has two principal seasons—the northeast monsoon and the southwest monsoon.

During the northeast monsoon the rainfall is light or nonexistent and even unimproved roads are unaffected by the limited rains. During the southwest monsoon the rainfall is heavy and almost daily. As a result, the unimproved roads in this region become soaked and will not support vehicular traffic. From the beginning of our efforts in Southeast Asia, operational personnel would rely on the coming wet season brought by the southwest monsoon to contribute greatly to the enemy's logistic difficulties.

The close monitoring of troop and truck traffic along routes where rain had fallen verified beyond any doubt the naturally adverse effects of rainfall and accumulated soil moisture on the enemy's logistic effort. From April to mid-May, as the spring transition to the southwest monsoon occurs, it was found that even isolated thundershowers temporarily interrupted logistic operations. Most unimproved vehicular route surfaces are hard due to the relatively dry weather conditions that prevail in Laos during the northeast monsoon. When intermittent rain falls on this kind of surface, runoff is quick and virtually complete. However, as both the amount and frequency of rainfall increases—this is from the period of May through June, the ground begins to soak up more and more moisture until it becomes saturated. When this condition is created, the

ground remains "soggy" for extended periods with only moderate amounts of rain needed to maintain saturation. At this point, vehicular travel becomes extremely difficult if not impossible. Typically, by the end of June, the southwest monsoon is well established and soil moisture has reached the point where roads remain soggy. These conditions continue through September. The fall transition to the dry northeast monsoon then begins with less rainfall in the area.

OBJECTIVE OF PROGRAM

The program was to increase rainfall sufficiently in carefully selected target areas to further soften the road surfaces, cause landslides along roadways, and to wash out river crossings. These events normally and naturally occur anyway during the height of the rainy season. By seeding it was intended to extend the period of occurrence beyond the normal rainy season and to supplement the natural rainfall as required to maintain the resultant poor traffic conditions.

[Chart 2 follows:]

CHART 2

OBJECTIVE

[SUPPLIED BY DEPARTMENT OF DEFENSE]

INCREASE RAINFALL SUFFICIENTLY IN CAREFULLY SELECTED AREAS TO DENY THE ENEMY THE USE OF ROADS BY:

(1) SOFTENING ROAD SURFACES

(2) CAUSING LANDSLIDES ALONG ROADWAYS

(3) WASHING OUT RIVER CROSSINGS

(4) MAINTAIN SATURATED SOIL CONDITIONS BEYOND THE NORMAL TIME SPAN

TECHNIQUE USED

Colonel SOYSTER. The technique that was used takes advantage of an important natural process that causes rainfall in cumulus clouds in the tropics. In this natural process when a strong temperature inversion exists, clouds frequently grow to the level of the inversion and only occasional turrets succeed in rising to greater heights.

Senator PELL. What is an inversion?

Colonel SOYSTER. Normally temperature goes from a warmer to a colder condition as you rise in altitude. In an inversion it is reversed, that is the cold air is on the bottom.

As the turret passes the inversion, it rises first through slightly warmer air and then into a colder, much drier region. As the turret reaches its apex and begins to cool larger droplets of moisture begin to form and the previously white clouds begin to darken and descend into

the mass below the collapsing portion of the cloud. The falling drops grow by condensation for a short while because they are colder and then by collision with the underlying, smaller, more slowly falling droplets. The techniques employed, which I will describe next, accentuate this natural process by causing cloud growth with subsequent collapse. In many respects, effective seeding of a marginal convective cloud is akin to bringing a banked furnace to life. With this in mind, let me now describe the technique used.

In general, cloudseeding involves locating updrafts in clouds and releasing small amounts of seeding material into the updrafts. The seeding agent causes supercooled drops to freeze, releasing energy (heat) and a more rapid condensation of water vapor on the frozen drops than is possible on the liquid droplets, with, of course, the accompanying faster release of energy. Clouds appear to operate at near equilibrium conditions and even a small change in energy release causes a change in updraft velocity, heating makes the air rise faster and the updraft area and velocity is increased, sucking in more moist air from below and causing condensation throughout the ascending column.

This chart illustrates the air flow. As shown at (A), rapidly growing towers frequently develop a pileus, or small cloud directly above the updraft. This is a good indication of updraft position. Air comes in the bottom of the cloud, flows up through it, past the visible top and down around the sides, much like a bubble fountain. A downdraft surrounds the sides of the clouds, at least at seeding altitudes.

At (B)—Following seeding, the central portion rises rapidly and the base widens. Usually, the portion above the freezing level doubles in volume in 3 to 5 minutes. Updrafts inside are intensified, the total downdraft external to the cloud increases.

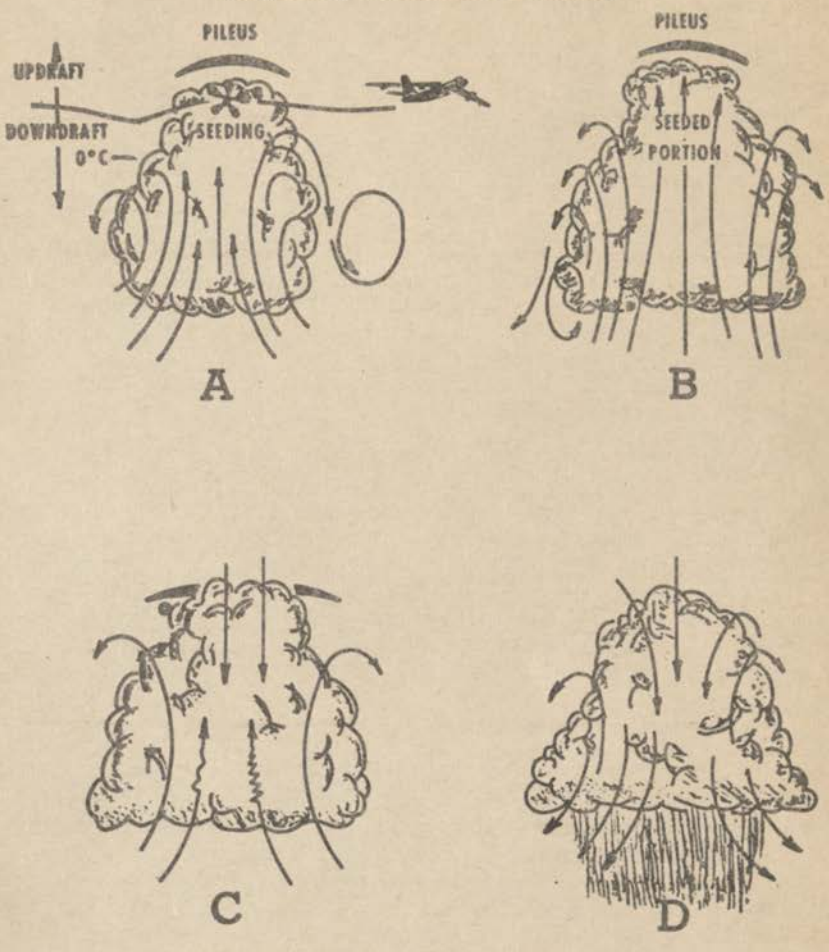
Turning to (C)—At apex, the cloud ceases to grow vertically, the top begins to evaporate and begins a gentle descent into the mass beneath, where the droplets run into still ascending air carrying cloud water upward.

And finally at (D)—A rain shower develops as the cloud collapses. The sequence closely resembles a typical rain shower process in the tropics, except that the presence of ice, which the seeding has caused to form in the process is not natural in tropical rain showers.

[Chart 3 follows:]

CHART 3.—Cloudseeding Technique

[Supplied by Department of Defense]



SEEDING UNITS AND TECHNIQUE

Colonel SOYSTER. The seeding units used to seed were developed at the Naval Weapons Center, China Lake, Calif. and are not classified. The seeding units and technique are identical to those used in publicized rainmaking projects—for example, Philippines, Okinawa, Texas—and the Stormfury research project.

The seeding units consist of a 40 mm aluminum photoflash-type cartridge case with primer and a candle assembly. The candle assembly incudes a plastic container 3 inches long with the seeding material and necessary delayed firing mechanism to ignite the free falling container. The silver iodide or lead iodide is produced as the chemical mixture burns.

The burning time is about 36 seconds for the most commonly used type. The unit drops about 3,000 feet during its functional burn. The units are dropped inside the cloud in the active updrafts at intervals of approximately one-half mile.

The release is normally controlled by the pilot flying the aircraft who can best determine the location of the updrafts. Two types of aircraft were used—the WC–130 weather reconnaissance aircraft and the RF–4C reconnaissance aircraft. The WC–130 carried pods containing 104 units each on both sides of the aircraft fuselage just forward of the paratroop jump door. The RF–4C carried a total of 104 units in the photo cartridge compartments. Typically, these aircraft could influence an average of 4–5 clouds or groups of clouds per day during the southwest monsoon.

The technique requires that specific individual clouds be seeded. Their growth is related to atmospheric conditions and the amount of seeding so that when the seeding ends, the thunderstorm created acts like any other storm and is short-lived because the seeding materials either rain out, disperse, or decompose.

REQUIREMENTS FOR AND EFFECTS OF FAVORABLE SEEDING

Over-seeding or improperly placed seeding tends to disperse the clouds. There is no chance of prolonged effects. Under nearly perfect conditions, effects last possibly 6 hours maximum. Normally, the effect is about one-half hour. Further, favorable seeding requires low velocity and unidirectional winds to prevent dispersal. The effects are therefore limited in area, perhaps 20-mile diameter under ideal conditions and continuous seeding where groups of clouds could be knitted together to form one large storm center. With this background in technique in mind, let me now turn specifically to our program.

1966 PILOT PROGRAM

In 1966, the Office of Defense Research and Engineering proposed a concept of using these known weather modification techniques in selected areas of Southeast Asia as a means of inhibiting enemy logistical operations.

During October 1966, a scientifically controlled test of the concept and seeding techniques was conducted in the Laos Panhandle. The test was conducted under the technical supervision and control of personnel from the Naval Ordnance Test Station (now Naval Weapons Center), China Lake, Calif., using in-theater resources. Fifty-six seedings were conducted, and over 85 percent of the clouds tested reacted favorably. On November 9, 1966, the Commander in Chief, Pacific [CINCPAC] reported the test completed and concluded that cloud-seeding to induce additional rain over infiltration routes in Laos could be used as a valuable tactical weapon.

Intelligence analysis of the area indicated that there would be no significant danger to life, health, or sanitation in the target areas. The sparsely populated areas over which seeding was to occur had a population very experienced in coping with the seasonal heavy rainfall

conditions. Houses in the area are built on stilts, and about everyone owns a small boat. The desired effects of rainfall on lines of communication are naturally produced during the height of the monsoon season just by natural rainfall. The objective was to extend these effects over a longer period. It was neither necessary nor desirable to increase the total rainfall above the levels experienced during a normal heavy monsoon season. In fact, the normal variations in total annual rainfall were greater than the variations we could induce.

