

IX

## APPENDIX 9

[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. KAHN, 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.

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[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

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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 localizing 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.

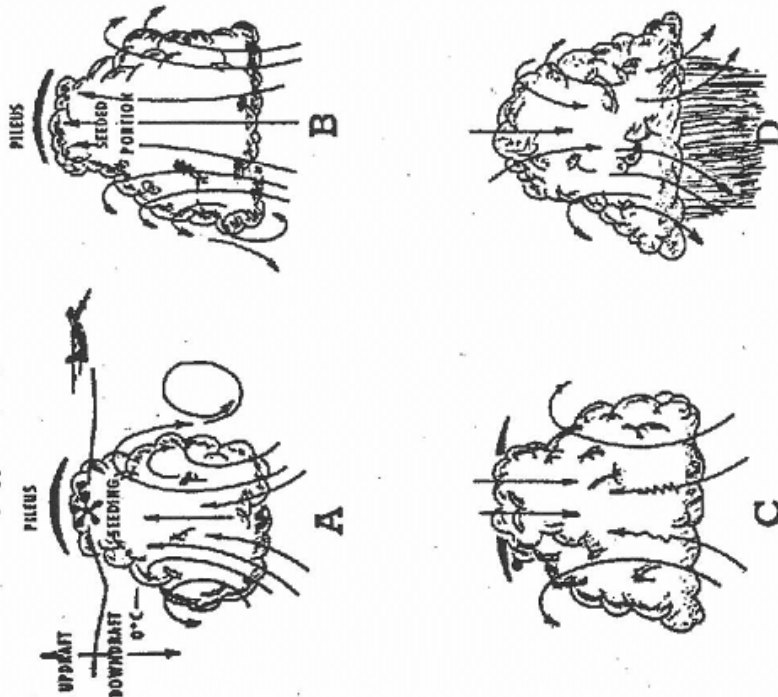
At (B)—Following seeding, the central portion rises rapidly and the base widens. Usually, the portion above the freezing level doubles in volume in 3 to 5 minutes. Updrafts inside are intensified, the total downdraft external to the cloud increases.

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 SOVSTER. 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 published 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 includes 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.

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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 PAUL. 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 cloud-seeding 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.

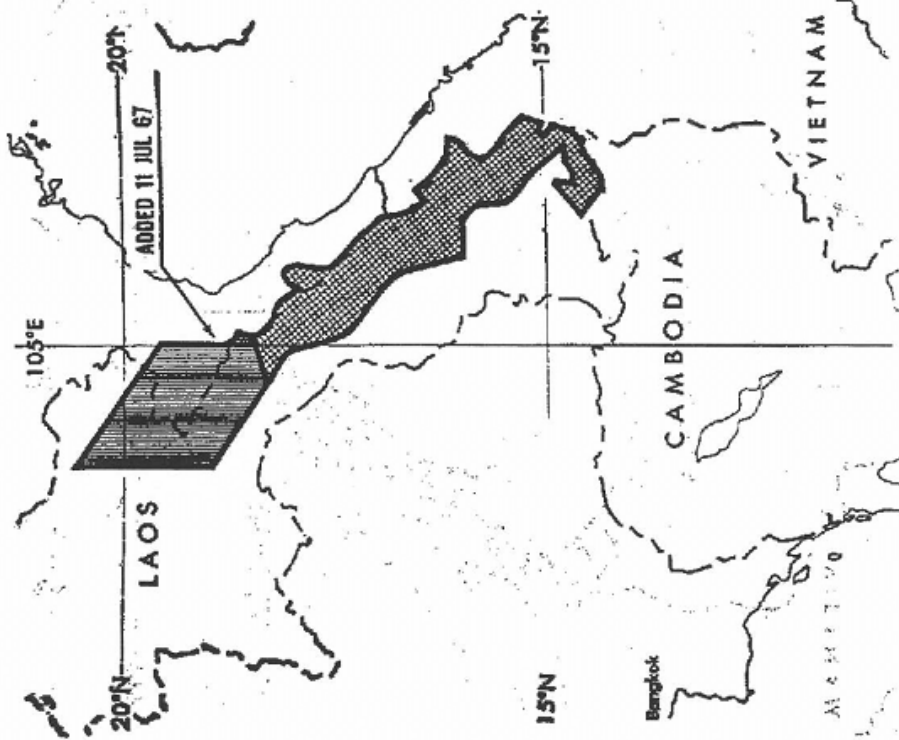
#### AUTHORIZED AREAS OF OPERATIONS

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.

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Colonel Soystra. An area encompassing additional portions of Laos and North Vietnam was added on July 11, 1967. [Chart 5 follows.]

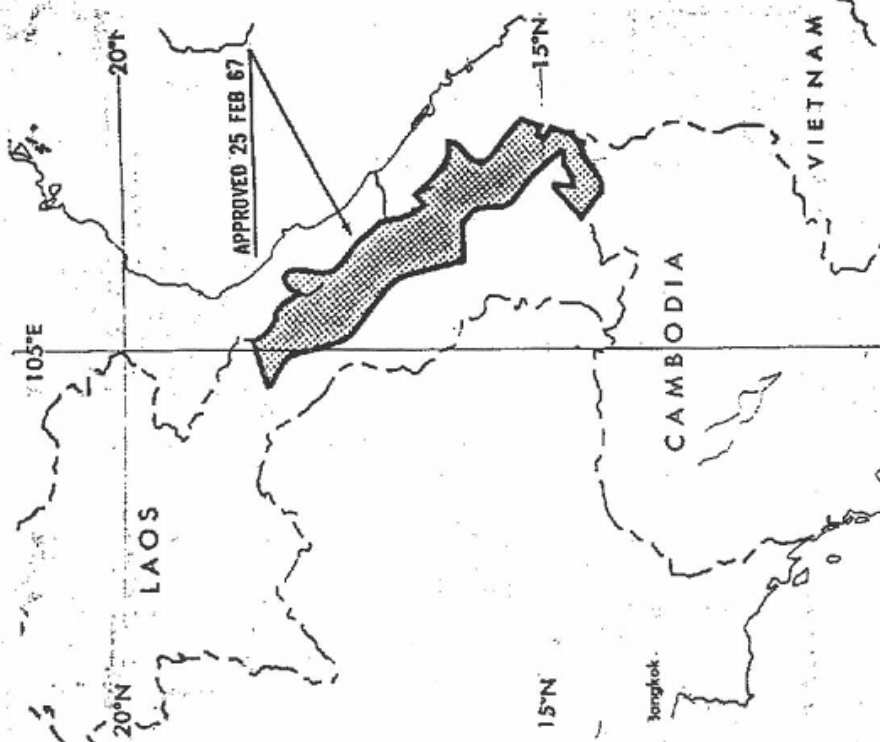
CHART 5.—Additional area of operations authorized on July 11, 1967. [Supplied by Department of Defense]



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This map illustrates the area initially authorized for operations in Laos and a very small portion of North Vietnam. [Chart 4 follows.]