The operation was closely monitored and controlled. When reconnaissance indicated that objectives were attained in one area, the limited resources were shifted to other areas. Seeding was not conducted during periods of tropical storms when large amounts of rainfall were falling naturally and accomplishing the military objectives. It is the consensus of the scientific community that the techniques employed could not be used to create large uncontrolled storm systems accidentally or purposely.

Conversely, seeding to the extent conducted in Southeast Asia did not cause drought in neighboring areas. There is simply too much moisture in the air in that part of the world, and operations affected only a small percent of it—probably less than 5 percent. The desired effect was simply to control where that small percentage fell to the ground.

OPERATIONAL PHASE

With the success of the pilot program and the considerations just presented, the operational phase began on March 20, 1967, and was conducted each subsequent year during the rainy southwest monsoon (March–November) until July 5, 1972.

Senator PELL. Would you repeat that sentence?

Colonel SOYSTER. Yes, sir. After the successful pilot program and the considerations I just presented, the operational phase began on March 20, 1967, and was conducted each subsequent year during the rainy southwest monsoon; that is the period March through November until July 5, 1972, when we flew the last mission.

The program was authorized three WC–130 and two RF–4C aircraft with associated crews and maintenance personnel. These aircraft provided two WC–130 and one RF–4C sorties per day, when required. However, these aircraft, which operated out of Thailand, were not dedicated exclusively to the cloudseeding missions. The WC–130's also conducted tropical typhoon reconnaissance and tactical weather reconnaissance support missions. RF–4C's performed regular photo reconnaissance missions. The annual cost of the total program was approximately $3.6 million covering operation and maintenance, temporary duty pay, and seeding materials.

AUTHORIZED AREAS OF OPERATIONS

In answer to the question "Where was it done?" I will now show the authorized areas as they developed chronologically with sortie rate and amount of seeding expended.

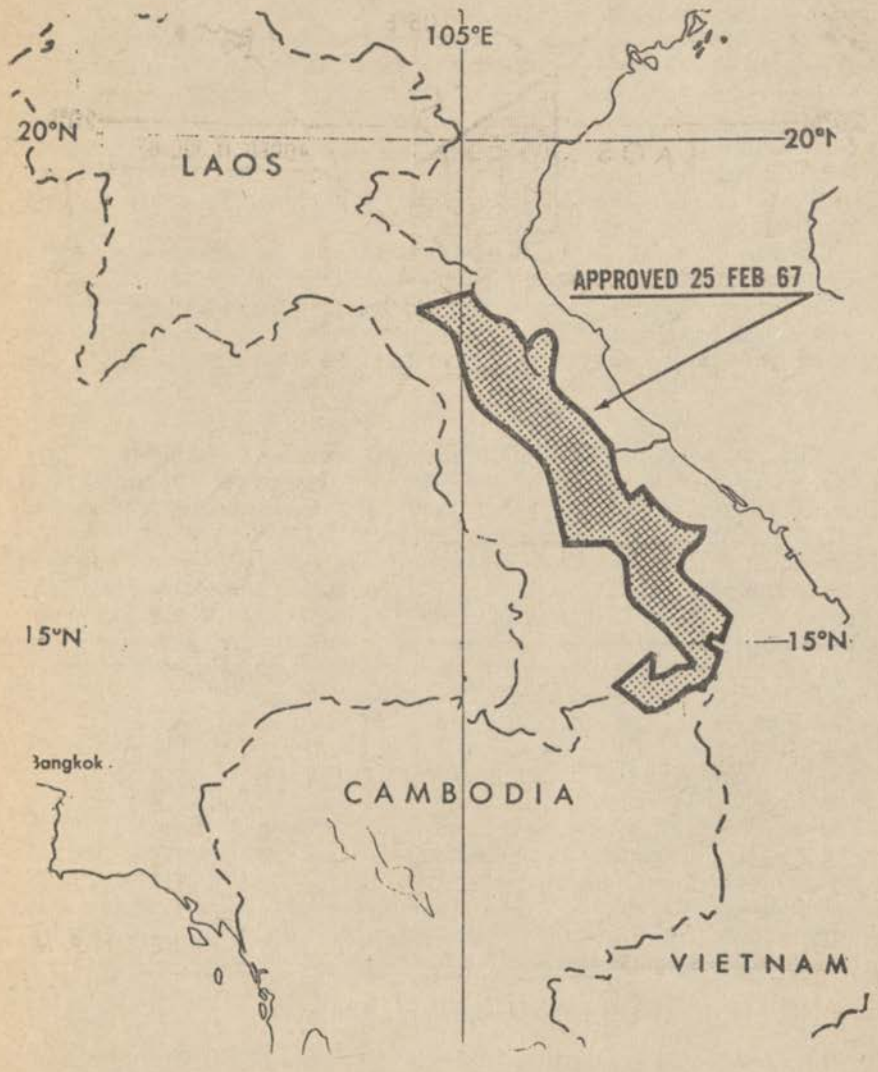
29-544 O - 74 - 7

This map illustrates the area initially authorized for operations in Laos and a very small portion of North Vietnam.

[Chart 4 follows:]

CHART 4.—Initially authorized area of operations.

[Supplied by Department of Defense]

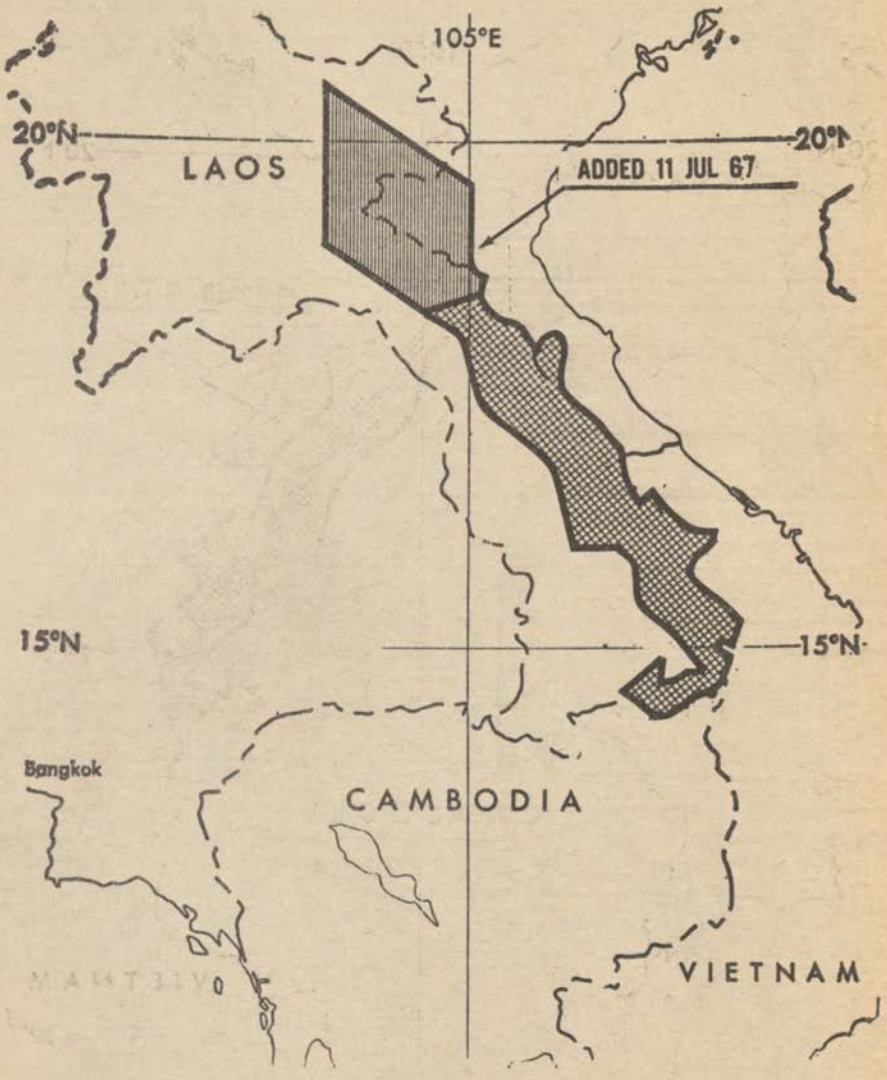


Colonel SOYSTER. An area encompassing additional portions of Laos and North Vietnam was added on July 11, 1967.

[Chart 5 follows:]

CHART 5.—Additional area of operations authorized on July 11, 1967.

[Supplied by Department of Defense]

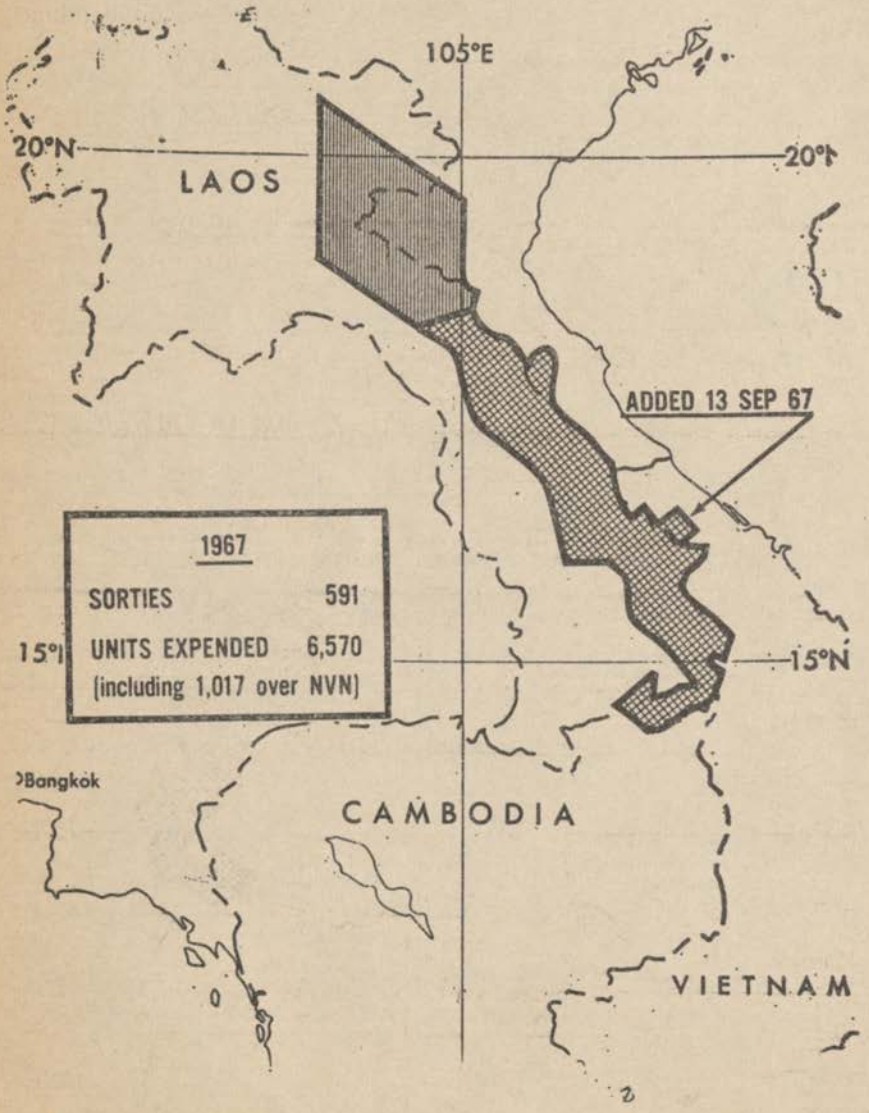


Colonel SOYSTER. Finally, a small area over the A Shau Valley in South Vietnam was added on September 13, 1967. The chart also shows the total sorties flown and the units expended for 1967.

[Chart 6 follows:]

CHART 6.—Area of operations added on September 13, 1967, and sorties flown and units expended for 1967.

[Supplied by Department of Defense]



Senator PELL. The units expended.

Colonel SOYSTER. Yes, sir; the number of 40 mm photoflash-type cartridges, as I have described, which were expended. We expended

1,017 over North Vietnam. The total sorties include both WC–130 and RF–4.

Senator PELL. Looking at the picture the concentration was more on North Vietnam, six of the units in those two small spaces. I see it would add up about the same.

Colonel SOYSTER. Yes, sir. Of course, these were expended over specific clouds over certain trails which I will talk about a little later.

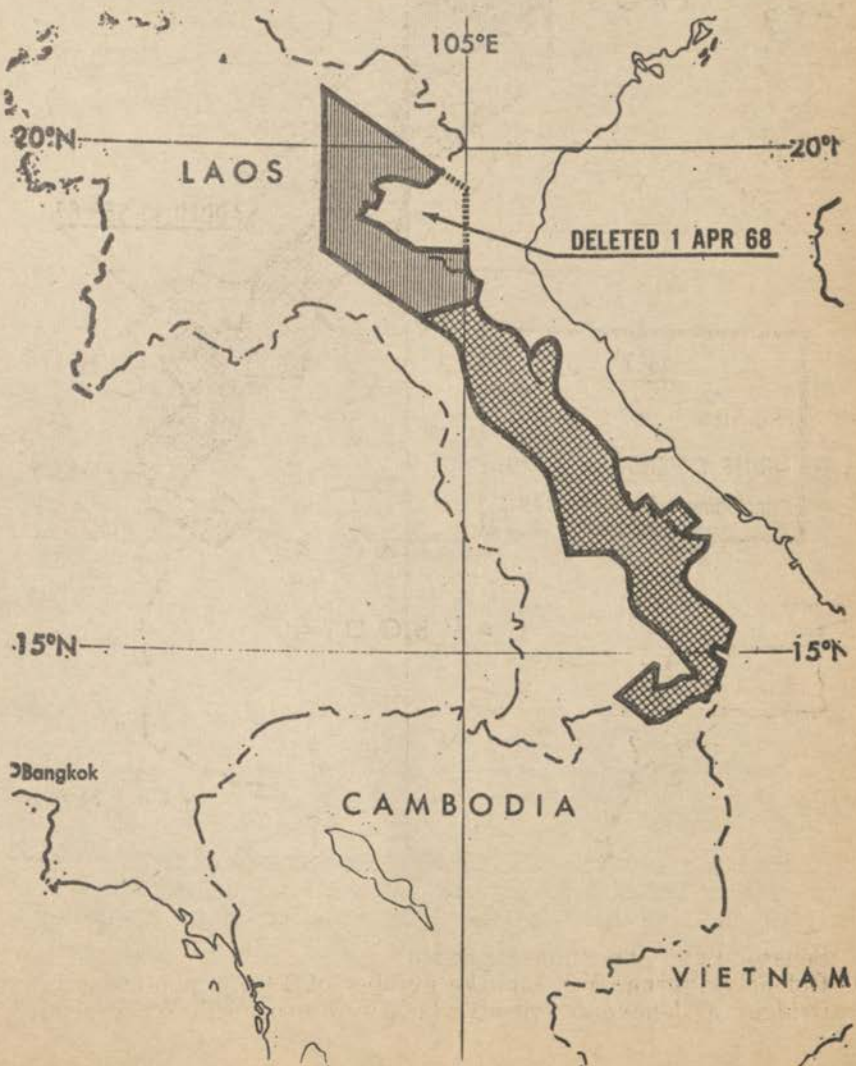
The next slide reflects the areas just briefed as they began in 1968.

On April 1, 1968, operations over North Vietnam were restricted to the area south of 19°N coincident with restrictions on bombing above that line.

[Chart 7 follows:]

CHART 7.—Restrictions of operations over North Vietnam on April 1, 1968.

[Supplied by Department of Defense]

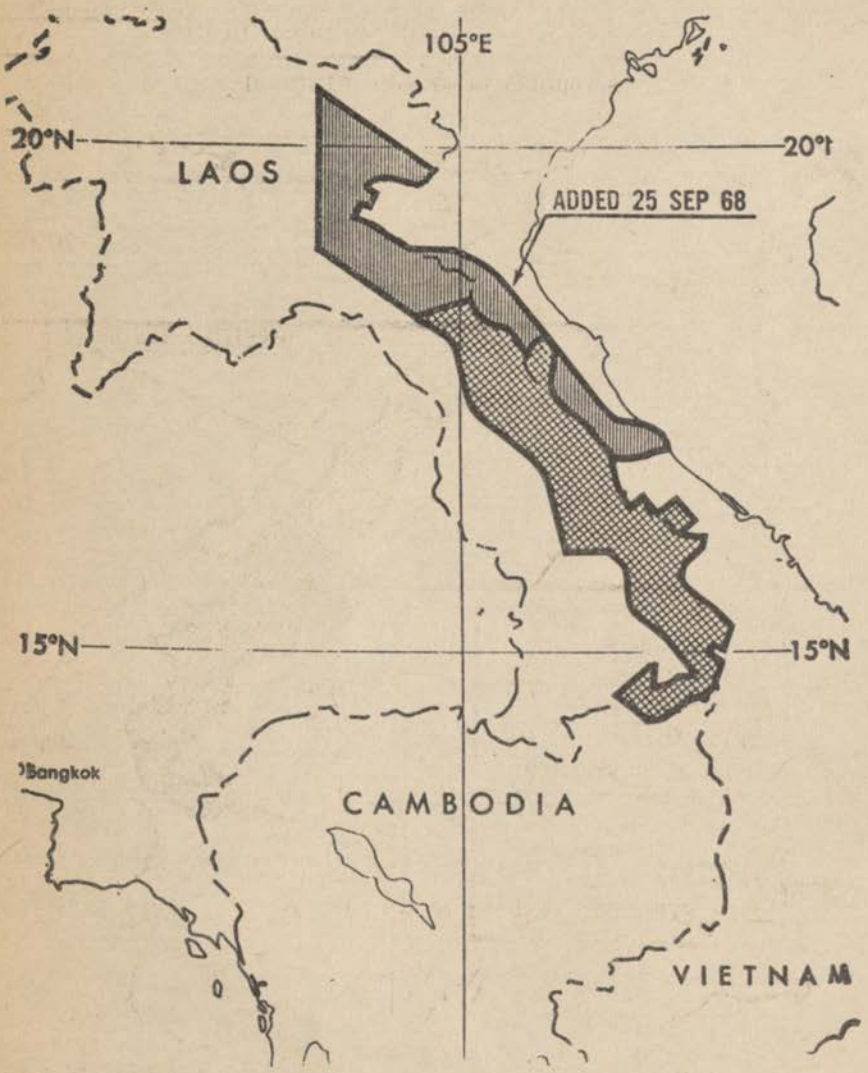


Colonel SOYSTER. An area of North Vietnam was added on September 25, 1968.

[Chart 8 follows:]

CHART 8.—Area of North Vietnam added on September 25, 1968.

[Supplied by Department of Defense]



Colonel SOYSTER. However, on November 1, 1968 all seeding operations within the boundaries of NVM were terminated and never reinstituted. This chart also shows the sorties and units expended for 1968.

Operations in 1969——

Senator PELL. Excuse me. When was it that you terminated?

Colonel SOYSTER. November 1, 1968, sir.

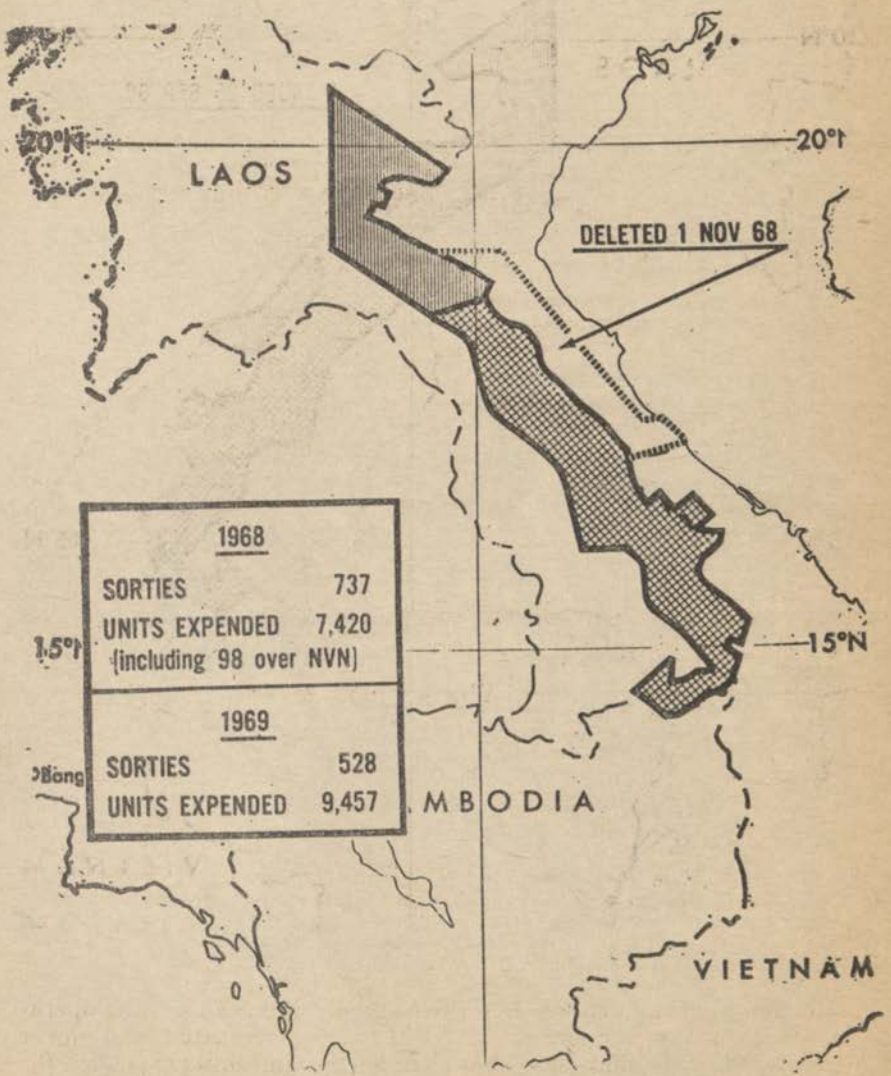
Senator PELL. Thank you.

Colonel SOYSTER. Operations in 1969 were conducted in the areas outside North Vietnam approved for 1968 and again the number of sorties and units expended are shown.