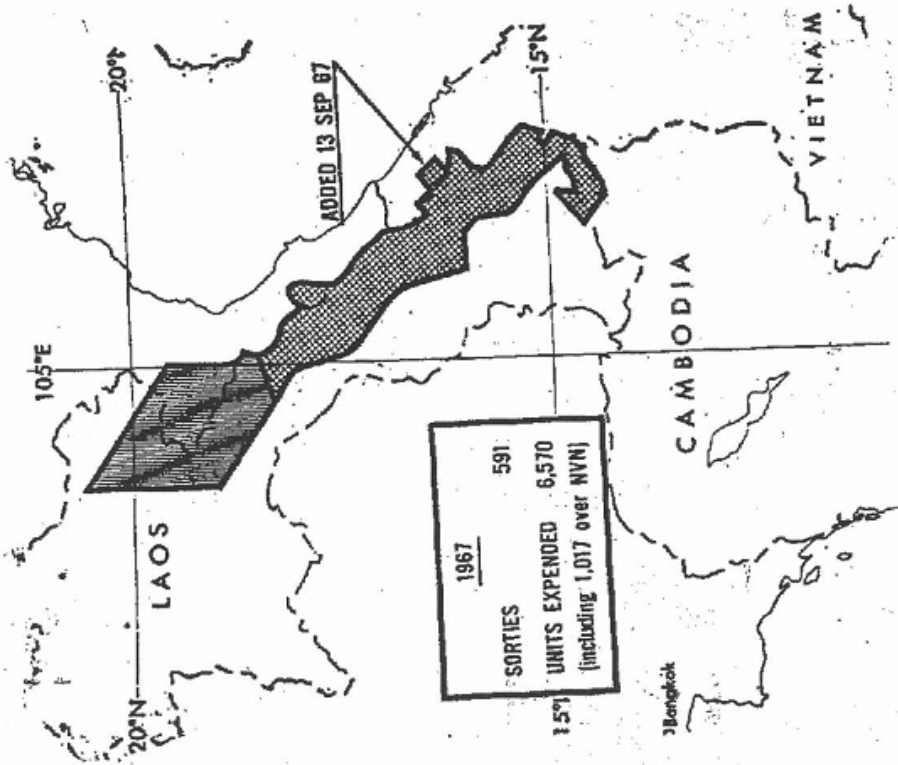
CHART 4.—Initially authorized area of operations. [Supplied by Department of Defense]



Colonel Soystrer. Finally, a small area over the A Chau 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]



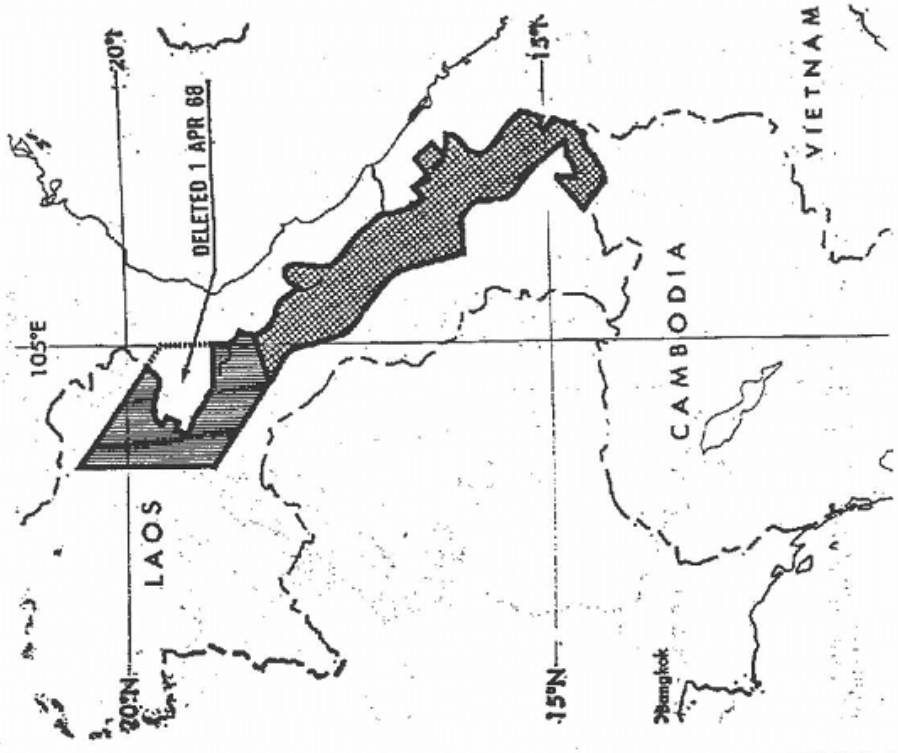
Senator Pezell. The units expended. Colonel Soystrer. Yes, sir; the number of 40 mm photoflash-type cartridges, as I have described, which were expended. Wa. expended

1,017 over North Vietnam. The total sorties include both WC-130 and RF-4.

Senator Pezell. 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 Soystrer. Yes, sir. Of course, those were expended over specific clouds over certain trails which I will talk about a little later.

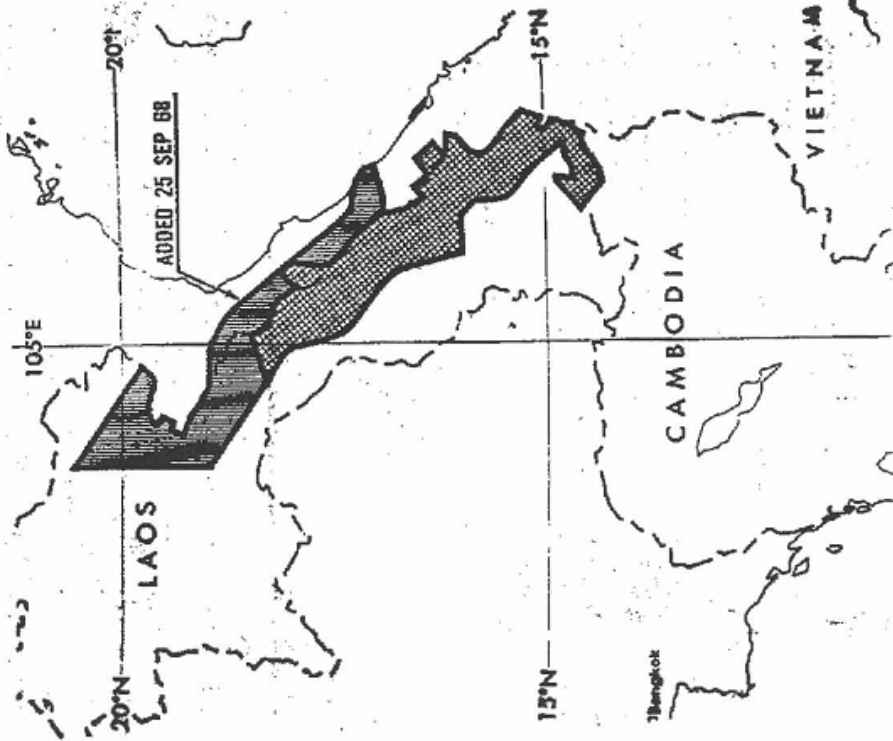
The next slide reflects the areas just briefed as they began in 1968. On April 1, 1968, operations over North Vietnam were restricted to the area south of 19°N coincident with restrictions on bombing above that line.  
[Chart 7 follows:]

CHART 7.—Restrictions of operations over North Vietnam on April 1, 1968.  
[Supplied by Department of Defense]



Colonel Soystrer. 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]



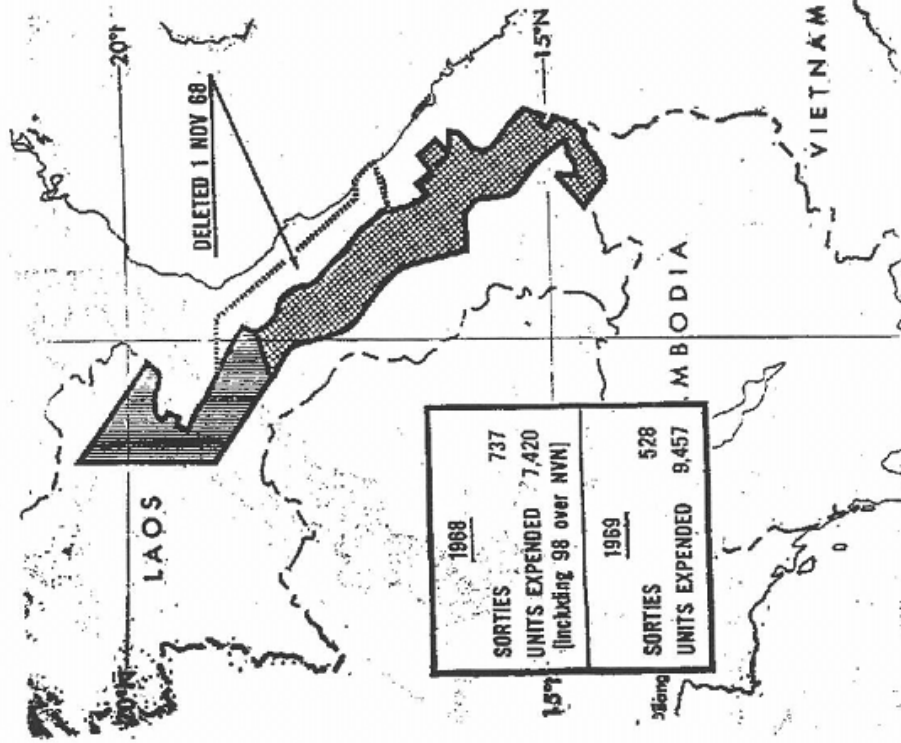
Colonel Soystrer. However, on November 1, 1968 all seeding operations within the boundaries of NVM were terminated and never reinstated. This chart also shows the sorties and units expended for 1968.

Operations in 1969—  
Senator FELL. Excuse me. When was it that you terminated?  
Colonel Soystrer. November 1, 1968, sir.

Senator FELL. Thank you.  
Colonel Soystrer. 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 Vietnam boundaries and sorties and units expended for 1968 and 1969.

[Supplied by Department of Defense]



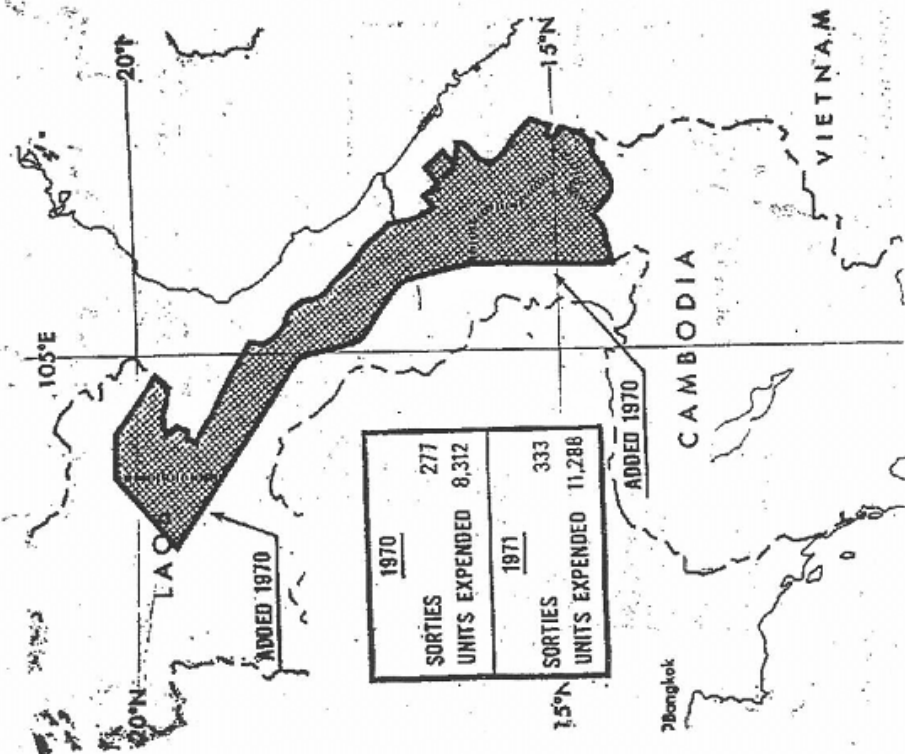
Colonel Soystrer. During 1970, operational areas in Laos were modified as shown in the north and in the south. These are the units expended.

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The 1971 area remained the same. These are the 1971 units and sorties expended in 1971.  
 [Chart 10 follows:]

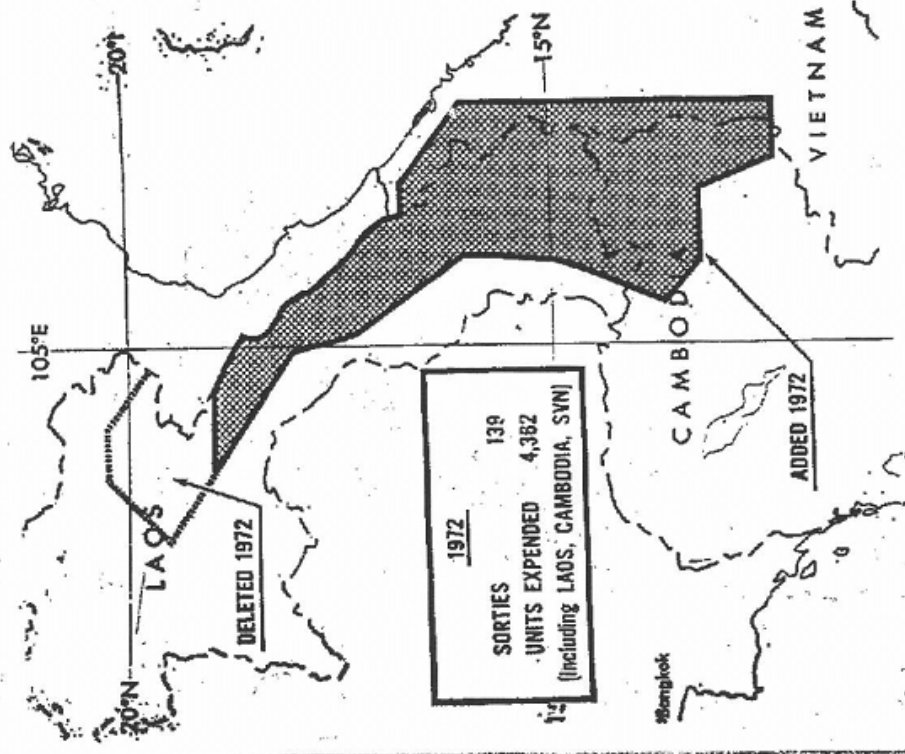
CHART 10.—1970 modification of operational areas in Laos and sorties and units expended, 1970 and 1971.  
 [Supplied by Department of Defense]



Colonel Soyserer. 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 Soyserer. The next chart provides a wrap-up of sorties and seeding units expended for the program.

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## 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 Gilda.