[Chart 9 follows:]

CHART 9.—November 1, 1968, termination within North Vietnamese boundaries and sorties and units expended for 1968 and 1969.

[Supplied by Department of Defense]



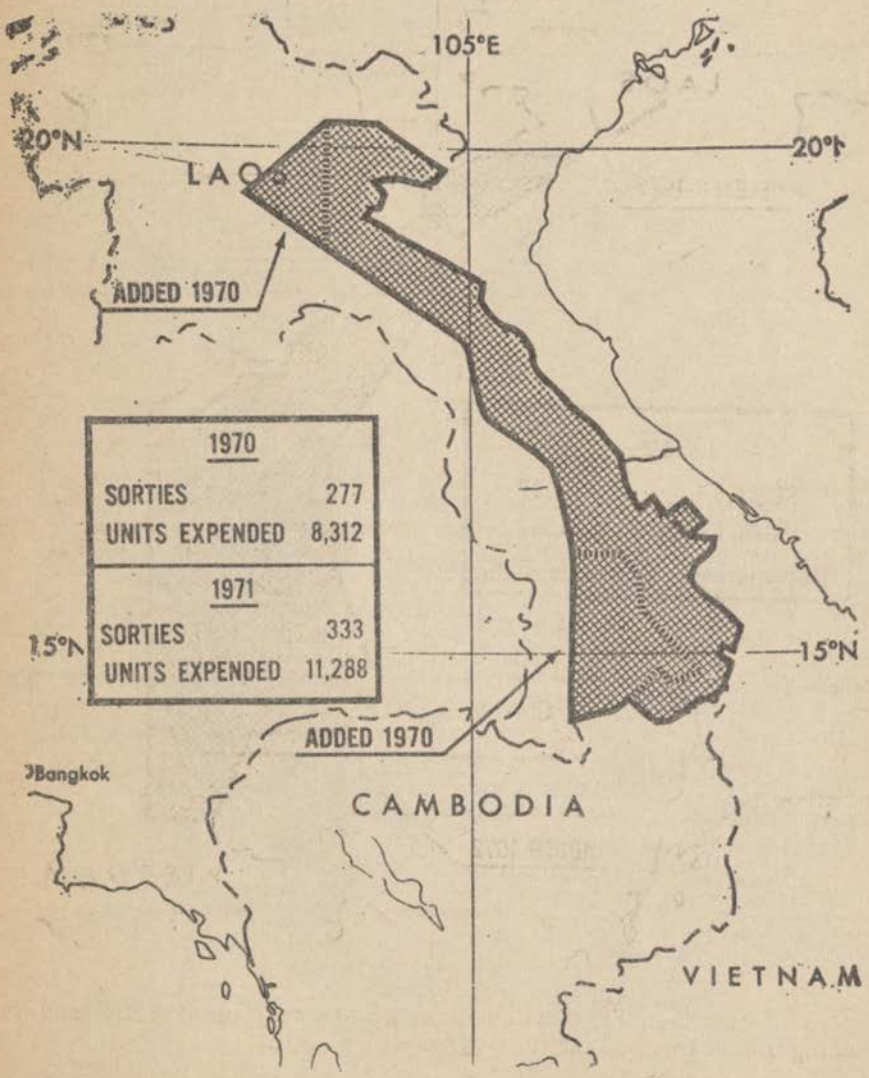
Colonel SOYSTER. During 1970, operational areas in Laos were modified as shown in the north and in the south. These are the units expended.

The 1971 area remained the same. These are the 1971 units and sorties expended in 1971.

[Chart 10 follows:]

CHART 10.—1970 modification of operational areas in Laos and sorties and units expended, 1970 and 1971.

[Supplied by Department of Defense]

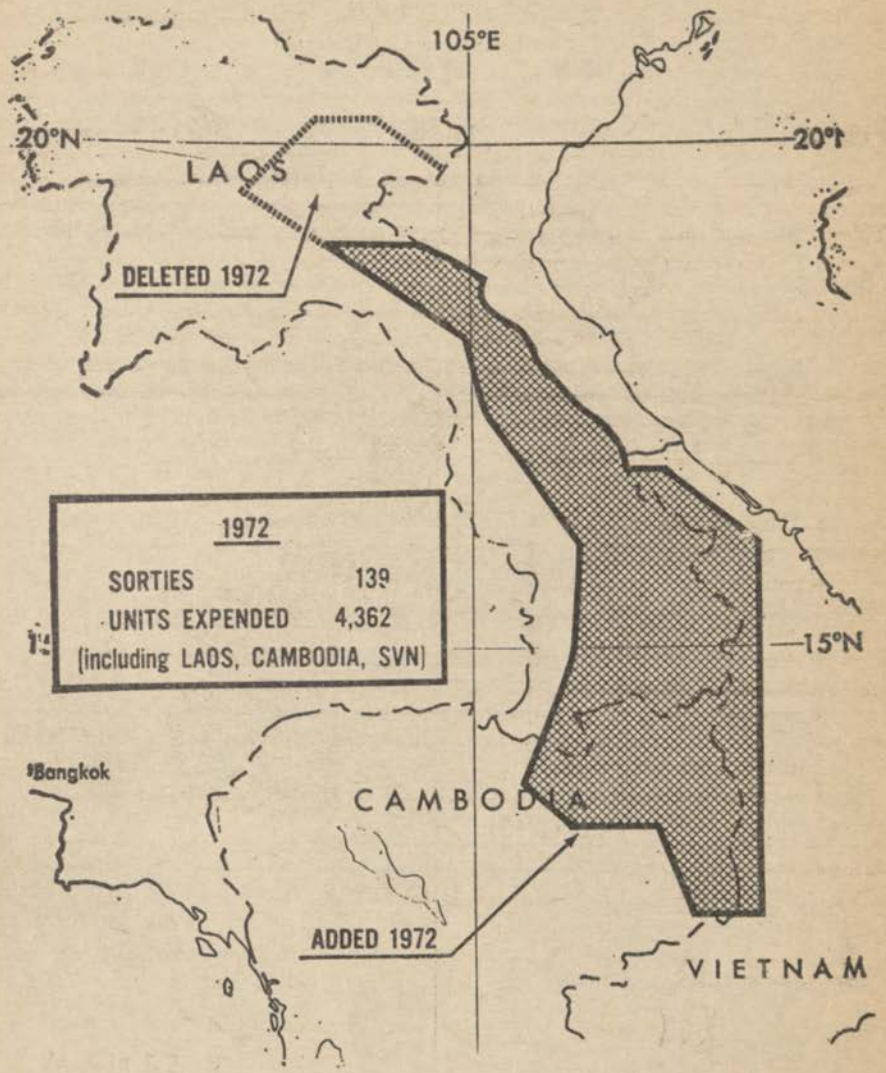


Colonel SOYSTER. The area was modified in 1972 to include portions of Northeast Cambodia and South Vietnam and to limit activity to south of 19° north in Laos.

[Chart 11 follows:]

CHART 11.—1972 modification of area.

[Supplied by Department of Defense]



Colonel SOYSTER. The next chart provides a wrap-up of sorties and seeding units expended for the program.

[Chart 12 follows:]

CHART 12.—Sorties and seeding units expended for program.

[Supplied by Department of Defense]

YEAR	SORTIES FLOWN	UNITS EXPENDED
1967	591	6,570 (INCLUDING 1,017 OVER NVN)
1968	734	7,420 (INCLUDING 98 OVER NVN)
1969	528	9,457
1970	277	8,312
1971	333	11,288
1972	139	4,362 (LAOS, CAMBODIA, SVN)
TOTALS	2602	47,409

AVAILABILITY OF CHARTS

Senator PELL. Incidentally, just for the record, could these charts be made available for the top secret record?

Mr. DOOLIN. Certainly, sir.

SELECTION OF TARGETS

Colonel SOYSTER. The selection of targets or areas of seeding was based on the strategic importance of lines of communication and their susceptibility to interdiction by increased rainfall. Target priorities were assigned and updated on the basis of continuous analysis of all available intelligence information at 7th Air Force, Tan Son Nhut, South Vietnam. Priorities were stated in terms of drainage basins rather than points because of the low probability that a cloud favorable for seeding would form over a specific point. It was usually possible to seed every suitable cloud within a drainage basin, but priority was given to seeding clouds directly over roads, intersections, and river crossings within each basin.

RESULTS OF PROJECT

The results of the project cannot be precisely quantified. This is due to the lack of sufficient ground stations to report. However, the Defense Intelligence Agency, using empirical and theoretical techniques based on units expended and the physical properties of the air mass seeded, estimated that rainfall was increased in limited areas up to 30 percent above that predicted for the existing conditions. Sensor recordings and other information following seeding indicated enemy difficulties from heavy rainfall.

Subjectively, it is believed that this rainfall was heavier than that which would have fallen normally and that it did contribute to slowing the flow of supplies into South Vietnam along the Ho Chi Minh trail.

EFFECTIVENESS OF PROJECT

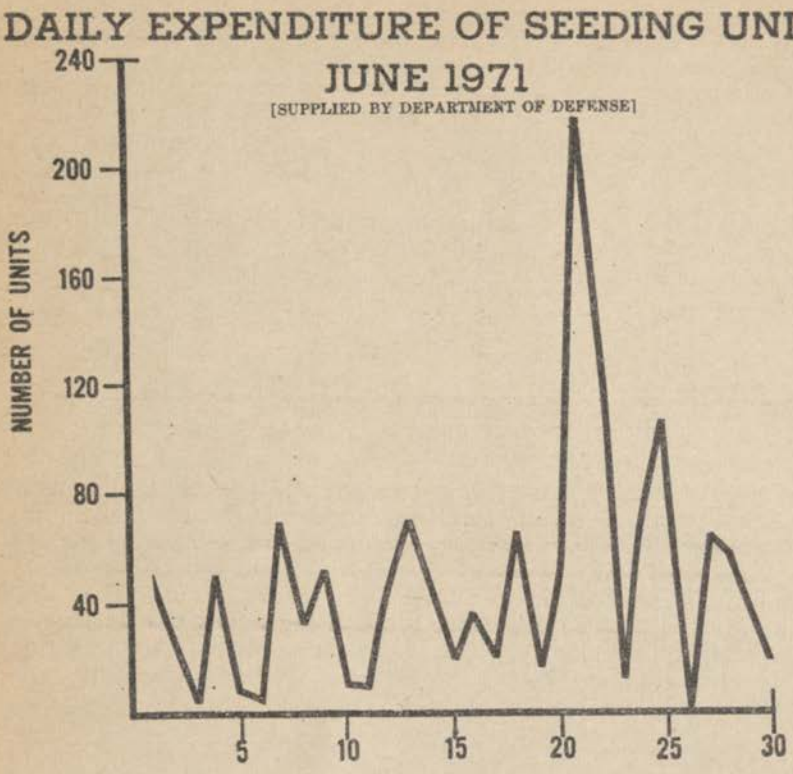
The next series of charts will be presented to provide some feel for the effectiveness of the project. The month of June 1971 will be addressed. June is a month in which the southwest monsoon is well established. It is also a month where it is not unusual for that southwest flow to be temporarily disrupted by the intrusion of a tropical storm moving into the Southeast Asian Peninsula from the east. This was the case for June 1971 when the southwest monsoon was disrupted by typhoon Anna as the month began and later in the month by typhoon Frieda and tropical storm Golda.