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 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 90 OVER NVN)
1969	528	9,457
1970	277	8,312
1971	333	11,288
1972	139	4,362 (LAOS, CAMBODIA, SVN)
<b>TOTALS</b>	<b>2602</b>	<b>47,409</b>

## 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

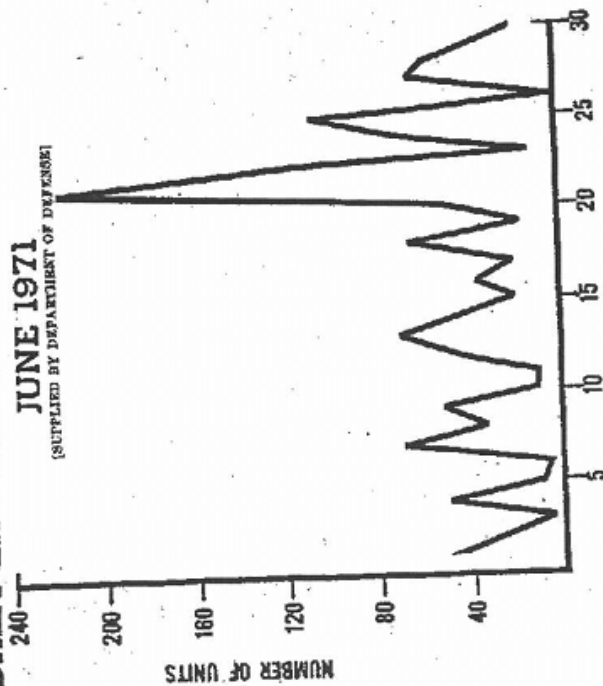
Colonel SOYSTER: The selection of targets or areas of seeding was based on the strategic importance of lines of communication and their susceptibility to interdiction by increased rainfall. Target priorities were assigned and updated on the basis of continuous analysis of all available intelligence information 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.

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[Chart 13 follows:]

### DAILY EXPENDITURE OF SEEDING UNITS

JUNE 1971  
[SUPPLIED BY DEPARTMENT OF DEFENSE]



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 "G" means successful as I have just described, "N" is no effect, and "P" 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	S	NE	F	S	NE	F	RF	INTD
1-8 JUNE	241	195		25	6	2	3	3	4	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.

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[Charts 15 and 16 follow:]

CHART 15.—Total Rainfall in Area, June 1971.

[Supplied by Department of Defense]

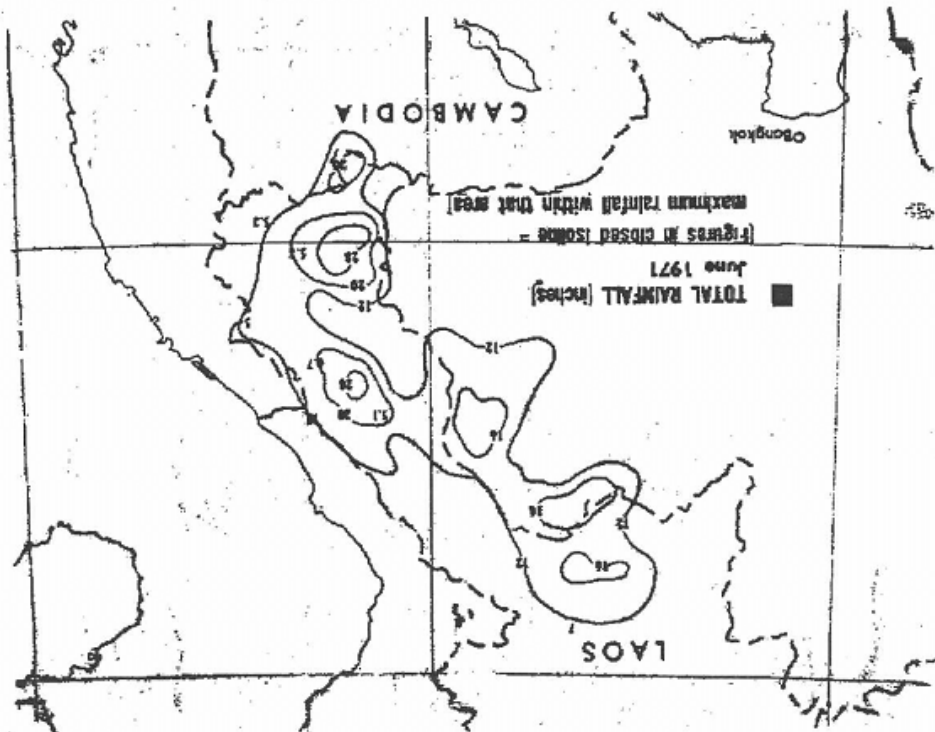
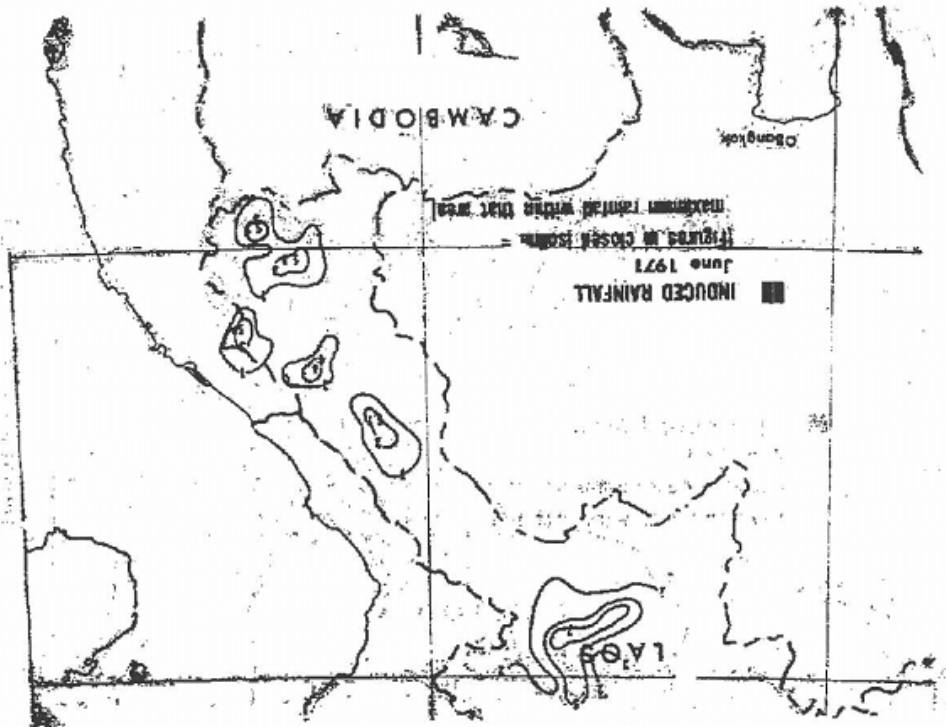


CHART 16.—Induced Rainfall in Area, June 1971.

[Supplied by Department of Defense]



PROPOSAL, TEST AND OPERATIONAL PHASE

Colonel Soystrer. 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.

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## 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

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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.

MELVIN R. LAIRD,  
Counselor for Domestic Affairs.

JANUARY 29, 1974.

Hon. MELVIN R. LAIRD,  
Counselor in the President's Office,  
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 DEPARTMENT 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

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.

L. NIEDERLEHNER,  
Acting General Counsel.

REASON FOR EXTRA SECURITY 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 security 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.

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## DECLASSIFICATION OF PROJECT

Together 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. That this bears directly on my proposed weather modification treaty.

Senator PELL. Right. The reason I am raising these questions is 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.

## 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, Com Patriot. 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 Com Patriot 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.

## 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 committees?

General FURLONG. Preceding testimony has shown four committee chairmen 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 coordinate 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 LAO GOVERNMENTS INFORMED?

Senator PELL. Were the Governments of Thailand and Laos, both of which countries were involved, informed about these operations?

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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?

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 KAERN. 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 KAERN. Exactly.

Senator PELL. And there is no law against it as of now in any case, either.

Colonel KAERN. 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 formulate American policy.

Did you have a representative on that panel?

Colonel KAERN. Yes.

Senator PELL. Were you he?

Colonel KAERN. No, I was not.

Senator PELL. Who was the representative?

Colonel KAERN. 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 KAERN. 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 KAERN. Yes.

Senator PELL. On this general field.

Colonel KAERN. That report was submitted in the spring of 1972.

Senator PELL. That would be the one.

Do you recall the classification?

Colonel KAERN. 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 KAERN. 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?

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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 Soyuzek 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 reinstated? What was the reason for that date?

Mr. DOOLIN. I cannot speak for the administration. General Funlong. 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 Funlong. 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 Soyuzek. 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 Soyuzek. Not under mine, sir.

Colonel Kaehn may be able to speak to that.

Colonel KAERN. Are you talking about clearing of fog in airports, sir?

Senator PELL. Yes.

Colonel KAERN. I can speak to that from an R. & D. standpoint.

Senator PELL. And also from the standpoint of rescuing people.

Colonel KAERN. 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 meteorological regimes, and encounters different variations.

Senator PELL. Which is your office?

Colonel KAERN. 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 KAERN. 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 KAERN. 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 KAERN. 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 KAERN. 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.

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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 Southeast Asia. Do you know if it was denied information by the Department of Defense in this area or can you recall that?

Colonel KAZHN. 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 referred 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. Harsh 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 know 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 rain-making 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 FLOW

Senator PELL. As you know, Operation Rome Flow 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.

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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 H LZ, 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 Soyser. 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 quoted 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 extrosensitivity 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 impassible.

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 Loatian 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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IX 20

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## APPENDIX 10



## 'How we made the Chernobyl rain'

By Richard Gray

Published: 12:01AM BST 22 Apr 2007

Russian military pilots have described how they created rain clouds to protect Moscow from radioactive fallout after the Chernobyl nuclear disaster in 1986.

Major Aleksei Grushin repeatedly took to the skies above Chernobyl and Belarus and used artillery shells filled with silver iodide to make rain clouds that would "wash out" radioactive particles drifting towards densely populated cities.

### Related Articles

**Kremlin revives plan for 60-mile tunnel to Alaska** (</news/worldnews/1549192/Kremlin-revives-plan-for-tunnel-to-Alaska.html>)

**Britain still affected by Chernobyl** (</news/uknews/1514492/20-years-on-Britain-still-feels-the-effects-of-Chernobyl.html>)

**Chernobyl protesters jailed** (</news/worldnews/europe/belarus/1488881/Chernobyl-protesters-are-jailed.html>)

More than 4,000 square miles of Belarus were sacrificed to save the Russian capital from the toxic radioactive material.

"The wind direction was moving from west to east and the radioactive clouds were threatening to reach the highly populated areas of Moscow, Voronezh, Nizhny Novgorod, Yaroslavl," he told Science of Superstorms, a BBC2 documentary to be broadcast today.

"If the rain had fallen on those cities it would've been a catastrophe for millions. The area where my crew was actively influencing the clouds was near Chernobyl, not only in the 30km zone, but out to a distance of 50, 70 and even 100 km."

In the wake of the catastrophic meltdown of the Chernobyl nuclear reactor, people in Belarus reported heavy, black-coloured rain around the city of Gomel. Shortly beforehand, aircraft had been spotted circling in the sky ejecting coloured material behind them.

Moscow has always denied that cloud seeding took place after the accident, but last year on the 20th anniversary of the disaster, Major Grushin was among those honoured for bravery. He claims he received the award for flying cloud seeding missions during the Chernobyl clean-up.

A second Soviet pilot, who asked not to be named, also confirmed to the programme makers that cloud seeding operations took place as early as two days after the explosion.

Alan Flowers, a British scientist who was one of the first Western scientists allowed into the area to examine the extent of radioactive fallout around Chernobyl, said that the population in Belarus was exposed to radiation doses 20 to 30 times higher than normal as a result of the rainfall, causing intense radiation poisoning in children.

Mr Flowers was expelled from Belarus in 2004 after claiming that Russia had seeded the clouds. He said: "The local population say there was no warning before these heavy rains and the radioactive fallout arrived."

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## APPENDIX 11

XI, 2

U.S. Patent No. 4,686,605

United States Patent [19]  
Eastlund

[11] Patent Number: 4,686,605  
[45] Date of Patent: Aug. 11, 1987

[54] METHOD AND APPARATUS FOR ALTERING A REGION IN THE EARTH'S ATMOSPHERE, IONOSPHERE, AND/OR MAGNETOSPHERE

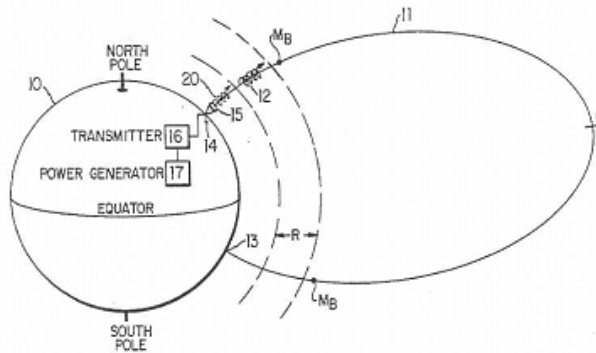
[75] Inventor: Bernard J. Eastlund, Spring, Tex.  
[73] Assignee: APTI, Inc., Los Angeles, Calif.  
[21] Appl. No.: 690,333  
[22] Filed: Jan. 10, 1985  
[51] Int. Cl.<sup>4</sup> ..... H05B 6/64; H05C 3/00; H05H 1/46  
[52] U.S. Cl. .... 361/231; 89/1.11; 380/59; 244/158 R  
[58] Field of Search ..... 361/230, 231; 244/158 R; 376/100; 89/1.11; 380/59

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Liberty Magazine, (2/35) p. 7 N. Tesla.  
New York Times (9/22/40) Section 2, p. 7 W. L. Lawrence.

New York Times (12/8/15) p. 8 Col. 3.  
Primary Examiner—Salvatore Cangialosi  
Attorney, Agent, or Firm—Roderick W. MacDonald

[57] ABSTRACT  
A method and apparatus for altering at least one selected region which normally exists above the earth's surface. The region is excited by electron cyclotron resonance heating to thereby increase its charged particle density. In one embodiment, circularly polarized electromagnetic radiation is transmitted upward in a direction substantially parallel to and along a field line which extends through the region of plasma to be altered. The radiation is transmitted at a frequency which excites electron cyclotron resonance to heat and accelerate the charged particles. This increase in energy can cause ionization of neutral particles which are then absorbed as part of the region thereby increasing the charged particle density of the region.