These storms, although bringing heavy natural rainfall, also caused poor seeding conditions by covering the area with a thick layer of high clouds which limit the effects of surface heating required for good convective activity. I provide this to point out that there was not a consistent presence of favorable conditions for seeding even in the middle of the rainy season. As a result, daily seeding unit expenditures vary greatly as shown on this chart.

I would like to point out while this chart is up that at the beginning of April remote sensors were detecting over 9,000 enemy logistic movers per week in eastern Laos. By the end of June this number was less than 900.

Two of the most significant weekly drops in detected traffic movement occurred during June. One of these weeks was June 2 to 9 during which a typhoon was increasing rainfall and the second was during June 16 to 23 when we were most active with seeding activities during the month.

[Chart 13 follows:]



This chart is an evaluation of the units expended by week. The left-hand column gives the total seeding units expended. The next column shows the number that were successful in the crews' judgment, which is to say that they had a positive effect on the cloud and either increased rainfall rate or caused cloud growth and development.

Under "Number of Groups" and "Number of Isolated Clouds" there is an evaluation where "S" means successful as I have just described, "NE" is no effect—and "F" indicates failure or a decrease in rainfall or cloud deterioration. The final columns show the number of lines of communications which were "influenced"—A route segment is said to have been influenced by project augmented rainfall if it is located directly under seeded clouds or within a reasonable distance so that runoff from the rainfall would cross it.

"Interdicted" are those instances where visual or photographic reconnaissance confirms significant water damage to a route segment previously listed as "influenced."

[Chart 14 follows:]

CHART 14.—Evaluation of units expended by week, June 1971.

[Supplied by Department of Defense]

DATES	# of UNITS		# of GROUPS			# of ISOD CLDS			# of LOC'S	
	TOTAL	SUCC	S	NE	F	S	NE	F	INF	IN'TD
1-8 JUNE	241	195	25	6	2	3	3	4	55	13
9-15 JUNE	240	223	23	0	1	24	10	0	80	5
16-22 JUNE	542	497	40	6	1	8	13	0	101	25
23-30 JUNE	368	360	27	3	0	16	0	0	93	3
1-30 JUNE	1391	1275	115	15	4	51	26	4	329	46

Colonel SOYSTER. The next slide measures effectiveness by the use of isolines. Chart 15 shows the total rainfall in inches which fell in the area for June 1971. This is a measured amount of rainfall from various points connected by isolines.

The lines in chart 16 are an estimate of the maximum rainfall that was induced in the area which the lines connect. The black numbers in the center of these lines on both charts show the maximum rainfall estimated for any one point.

[Charts 15 and 16 follow:]

CHART 15.—Total Rainfall in Area, June 1971.

[Supplied by Department of Defense]

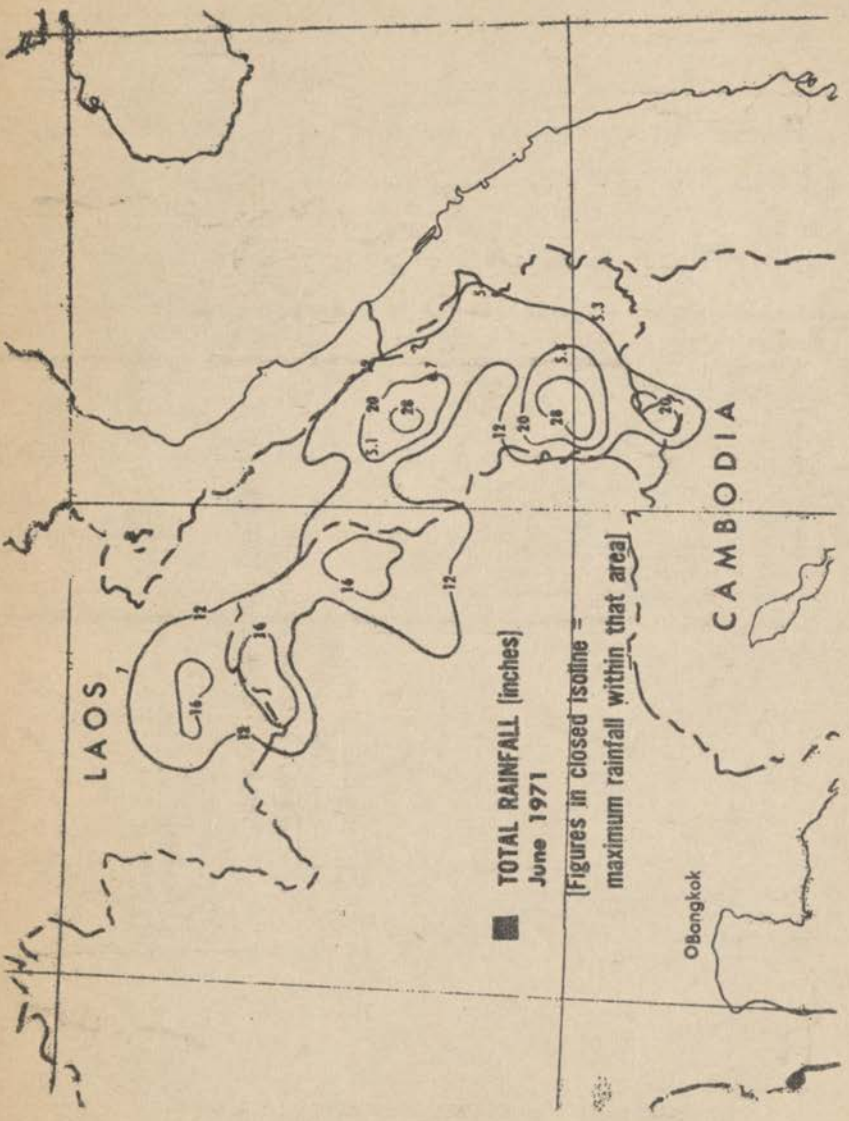
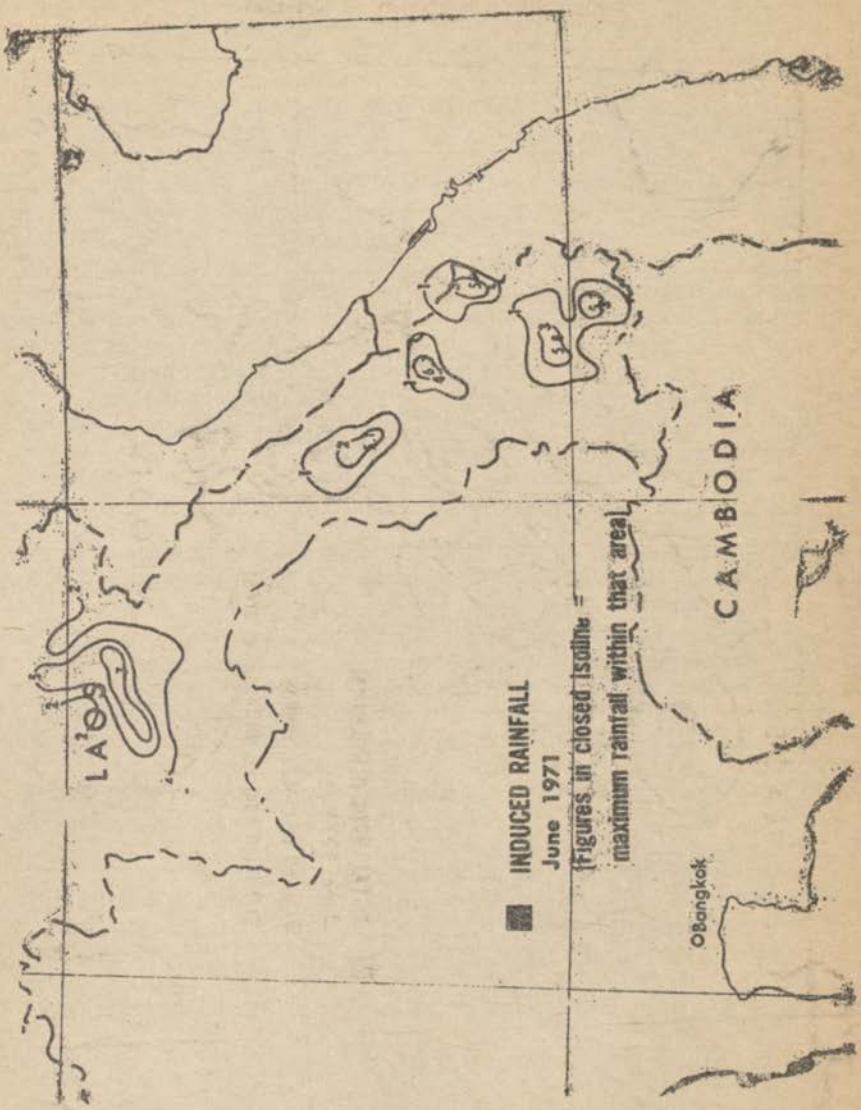


CHART 16.—Induced Rainfall In Area, June 1971.

[Supplied by Department of Defense]



PROPOSAL, TEST AND OPERATIONAL PHASE

Colonel SOYSTER. As previously mentioned, the concept of the operation was proposed in 1966 by the Office of Defense Research and Engineering.

After approval by civilian authority, the test was conducted in October 1966 and the operational phase began March 20, 1967.

REPORTING PROCEDURES

Because the program was considered sensitive, reporting procedures were instituted to limit knowledge of the program. The WC–130 missions were flown, recorded, and reported through normal channels as weather reconnaissance flights.

The crews performed weather reconnaissance and made normal factual weather reports through regular unclassified worldwide weather channels. The RF–4C's were flown as normal reconnaissance missions. In addition to these reports, special reports to provide information to higher headquarters and to allow evaluation of the project were transmitted through special communications channels. Daily reports were submitted to the command project officer. Weekly reports were submitted through channels to the Joint Chiefs of Staff. Semiannual reports were also submitted.

Periodic reports were prepared by the Joint Staff and submitted through the chairman, Joint Chiefs of Staff to the Secretary of Defense. In order to conduct the operation approximately 14,00 personnel had to be given access to project information over a 6-year period.

These people were briefed into the project and then debriefed when they no longer required a clearance.

RESULTS OF PROGRAM

While this program had an effect on the primitive road conditions in these areas the results were certainly limited and unverifiable. It was conducted because of its apparent contribution to the interdiction mission and the relatively low program costs.

An operation such as this is almost unique to this area of the world. Rainfall can be significantly induced only where and when there are natural occurrences of heavy rains. Furthermore, induced rain can have a significant interdiction effect only where the lines of communication are relatively primitive.

Both of these conditions existed in the operating areas in Southeast Asia and, as noted, even here program effectiveness cannot be conclusively established.

This concludes the formal part of my presentation.

Senator PELL. Thank you very much, Colonel, for your good and full and frank briefing.

Is there anything further you wish to add?