15 Claims, 5 Drawing Figures

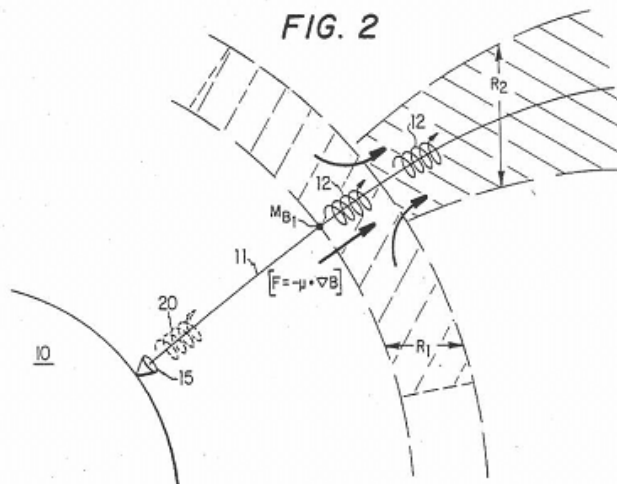
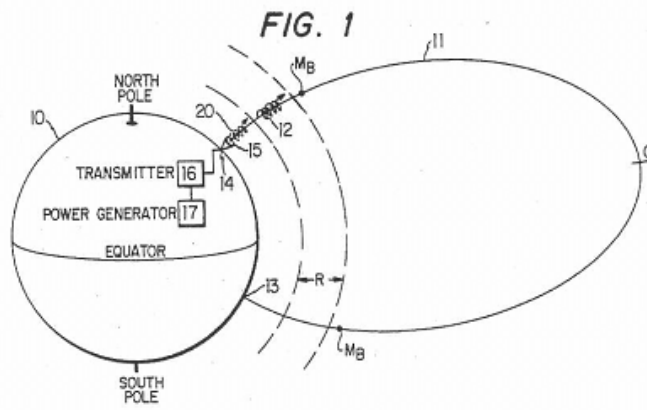




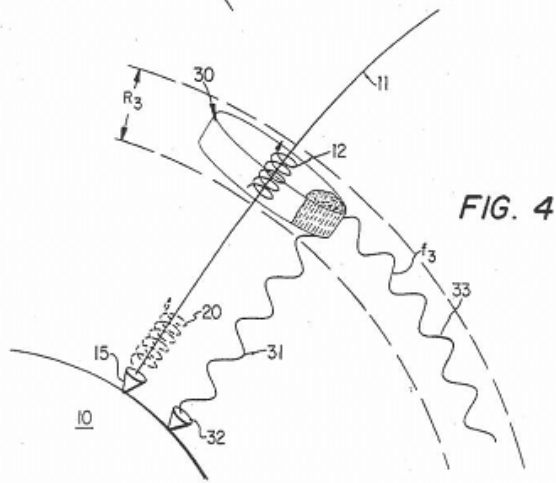
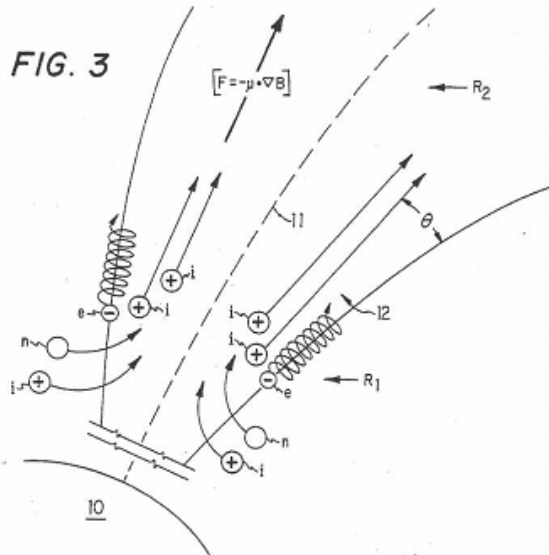
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U.S. Patent No. 4,686,605

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U.S. Patent No. 4,686,605

U.S. Patent Aug. 11, 1987 Sheet 3 of 3 4,686,605

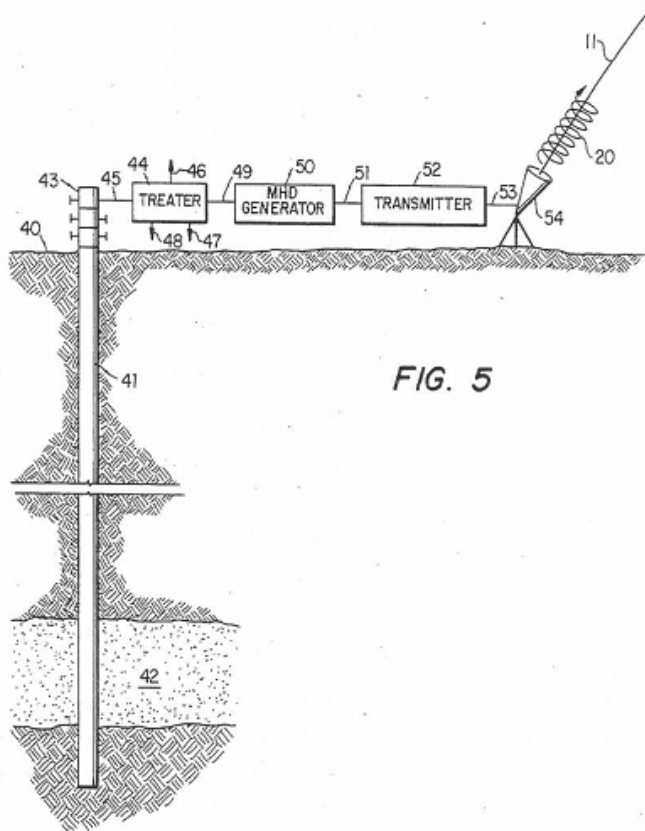


FIG. 5

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METHOD AND APPARATUS FOR ALTERING A REGION IN THE EARTH'S ATMOSPHERE, IONOSPHERE, AND/OR MAGNETOSPHERE

DESCRIPTION

1. Technical Field

This invention relates to a method and apparatus for altering at least one selected region normally existing above the earth's surface and more particularly relates to a method and apparatus for altering said at least one region by initially transmitting electromagnetic radiation from the earth's surface essentially parallel to and along naturally-occurring, divergent magnetic field lines which extend from the earth's surface through the region or regions to be altered.

2. Background Art

In the late 1950's, it was discovered that naturally-occurring belts exist at high altitudes above the earth's surface, and it is now established that these belts result from charged electrons and ions becoming trapped along the magnetic lines of force (field lines) of the earth's essentially dipole magnetic field. The trapped electrons and ions are confined along the field lines between two magnetic mirrors which exist at spaced apart points along those field lines. The trapped electrons and ions move in helical paths around their particular field lines and "bounce" back and forth between the magnetic mirrors. These trapped electrons and ions can oscillate along the field lines for long periods of time.

In the past several years, substantial effort has been made to understand and explain the phenomena involved in belts of trapped electrons and ions, and to explore possible ways to control and use these phenomena for beneficial purposes. For example, in the late 1950's and early 1960's both the United States and U.S.S.R. detonated a series of nuclear devices of various yields to generate large numbers of charged particles at various altitudes, e.g., 200 kilometers (km) or greater. This was done in order to establish and study artificial belts of trapped electrons and ions. These experiments established that at least some of the extraneous electrons and ions from the detonated devices did become trapped along field lines in the earth's magnetosphere to form artificial belts which were stable for prolonged periods of time. For a discussion of these experiments see "The Radiation Belt and Magnetosphere", W. N. Hess, Blaisdell Publishing Co., 1968, pps. 155 et seq.

Other proposals which have been advanced for altering existing belts of trapped electrons and ions and/or establishing similar artificial belts include injecting charged particles from a satellite carrying a payload of radioactive beta-decay material or alpha emitters; and injecting charged particles from a satellite-borne electron accelerator. Still another approach is described in U.S. Pat. No. 4,042,196 wherein a low energy ionized gas, e.g., hydrogen, is released from a synchronous orbiting satellite near the apex of a radiation belt which is naturally-occurring in the earth's magnetosphere to produce a substantial increase in energetic particle precipitation and, under certain conditions, produce a limit in the number of particles that can be stably trapped. This precipitation effect arises from an enhancement of the whistler-mode and ion-cyclotron mode interactions

that result from the ionized gas or "cold plasma" injection.

It has also been proposed to release large clouds of barium in the magnetosphere so that photoionization will increase the cold plasma density, thereby producing electron precipitation through enhanced whistler-mode interactions.

However, in all of the above-mentioned approaches, the mechanisms involved in triggering the change in the trapped particle phenomena must be actually positioned within the affected zone, e.g., the magnetosphere, before they can be actuated to effect the desired change.

The earth's ionosphere is not considered to be a "trapped" belt since there are few trapped particles therein. The term "trapped" herein refers to situations where the force of gravity on the trapped particles is balanced by magnetic forces rather than hydrostatic or collisional forces. The charged electrons and ions in the ionosphere also follow helical paths around magnetic field lines within the ionosphere but are not trapped between mirrors, as in the case of the trapped belts in the magnetosphere, since the gravitational force on the particles is balanced by collisional or hydrostatic forces.

In recent years, a number of experiments have actually been carried out to modify the ionosphere in some controlled manner to investigate the possibility of a beneficial result. For detailed discussions of these operations see the following papers: (1) Ionospheric Modification Theory; G. Meltz and F. W. Perkins; (2) The Platteville High Power Facility; Carrol et al.; (3) Aracibo Heating Experiments; W. E. Gordon and H. C. Carlson, Jr.; and (4) Ionospheric Heating by Powerful Radio Waves; Meltz et al., all published in Radio Science, Vol. 9, No. 11, November, 1974, at pages 885-888; 889-894; 1041-1047; and 1049-1063, respectively, all of which are incorporated herein by reference. In such experiments, certain regions of the ionosphere are heated to change the electron density and temperature within these regions. This is accomplished by transmitting from earth-based antennae high frequency electromagnetic radiation at a substantial angle to, not parallel to, the ionosphere's magnetic field to heat the ionospheric particles primarily by ohmic heating. The electron temperature of the ionosphere has been raised by hundreds of degrees in these experiments, and electrons with several electron volts of energy have been produced in numbers sufficient to enhance airglow. Electron concentrations have been reduced by a few percent, due to expansion of the plasma as a result of increased temperature.

In the Elmo Bumpy Torus (EBT), a controlled fusion device at the Oak Ridge National Laboratory, all heating is provided by microwaves at the electron cyclotron resonance interaction. A ring of hot electrons is formed at the earth's surface in the magnetic mirror by a combination of electron cyclotron resonance and stochastic heating. In the EBT, the ring electrons are produced with an average "temperature" of 250 kilo electron volts or kev ( $2.5 \times 10^9$ K) and a plasma beta between 0.1 and 0.4; see, "A Theoretical Study of Electron-Cyclotron Absorption in Elmo Bumpy Torus", Batchelor and Goldfinger, Nuclear Fusion, Vol. 20, No. 4 (1980) pps. 403-418.

Electron cyclotron resonance heating has been used in experiments on the earth's surface to produce and accelerate plasmas in a diverging magnetic field. Kosmahl et al. showed that power was transferred from the electromagnetic waves and that a fully ionized plasma

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3 was accelerated with a divergence angle of roughly 13 degrees. Optimum neutral gas density was  $1.7 \times 10^{14}$  per cubic centimeter; see, "Plasma Acceleration with Microwaves Near Cyclotron Resonance", Kosmahl et al., Journal of Applied Physics, Vol. 38, No. 12, Nov., 1967, pps. 4576-4582.

DISCLOSURE OF THE INVENTION

The present invention provides a method and apparatus for altering at least one selected region which normally exists above the earth's surface. The region is excited by electron cyclotron resonance heating of electrons which are already present and/or artificially created in the region to thereby increase the charged particle energy and ultimately the density of the region.

In one embodiment this is done by transmitting circularly polarized electromagnetic radiation from the earth's surface at or near the location where a naturally-occurring dipole magnetic field (force) line intersects the earth's surface. Right hand circular polarization is used in the northern hemisphere and left hand circular polarization is used in the southern hemisphere. The radiation is deliberately transmitted at the outset in a direction substantially parallel to and along a field line which extends upwardly through the region to be altered. The radiation is transmitted at a frequency which is based on the gyrofrequency of the charged particles and which, when applied to the at least one region, excites electron cyclotron resonance within the region or regions to heat and accelerate the charged particles in their respective helical paths around and along the field line. Sufficient energy is employed to cause ionization of neutral particles (molecules of oxygen, nitrogen and the like, particulates, etc.) which then become a part of the region thereby increasing the charged particle density of the region. This effect can further be enhanced by providing artificial particles, e.g., electrons, ions, etc., directly into the region to be affected from a rocket, satellite, or the like to supplement the particles in the naturally-occurring plasma. These artificial particles are also ionized by the transmitted electromagnetic radiation thereby increasing charged particle density of the resulting plasma in the region.

In another embodiment of the invention, electron cyclotron resonance heating is carried out in the selected region or regions at sufficient power levels to allow a plasma present in the region to generate a mirror force which forces the charged electrons of the altered plasma upward along the force line to an altitude which is higher than the original altitude. In this case the relevant mirror points are at the base of the altered region or regions. The charged electrons drag ions with them as well as other particles that may be present. Sufficient power, e.g.,  $10^{15}$  joules, can be applied so that the altered plasma can be trapped on the field line between mirror points and will oscillate in space for prolonged periods of time. By this embodiment, a plume of altered plasma can be established at selected locations for communication modification or other purposes.

In another embodiment, this invention is used to alter at least one selected region of plasma in the ionosphere to establish a defined layer of plasma having an increased charged particle density. Once this layer is established, and while maintaining the transmission of the main beam of circularly polarized electromagnetic radiation, the main beam is modulated and/or at least one second different, modulated electromagnetic radi-

4 tion beam is transmitted from at least one separate source at a different frequency which will be absorbed in the plasma layer. The amplitude of the frequency of the main beam and/or the second beam or beams is modulated in resonance with at least one known oscillation mode in the selected region or regions to excite the known oscillation mode to propagate a known frequency wave or waves throughout the ionosphere.

BRIEF DESCRIPTION OF THE DRAWINGS

The actual construction, operation, and apparent advantages of this invention will be better understood by referring to the drawings in which like numerals identify like parts and in which:

FIG. 1 is a simplified schematical view of the earth (not to scale) with a magnetic field (force) line along which the present invention is carried out;

FIG. 2 is one embodiment within the present invention in which a selected region of plasma is raised to a higher altitude;

FIG. 3 is a simplified, idealized representation of a physical phenomenon involved in the present invention; and

FIG. 4 is a schematic view of another embodiment within the present invention.

FIG. 5 is a schematic view of an apparatus embodiment within this invention.