Mr. DOOLIN. No; Mr. Chairman. We just wish to respond to any questions you may have, and I can leave a copy in advance of the transcript.

Senator PELL. Thank you so much.

CLASSIFICATION OF PROGRAM

As you know, in connection with the Vietnam war, all the other combat sorties and ordnance tonnages have been declassified. Why are these statistics still top secret? Why is this program still considered top secret or is it still considered top secret?

Mr. DOOLIN. We are looking at this right now, Mr. Chairman.

Senator PELL. My own reaction is one of a little bit of puzzlement. What was the reasoning behind it being so highly classified.

Mr. DOOLIN. May I ask General Furlong?

Senator PELL. What was the logic behind it?

General FURLONG. It was, of course, at that time a combat operation. I would speculate that there was concern politically as well. We did not at the time when this began discuss normal combat interdiction operations in Laos. The Government of Laos was aware of our interdiction efforts and acquiesced in it. This operation fell into a similar category.

Senator PELL. But the classification was considerably higher. I know in my own experience here that this particular program was the only program about which the DOD did not feel able to respond to questions in either public or private session.

From what you say, I am reminded of the old maxim. An "elephant labored and a mouse came forth." What was the reason for this great secrecy?

General FURLONG. Your observation—the elephant laboring and bringing forth a mouse—I think reflects in large measure our current perception of the classification.

Senator PELL. I thank you.

Mr. DOOLIN. Certainly, Mr. Chairman, I must say that it reflects my perception of the results of the program.

Senator PELL. Yes.

Mr. DOOLIN. We are actively pursuing this in terms of declassification of the information.

DECLASSIFICATION OF SECRETARY LAIRD'S LETTER

Senator PELL. In connection with declassification, you should include Secretary Laird's letter. I don't believe this end of the avenue is responsible, but copies or knowledge of copies of it seems to be available to the press. And is there any reason why you should not go ahead right quickly with the declassification of his letter?

General FURLONG. We would do that in connection with the whole. That is, you would not declassify the letter and not go ahead and declassify more.

As Mr. Doolin points out, that is being considered.

[The information referred to follows:]

THE WHITE HOUSE,
Washington, January 28, 1974.

Hon. J. W. FULBRIGHT,
Chairman, Senate Foreign Relations Committee,
U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: I have just received new information dealing with a DOD weather modification program. Since I discussed this program with you in my April 18, 1972, appearance before your committee I want to share this information with you.

During my appearance I responded to your question concerning weather modification with the statement "we have never engaged in that type of activity over North Vietnam." That statement represented, first, my knowledge that I had never approved operations over North Vietnam and secondly, my understanding of activities authorized by preceding Secretaries of Defense. I have just been informed that such activities were conducted over North Vietnam in 1967 and again in 1968. I want to take this opportunity to both express my regret that this

information was not available to me at the time of my appearance before your Committee and to provide you with this information.

Please accept my personal appreciation for your friendship and assistance throughout my years in the Congress and the Executive Branch.

Sincerely,

MELVIN R. LAIRD,
Counselor to the President
for Domestic Affairs.

JANUARY 29, 1974.

Hon. MELVIN R. LAIRD,
Counsellor to the President for Domestic Affairs,
The White House, Washington, D.C.

DEAR MR. LAIRD: Thank you for your letter of January 28 clarifying your testimony of April 18, 1972 concerning the Defense Department's weather modification activities.

I brought your letter to the attention of the Foreign Relations Committee at its meeting this morning, and the Committee instructed me to ask you if, in view of the fact, that your 1972 testimony was in public, you have any objection to making your letter public.

Sincerely yours,

J. W. FULBRIGHT,
Chairman.

FEBRUARY 11, 1974.

Hon. J. W. FULBRIGHT,
Chairman, Committee of Foreign Relations,
U.S. Senate,
Washington, D.C.

DEAR MR. CHAIRMAN: I appreciate your prompt response to my letter of January 28 concerning my testimony of April 18, 1972. Through my earlier letter I sought only to assure that you were provided with accurate information as rapidly as I received it.

It was thoughtful of you to afford me the opportunity to clarify the public record. However, to the best of my knowledge, the Department of Defense retains a security classification on this material which accounts for the classification of my letter to you.

I must, therefore, ask that my letter to you retain its classification as it would be inappropriate for me to act unilaterally without Department of Defense declassification approval.

With best wishes and kindest personal regards, I am

Sincerely,

MELVIN R. LAIRD.

FEBRUARY 14, 1974.

Hon. JAMES R. SCHLESINGER,
Secretary of Defense,
Washington, D.C.

DEAR MR. SECRETARY: In the absence of Senator Fulbright during the recess of the Senate I am enclosing copies of correspondence between him and Mr. Laird respecting Defense Department weather modification programs.

I would appreciate it if the Foreign Relations Committee could have a determination from the Department of Defense with respect to making this correspondence public.

Sincerely,

PAT M. HOLT.

GENERAL COUNSEL OF THE D PARTMENT OF DEFENSE,
Washington, D.C., February 22, 1974.

Mr. PAT M. HOLT,
Chief of Staff,
Committee on Foreign Relations,
U.S. Senate,
Washington, D.C.

DEAR MR. HOLT: Secretary Schlesinger has asked that I respond to your letter of February 14, 1974 concerning correspondence between Mr. Laird and Senator Fulbright.

The Department of Defense has reviewed this matter and it is our determination that the SECRET security classification originally applied to this correspondence is still appropriate.

Sincerely,

L. NIEDERLEHNER,
Acting General Counsel.

REASON FOR EXTRA SECRECY CONCERNING OPERATION

Senator PELL. There still may be no response, but I want to repeat my question. Do you have any idea or can you speculate as to the reason for the extra secrecy on this besides the interdiction factor, which I realize was classified.

Mr. DOOLIN. I speak in a personal capacity, and not in my official capacity, Mr. Chairman. I have been in this job for 5 years, and I didn't have this clearance even though Southeast Asia is in my area of responsibility in the Office of the Secretary of Defense. The first I learned of it was, as the result of a Jack Anderson column, and I made inquiries at the time—simply for my own edification—to find out if the rain that was artificially generated in a given area would deprive a friendly country also in the area of rain. For example, were we denying water to Thai rice paddies. I was told, no, that was not the case, that there was so much moisture in the air that you could not reduce the amount really in another area; and not to pursue the matter. It was an operation that was held in a special channel and access was very, very limited. I think, because of the perceived sensitivity of the operation.

Senator PELL. In retrospect, I think if this had been unclassified, there would have been far less feeling about it, but that I guess, is water over the dam.

CIVILIAN AUTHORITIES WHO APPROVED OPERATIONS

What civilian authorities approved these operations over the years 1966 to 1972?

Mr. DOOLIN. These operations were initially conceived by the Office of the Civilian Director of Defense Research and Engineering. They were then approved by the Secretary of Defense.

Senator PELL. What was that division again?

Mr. DOOLIN. The Director of Defense Research and Engineering, Dr. Foster, John Foster.

Senator PELL. Right.

Would that be Dr. Currie——

Mr. DOOLIN. It is now Dr. Currie.

Senator PELL. That is the same post.

Mr. DOOLIN. Yes.

Senator PELL. It would go directly from him to the Secretary of Defense.

Mr. DOOLIN. I don't know whether it went to the Joint Chiefs first but the Joint Chiefs obviously were in the chain.

Senator PELL. Right.

Mr. DOOLIN. But the approval authority in the Department was the Secretary of Defense.

From there it did go to the White House.

WHO WAS INFORMED IN STATE DEPARTMENT?

Senator PELL. Who was informed in the State Department? Was anyone informed?

General FURLONG. There were a few informed in the State Department. I cannot give you their names.

Senator PELL. The functions.

General FURLONG To the best of my knowledge the Under Secretary of State for Political Affairs was informed.

Senator PELL. Right.

General FURLONG. I cannot say whether that is the limit or not.

WAS ANYONE IN ACDA INFORMED?

Senator PELL. Was anyone in the ACDA informed about it?

General FURLONG. No.

Senator PELL. They were not.

WAS THIS ONLY CLASSIFIED WEATHER MODIFICATION OPERATION?

From what you said earlier, as I understand it, this is the only classified weather modification operation that has been carried out by the Government in the last 10 years. Would that be a correct statement, to the best of your knowledge?

General FURLONG. To the best of our knowledge.

Colonel SOYSTER. It is the only one, to my knowledge.

Senator PELL. To the best of your knowledge it was the only one.

Mr. DOOLIN. The only one.

Senator PELL. There were different code names, Operation Popeye and Operation Intermediary, Compatriot. Were they one and the same?

Mr. DOOLIN. They were one and the same.

Senator PELL. This was it.

Mr. DOOLIN. When the code names Compatriot and Intermediary were uncovered they were changed.

ENVIRONMENTAL WARFARE

Senator PELL. Is there a coordinated executive branch position on environmental warfare, not just weather modification, but the other means of environmental warfare?

Mr. DOOLIN. That is my understanding, there is not.

Senator PELL. The thing that concerns me is not rainmaking per se, but when you open that Pandora's box what comes out with it? Will we achieve a technique to be able to both create and point a hurricane or typhoon? Will we be able to do geophysical modification, put a charge under the surface and let the earthquake follow?

General FURLONG. The testimony you have already received is I believe from personnel more competent than anybody from the DOD. I don't think we can contribute to your record.

Senator PELL. Thank you.

As you know, Dr. MacDonald has seen what it was, not the state of the art now but what it conceivably could be.

DECLASSIFICATION OF PROJECT

I gather your personal views are that this project could be declassified without any great breach of national security?

Mr. DOOLIN. All I can say on that, sir, is that would be my recommendation to my superiors.

Senator PELL. Right.

WEATHER MODIFICATION STUDY

Are you familiar with the study presently going on on the subject of weather modification, in which the Department is engaged as the lead agency?

Mr. DOOLIN. I am aware of a study that is being done for the White House.

Senator PELL. That is right.

Mr. DOOLIN. That includes some items such as that, yes.

Senator PELL. Yes.

When do you expect that study to be finished?

Mr. DOOLIN. I checked on that today, Mr. Chairman, and the estimate is it will be another 2 weeks or so before it is available for consideration in the DOD and then for transmittal to the White House.

Senator PELL. It will be another 2 weeks before pulled together by DOD.

Mr. DOOLIN. Yes, sir.

Senator PELL. What classification will that study have?

Mr. DOOLIN. I do not know, sir.

Senator PELL. You do not know.

Mr. DOOLIN. I am not involved in the preparation of that study.

Senator PELL. Right. The reason I am raising these questions is. that this bears directly on my proposed weather modification treaty When that study is in, we want to have another meeting with the Defense Department and the executive branch to discuss it.

Mr. DOOLIN. Mr. Chairman, this will be, of course, a report transmitted to the President at his request, so we would not have any control over its dissemination other than to the President.

Senator PELL. Senator Case, I have a series of other specific questions. Any time you wish to ask some, go ahead.

Senator CASE. Go ahead, Mr. Chairman, you are covering much of the ground I was interested in.

Senator PELL. I have already taken up my 10 minutes.

CHANNEL OF APPROVAL OF OPERATIONS

Senator CASE. There were two questions suggested here, following the chairman's inquiry. Would you specify the precise channel for the approval of the operations?

General FURLONG. Yes, sir.

Senator PELL. Excuse me. Do you mean the other departments that are involved?

Senator CASE. Yes, and the Defense Department, too.

THOSE WHO KNEW ABOUT PROGRAMS

And then a list of all of those who knew about the programs if you can.

Mr. DOOLIN. There were over 1,400 people at one time that did have this clearance including the men who flew the missions. I think it would be very difficult to compile.

Senator CASE. If not by name, give us a list by category, if you will, so we can see who had knowledge.

Mr. DOOLIN. We will do that, sir.

[The information referred to follows:]

PERSONNEL INFORMED OF OPERATION AND ITS SCOPE

[Supplied by Department of Defense]

The following categories of personnel were informed in varying degrees as to the operation and its scope:
White House
Congress of the U.S.—Chairmen of DoD Jurisdictional Committees
Secretary of Defense
Deputy Secretary of Defense
Director of Defense Research and Engineering
Limited members of the staff of the Office of the Secretary of Defense
The Joint Chiefs of Staff
Commander-in-Chief Pacific
Commander, US Military Assistance Command, Vietnam
Commander 7AF
Limited members of staff supporting these officers
Operational crews and supporting personnel
Secretary of State and limited supporting staff
Director CIA and limited supporting staff

DoD can verify that information was given to its personnel and the Chairman of its Jurisdictional Committees. Categories of non DoD personnel listed represent DoD's best estimate of those informed.

APPROVAL BY OR DISCUSSION WITH CONGRESSIONAL COMMITTEES

Senator CASE. Was it ever approved by any congressional committee or discussed with any congressional committee?

General FURLONG. Preceding testimony has shown four committee chairman were informed. We have nothing to add to the information already provided to the committee.

Senator CASE. Was that as a part of an oversight operation of some sort?

General FURLONG. No, sir. It was not done on a recurring basis.

Senator CASE. You just told four committee chairmen at a particular time.

General FURLONG. Yes, sir, that is correct.

Senator CASE. What were they? The Armed Services Committees——

General FURLONG. Yes, sir, the Armed Services and Appropriations Committees.

Senator CASE. That only let Democrats in, didn't it?

[Laughter.]

Senator PELL. That is when it occurred in North Vietnam.

Senator CASE. Thank you, Mr. Chairman, go ahead.

WHITE HOUSE KNOWLEDGE, APPROVAL, OR CLEARANCE

Senator PELL. As I say, I think you may have exaggerated the importance of the program. Who knew about it or gave the approval or cleared it in the White House? Could you submit for the record a list of the people?

Mr. DOOLIN. No, sir, I do not believe we can.

Senator PELL. Why?

Mr. DOOLIN. I know that information on this operation was sent to the White House. Whether it was for information or whether it was for approval, I do not know. I have been unable to find out.

Senator PELL. I realize you may have problems in trying it again. Could you try once more and submit for the record at the committee's request those who approved it at the White House and also for the record the list of other officials?

Mr. DOOLIN. We will try again, Mr. Chairman, because—we did try—because we wanted to be as fully responsive as we could be today, but unfortunately some of the principals who were involved at the time are dead.

[As of the date of publication, the information referred to had not been supplied.]

DOD POSITION AT STOCKHOLM CONFERENCE

Senator PELL. Both Senator Case and I were at the Stockholm Conference on Environment. There was a tremendous flap there over the question of ecological warfare and weather modification. I remember the DOD representative, took a very strong position on the question of reporting weather and environmental activities to other governments. It was a mandatory provision in the first draft of the U.N. resolution. The DOD took a very strong position in that conference that it be changed to "whenever feasible."

What was the reason for the position of the Defense Department? I cannot understand why they are so concerned.

Mr. DOOLIN. I would not be competent to answer that. I really cannot go beyond what Mr. Forman has said on previous occasions.

Senator PELL. You read his testimony. He was very unforthcoming basically.

Mr. DOOLIN. I read the transcript of your last hearing, sir, partially to educate myself for this meeting.

COORDINATION OF OPERATIONS

Senator PELL. Going to the question of the coordination of these operations, you say the State Department was informed but you did not necessarily coordinated with them.

General FURLONG. I don't think we ought to characterize the nature of that, sir. I am not confident which phrase is the correct description.

WERE THAI AND LOA GOVERNMENTS INFORMED?

Senator PELL. Were the Governments of Thailand and Laos, both of which countries were involved, informed about these operations?

Mr. DOOLIN. The Royal Lao Government had given approval for interdiction efforts against the trail system and we considered this to be part of the interdiction effort.

The Royal Thai Government to my understanding was not informed.

OTHER WEATHER MODIFICATION PROGRAMS

Senator PELL. Since the secrecy of this program is held so tightly, do you think there could be other weather modification programs going on now in the Government of which you are not aware?

I am not asking this facetiously. I just don't know.

Mr. DOOLIN. It is possible, but I would think not. We have a Presidential decision of 2 years ago on weather modification. Only two foreign weather modification projects have been approved since then—one with regard to Panama to keep the canal clear of fog, and the other was a drought relief operation in the Azores.

Senator PELL. We used it also, I thought, on a friendly basis with other countries for clearing airfields and so forth.

Mr. DOOLIN. Those, sir, as I understand it, are the only two since the Presidential decision a few years ago. Before that, for example, we operated on Okinawa for drought relief. We assisted the Philippines at one time. Since the decision, as I understand it, there was a request from some of the Sahelian states in Africa. Our position has been that the technology is available through commercial contractors and therefore we have advised the countries to go to a commercial contractor for assistance in this regard.

Senator PELL. Have the armed services provided support or training or equipment in this regard to any foreign groups or any foreign governments or troops?

Colonel KAEHN. To some degree there has been interest shown by the Philippines in the techniques, the R. & D. we have done, and the methodology. The apparatus is commercially available.

Senator PELL. It is unclassified anyway, the research.

Colonel KAEHN. Exactly.

Senator PELL. And there is no law against it as of now in any case, either.

Colonel KAEHN. No, sir, not to the best of my knowledge.

Senator PELL. As far as you know, then we have not conducted any weather modification activity over Cuba?

Mr. DOOLIN. No, sir.

Senator PELL. The only ones we have done are in this part of the world?

Mr. DOOLIN. Yes, sir.

NSC INTERAGENCY PANEL

Senator PELL. In 1972 there was an NSC interagency panel under the chairmanship of Mr. Pollack to study the problems of weather modification, to formula American policy.

Did you have a representative on that panel?

Colonel KAEHN. Yes.

Senator PELL. Were you he?

Colonel KAEHN. No, I was not.

Senator PELL. Who was the representative?

Colonel KAEHN. The representative in 1972 was from the office of the Assistant Secretary of Defense for ISA [International Security Affairs]. That is the Under Secretary's committee's report which was produced 2 years ago, you are talking about?

Mr. DOOLIN. That would not have been my office, but the Deputy Assistant Secretary of Defense for Policy Plans, and NSC Affairs.

Senator PELL. It would not have been you, then?

Mr. DOOLIN. No, sir, but it would have been from the Office of Assistant Secretary of Defense for International Security Affairs.

NSC INTERAGENCY PANEL'S REPORT

Senator PELL. Are you at liberty to recall when the final report was made by this panel and what the classification is of that report?

Colonel KAEHN. If we are talking about the same one ——

Senator PELL. I am talking about the one the Pollack Panel did. He was the chairman of it in 1972.

Colonel KAEHN. Yes.

Senator PELL. On this general field.

Colonel KAEHN. That report was submitted in the spring of 1972.

Senator PELL. That would be the one.

Do you recall the classification?

Colonel KAEHN. Yes. As I recall the classification was "Secret."

Senator PELL. "Secret." Would you be at liberty to tell us or can you recall the recommendations and findings of that report?

Colonel KAEHN. Without it in front of me, sir, I would rather not.

Senator PELL. I understand.

Perhaps you could look it up for the record. We are not asking for the whole report.

Mr. DOOLIN. I wonder if Mr. Chapin could be of any assistance?

Mr. CHAPIN. I do not know. I would like to look it up. I would prefer to verify the classification.

Senator PELL. All right.

Would you make note of our request that we receive the conclusions and recommendations of that report and give us something on that?

In fact, we would like to have for our file, unless there is some reason against it, and naturally observing its classification, a copy of them.

[As of the date of publication, the information referred to had not been supplied.]

DECLASSIFICATION OF SECRETARY LAIRD'S LETTER

Going for a second to Secretary Laird's letter, you are going to take that under advisement. My view would be that you would declassify the whole business.

Mr. DOOLIN. The specific matter of Mr. Laird's letter would depend on the decision that was made on the larger item.

PROPOSED DRAFT TREATY

Senator PELL. Are you at liberty to express a view with regard to our proposed draft treaty, what its effect would be on the Defense Department, your plans in being? Would it in any way inhibit you?

Mr. DOOLIN. Mr. Chairman, it is just not in my area of competence. I was here just in context of a briefing on the operations in Southeast Asia which is my area. I have my personal views on rainmaking, but I think you have had plenty of experts speak to you on that.

HEAVY FLOODING IN NORTH VIETNAM

Senator PELL. Was there any relationship between the rainmaking that went on in Southeast Asia and the extraordinarily high floods that occurred at that time in North Vietnam?

Mr. DOOLIN. There were not, sir. At the time of the heavy flooding in North Vietnam there were no rainmaking operations conducted. As Lieutenant Colonel Soyster said in his briefing, in the cases where adequate rainfall did occur then the seeding would have been superfluous and possibly counterproductive. Seeding could have destroyed the clouds. The flooding in North Vietnam, as you will recall, generated widespread civilian suffering and that was never the intention nor the result of this program. Rainmaking in this case would have not only been inappropriate, but also would have been prohibited by the standing orders.

NOVEMBER 1, 1968, PROHIBITION OF RAINMAKING OVER NORTH VIETNAM

Senator PELL. Why on November 1, 1968, was rainmaking over North Vietnam prohibited and never reinstituted? What was the reason for that date?

Mr. DOOLIN. I cannot speak for the administration.

General FURLONG. That was the day President Johnson announced the bombing halt. This fit in with the bombing halt. When you stopped operations in North Vietnam this operation was included as well.

Senator PELL. Right. Didn't we resume bombing of North Vietnam?

Mr. DOOLIN. Yes, sir.

Senator PELL. But these weather modifications were never resumed.

General FURLONG. No, sir.

EFFECTIVENESS OF PROGRAM

Senator PELL. What is your general view as to the effectiveness of this program? I gather from the testimony that you believe it did work and accomplished the purpose you wished.

Mr. DOOLIN. Again, I am not a scientist. I would go back to your elephant-mouse analogy. When you look at those isolines, and the amount of rainfall that was in these given areas anyway, and what was added to it possibly by these extra seedings, it looks to me like when you are getting 21 inches in a given area, and we add 2 inches, if I was on the bottom, I do not think I would know the difference between 21 and 23.

Senator PELL. Was that opinion shared in by the military?

Mr. DOOLIN. I cannot say.

Colonel SOYSTER. It was one of the most difficult parts of the project to try to quantify how well we were doing. The reports indicated we were able to induce rainfall and we knew that from other projects.

The quantification of it was the difficult portion.

OTHER PROGRAMS BEING WORKED ON

Senator PELL. Are you familiar with any other programs we are working on now using rainmaking or, to clear fog from airports and for rescue operations? Do they come under your office?

Colonel SOYSTER. Not under mine, sir.

Colonel Kaehn may be able to speak to that.

Colonel KAEHN. Are you talking about clearing of fog in airports, sir?

Senator PELL. Yes.

Colonel KAEHN. I can speak to that from an R. & D. standpoint.

Senator PELL. And also from the standpoint of rescuing people.

Colonel KAEHN. There are two types of fog to deal with: one is called cold fog where the water exists at temperatures below freezing; it actually exists in water from below zero degrees centigrade: that is commonly called cold fog. We have demonstrated in the R. & D. sense the feasibility of eliminating this fog and we have attempted it at places like Elmendorf, Alaska, so you can get a C–141 in and out of there.

We have a more vexing problem, though, in the handling of warm fog. This is a more difficult problem considerably and one which we continue to do research and development work on.

The Navy is particularly interested in marine fog, the kind of fog that the Navy would encounter in its global mission at sea when it goes everywhere from the Polar to tropical meterological regimes, and encounters different variations.

Senator PELL. Which is your office?

Colonel KAEHN. I am in the Office of the Director of Defense Research and Engineering.

Senator PELL. Are you aware of any other research that we are doing now with regard to other forms of weather modification for military reasons?

Colonel KAEHN. No, sir. To the best of my knowledge, the three main thrusts are the cold fog, warm fog, and the cumulus cloud work.

Senator PELL. You are not working on any of these far out thoughts that have been brought out in testimony before? You are not working on any of those projects at this time?

Colonel KAEHN. No, sir.

Senator PELL. The development of typhoons or the creation of earthquakes or the melting of the Greenland Icecap, anything of that sort?

Colonel KAEHN. No, sir.

Senator PELL. Obviously melting the Greenland Icecap would be very disadvantageous for us.

Mr. DOOLIN. That would really be what you would call climate modification rather than weather modification.

Senator PELL. Exactly.

Colonel KAEHN. The lead agency in the tropical storm modification program is the Department of Commerce: the program is called Stormfury.

In the past the Department of Defense has provided assets to Commerce to do the seeding work since we have the airframes to help them conduct the program. But the lead agency in that effort is the Department of Commerce.

WEATHER MODIFICATION INFORMATION SOUGHT BY POLLACK COMMITTEE

Senator PELL. I would like to go back for a second to a previous question. The National Security Council Interagency Panel, the Pollack committee, was seeking information on military weather modification in Southest Asia. Do you know if it was denied information by the Department of Defense in this area or can you recall that?

Colonel KAEHN. Sir, that was prior to my arrival in the Pentagon and I would rather research that.

Senator PELL. Could you, and submit it for the record.

In other words, I have three questions to ask you for the record in this regard: Did the Pollack committee seek information on weather modification in Southeast Asia? That is question No. 1. Was this information denied an agency of the Government. That is Question No. 2. If there was any denial of it, why was the committee denied this access? What was the reason for it? That is Question No. 3. These answers may all be very simple, but I do feel compelled to ask the questions.

[The information refered to follows:]

POLLACK COMMITTEE'S SEEKING OF INFORMATION ON WEATHER MODIFICATION IN SOUTHEAST ASIA

[Supplied by Department of Defense]

Question 1. Did the Pollack Committee seek information on weather modification in Southeast Asia?

Answer. Yes.

Question 2. Was this information denied an agency of the Government?

Answer. Yes.

Question 3. If there was any denial of it, why was the committee denied this access; what was the reason for it.

Answer. Classification then assigned to this information precluded its availability.

HAS DEPARTMENT OF DEFENSE WORKED WITH CENTRAL INTELLIGENCE AGENCY?

Have you worked at all with the Central Intelligence Agency in trying to carry out weather modification activities or was this completely a Department of Defense operation?

Mr. DOOLIN. Within the operations that were performed in Southeast Asia?

Senator PELL. That is right.

Mr. DOOLIN. This was the only time such an operation was carried out. It was done by the U.S. Air Force.

General FURLONG. This was all Department of Defense.

Senator PELL. Not the Central Intelligence Agency.

IS THIS ONLY U.S. MILITARY WEATHER MODIFICATION ACTIVITY?

Is this the only weather modification activity that the U.S. Government has carried out for military reasons?

Mr. DOOLIN. We can only speak to what the Department of Defense did.

Senator PELL. I see.

Mr. DOOLIN. But, to the best of our knowledge, this is the only weather modification activity conducted by the Department of Defense that was classified.

We are aware of a series that were unclassified.

Senator PELL. Senator Case.

Senator CASE. No more, thanks, I think you have covered it.

DECLASSIFICATION RECOMMENDED

Senator PELL. I must say in conclusion that my own strong recommendation and thought is that you ought to declassify this, and we will ask you to declassify. We will keep your confidence, but you should give us your permission to declassify and publish today's hearing and the whole program because I think it would restore a great deal of confidence, not only in America, but around the world, in the intentions and capacities of the U.S. Government in this regard. There is nothing I can think of that we have said here today which, if published in the public press, would be of any harm. But we will leave that to you and your Department, keeping your confidence, although the Laird letter is slipping away out of our control because it seems to be known around town.

Mr. DOOLIN. Mr. Hersh has been trying to get ahold of me, from the New York Times, and I understand he would have been a better witness before you today than I am. [Laughter.]

Senator PELL. I thank you very much for your frankness and candor and your willingness to be with us. As I say, I hope you will very quickly look into this question of permitting this transcript to be released and the program to be released.

You have been hung for worse things than this, and if people knew what this was, all the people would——

Mr. DOOLIN. We will try our best.

POTENTIAL ADVISABILITY OF WEATHER MODIFICATION TREATY

Senator PELL. Are any of you willing to advance a personal view with regard to the potential advisability of our weather modification treaty, or do you not feel in a position to do so?

Mr. DOOLIN. Well, as I said, all I can really speak to is the rainmaking aspect of it. If an adversary wanted to stop me from getting from point A to point B so I could do something at point B, I would rather he stopped me with a rainstorm than stopped me with a bunch of bombs. Frankly, I view this in that context as really quite humane, if it works.

In my own mind on the basis of the material that I have seen, I am not convinced that it had anything more than a marginal effect, but that is something that even the experts disagree on.

OPERATION ROME PLOW

Senator PELL. As you know, Operation Rome Plow stripped the green cover in Vietnam——

Mr. DOOLIN. To create the landing zones.

Senator PELL [continuing]. To create the landing zones and also make it more militarily controllable. That has resulted in a degree of climate modification. I am wondering if you had any view on that?

Mr. DOOLIN. The Rome Plow?

Senator PELL. Yes.

Mr. DOOLIN. I know in some areas it was necessary to use Rome Plow for reasons of urgent military necessity for clearing roads or an HLZ, helicopter landing zone, for example. The Rome Plow was not generally used in the context of expanding perimeter security. I may be wrong, but that was done primarily around fire bases, by the use of defoliants and active patrolling and not by Rome Plow.

Colonel SOYSTER. In my experience in Vietnam, which included a lot of perimeter defense, we did not have the equipment to do it. I never saw it in 10 months in Vietnam.

EFFECT OF VIETNAM WAR ON VIETNAM

Senator PELL. I think the effect of the war, as I understand it, not having been to Vietnam in the past few years, has been to radically change the character of the country and some of the climate of the country because the green cover has been eliminated. Obviously, these bomb hollows scattered over the country change the character of the country.

Mr. DOOLIN. I think you have to discriminate rather carefully there, Senator, as to what areas of Vietnam you are addressing. I have just returned from a—albeit much too brief—visit to Vietnam with Deputy Secretary Rush. I have made countless visits to Vietnam; I must say it is now the Vietnam I remember from the early 1950's. Saigon again looks like a Vietnamese city. The streets are being cleaned. The buildings are being painted. The bars are being shut down. There are no GI's running around.

The Delta exhibited an incredible prosperity. Aside from the money problems they have—inflation in the major cities which I think can be easily controlled if they get a handle on their commodity imports—the average farmer in the Delta is doing very, very well.

I think that the areas that you are talking about are primarily in the highlands.

Senator PELL. In the highlands, in the north.

Mr. DOOLIN. And in northwest MR–1, which are areas that basically are not considered part of Vietnam in the sense of the real vital living Vietnam even by the Vietnamese themselves.

General FURLONG. Mr. Chairman, one other thing that you might have your staff look at for you and that is the National Academy of Sciences report on herbicides. One of its findings addresses climatological modification resulting from defoliation. I believe it is their conclusion that that is not the case.

Mr. DOOLIN. In fact, I received a request, sir, if I recall, it was about 2 years ago by a team that went out there to study the effects of herbicides in Vietnam, and they went to an area that had been fairly extensively sprayed with herbicide, and they could find no lasting damage, and they requested permission from us to provide them with herbicides so they could respray it and take a look at it, and we told them no.

Senator PELL. I thank you.

DECLASSIFICATION OF PROGRAM

I don't mean to divert from the subject at hand, but I thank you for the testimony. If I get queried by the press, I will relay to them what I have said to you, that I would urge you to declassify the whole program, that perhaps the secrecy has been exaggerated, and that I have not been able to ascertain a reason for this tremendous secrecy. I do not think anybody in this room understands the extrasensitivity for this program.

Senator CASE. It is the kind of thing that you maybe never will know, and maybe they won't, either.

[Discussion off the record.]

DROPPING OF EMULSIFIERS ON LAO PANHANDLE

Senator PELL. One final and specific query here. Do you know anything about the dropping of emulsifiers on trails in the Loatian Panhandle?

Mr. DOOLIN. I do not.

General FURLONG. I heard there was to have been such a proposal. I have heard that it did not work very well and that we did not do any more of it. I do not think it was done by the DOD.

Senator PELL. What it basically does, I understand, is to make the trails slippery and impossible.

General FURLONG. Yes, sir.

Senator PELL. So it may have been attempted, but it was not under the Defense Department's jurisdiction.

General FURLONG. No, sir. First of all, it just would not work, and secondly, it would be dangerous for the crews, and third, we did not want to do it.

Senator PELL. Why would it be dangerous for the crews?

General FURLONG. Because if you were to do something effective, you are talking about lots of pounds of emulsifier. It is the kind of thing that takes a lot of poundage, and you have limited access to some fairly confined area in something like a C–130. As a former C–130 pilot, I would be less than enthused at flying low level over the Laotian Panhandle and shoveling out emulsifier. It just doesn't turn me on. I think sound military judgment prevailed and came to the same conclusion.

Senator PELL. Thank you. I thank you very much indeed and thank you for your frankness and for your being here.

The subcommittee will adjourn, subject to the call of the Chair.

[Whereupon, at 3:35 p.m., the subcommittee adjourned, subject to the call of the Chair.]

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