BEST MODES FOR CARRYING OUT THE INVENTION

The earth's magnetic field is somewhat analogous to a dipole bar magnet. As such, the earth's magnetic field contains numerous divergent field or force lines, each line intersecting the earth's surface at points on opposite sides of the Equator. The field lines which intersect the earth's surface near the poles have apexes which lie at the furthest points in the earth's magnetosphere while those closest to the Equator have apexes which reach only the lower portion of the magnetosphere.

At various altitudes above the earth's surface, e.g., in both the ionosphere and the magnetosphere, plasma is naturally present along these field lines. This plasma consists of equal numbers of positively and negatively charged particles (i.e., electrons and ions) which are guided by the field line. It is well established that a charged particle in a magnetic field gyrates about field lines, the center of gyration at any instance being called the "guiding center" of the particle. As the gyrating particle moves along a field line in a uniform field, it will follow a helical path about its guiding center, hence linear motion, and will remain on the field line. Electrons and ions both follow helical paths around a field line but rotate in opposite directions. The frequencies at which the electrons and ions rotate about the field line are called gyromagnetic frequencies or cyclotron frequencies because they are identical with the expression for the angular frequencies of gyration of particles in a cyclotron. The cyclotron frequency of ions in a given magnetic field is less than that of electrons, in inverse proportion to their masses.

If the particles which form the plasma along the earth's field lines continued to move with a constant pitch angle, often designated "alpha", they would soon impact on the earth's surface. Pitch angle alpha is defined as the angle between the direction of the earth's magnetic field and the velocity (V) of the particle. However, in converging force fields, the pitch angle does change in such a way as to allow the particle to

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turn around and avoid impact. Consider a particle moving along a field line down toward the earth. It moves into a region of increasing magnetic field strength and therefore sine alpha increases. But sine alpha can only increase to 1.0, at which point, the particle turns around and starts moving up along the field line, and alpha decreases. The point at which the particle turns around is called the mirror point, and there alpha equals ninety degrees. This process is repeated at the other end of the field line where the same magnetic field strength value B, namely Bm, exists. The particle again turns around and this is called the "conjugate point" of the original mirror point. The particle is therefore trapped and bounces between the two magnetic mirrors. The particle can continue oscillating in space in this manner for long periods of time. The actual place where a particle will mirror can be calculated from the following:

$$\sin^2 \alpha_{m0} = B_0 / B_m \quad (1)$$

wherein:  
alpha<sub>0</sub> = equatorial pitch angle of particle  
B<sub>0</sub> = equatorial field strength on a particular field line  
B<sub>m</sub> = field strength at the mirror point

Recent discoveries have established that there are substantial regions of naturally trapped particles in space which are commonly called "trapped radiation belts". These belts occur at altitudes greater than about 500 km and accordingly lie in the magnetosphere and mostly above the ionosphere.

The ionosphere, while it may overlap some of the trapped-particle belts, is a region in which hydrostatic forces govern its particle distribution in the gravitational field. Particle motion within the ionosphere is governed by both hydrodynamic and electrodynamic forces. While there are few trapped particles in the ionosphere, nevertheless, plasma is present along field lines in the ionosphere. The charged particles which form this plasma move between collisions with other particles along similar helical paths around the field lines and although a particular particle may diffuse downward into the earth's lower atmosphere or lose energy and diverge from its original field line due to collisions with other particles, these charged particles are normally replaced by other available charged particles or by particles that are ionized by collision with said particle. The electron density (N<sub>e</sub>) of the plasma will vary with the actual conditions and locations involved. Also, neutral particles, ions, and electrons are present in proximity to the field lines.

The production of enhanced ionization will also alter the distribution of atomic and molecular constituents of the atmosphere, most notably through increased atomic nitrogen concentration. The upper atmosphere is normally rich in atomic oxygen (the dominant atmospheric constituent above 200 km altitude), but atomic nitrogen is normally relatively rare. This can be expected to manifest itself in increased airglow, among other effects.

As known in plasma physics, the characteristics of a plasma can be altered by adding energy to the charged particles or by ionizing or exciting additional particles to increase the density of the plasma. One way to do this is by heating the plasma which can be accomplished in different ways, e.g., ohmic, magnetic compression, shock waves, magnetic pumping, electron cyclotron resonance, and the like.

Since electron cyclotron resonance heating is involved in the present invention, a brief discussion of

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same is in order. Increasing the energy of electrons in a plasma by invoking electron cyclotron resonance heating, is based on a principle similar to that utilized to accelerate charged particles in a cyclotron. If a plasma is confined by a static axial magnetic field of strength B, the charged particles will gyrate about the lines of force with a frequency given, in hertz, as  $f_c = 1.54 \times 10^3 B/A$ , where: B = magnetic field strength in gauss, and A = mass number of the ion.

Suppose a time-varying field of this frequency is superimposed on the static field B confining the plasma, by passage of a radiofrequency current through a coil which is concentric with that producing the axial field, then in each half-cycle of their rotation about the field lines, the charged particles acquire energy from the oscillating electric field associated with the radio frequency. For example, if B is 10,000 gauss, the frequency of the field which is in resonance with protons in a plasma is 15.4 megahertz.

As applied to electrons, electron cyclotron resonance heating requires an oscillating field having a definite frequency determined by the strength of the confining field. The radio-frequency radiation produces time-varying fields (electric and magnetic), and the electric field accelerates the charged particle. The energized electrons share their energy with ions and neutrals by undergoing collisions with these particles, thereby effectively raising the temperature of the electrons, ions, and neutrals. The apportionment of energy among these species is determined by collision frequencies. For a more detailed understanding of the physics involved, see "Controlled Thermonuclear Reactions", Glasstone and Lovberg, D. Van Nostrand Company, Inc., Princeton, N.J., 1960 and "The Radiation Belt and Magnetosphere", Hess, Blaisdell Publishing Company, 1968, both of which are incorporated herein by reference.

Referring now to the drawings, the present invention provides a method and apparatus for altering at least one region of plasma which lies along a field line, particularly when it passes through the ionosphere and/or magnetosphere. FIG. 1 is a simplified illustration of the earth 10 and one of its dipole magnetic force or field lines 11. As will be understood, line 11 may be any one of the numerous naturally existing field lines and the actual geographical locations 13 and 14 of line 11 will be chosen based on a particular operation to be carried out. The actual locations at which field lines intersect the earth's surface is documented and is readily ascertainable by those skilled in the art.

Line 11 passes through region R which lies at an altitude above the earth's surface. A wide range of altitudes are useful given the power that can be employed by the practice of this invention. The electron cyclotron resonance heating effect can be made to act on electrons anywhere above the surface of the earth. These electrons may be already present in the atmosphere, ionosphere, and/or magnetosphere of the earth, or can be artificially generated by a variety of means such as x-ray beams, charged particle beams, lasers, the plasma sheath surrounding an object such as a missile or meteor, and the like. Further, artificial particles, e.g., electrons, ions, etc., can be injected directly into region R from an earth-launched rocket or orbiting satellite carrying, for example, a payload of radioactive beta-decay material; alpha emitters; an electron accelerator; and/or ionized gases such as hydrogen; see U.S. Pat. No. 4,042,196. The altitude can be greater than about 50 km if desired.

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7 e.g., can be from about 50 km to about 800 km, and, accordingly may lie in either the ionosphere or the magnetosphere or both. As explained above, plasma will be present along line 11 within region R and is represented by the helical line 12. Plasma 12 is com-  
5 10 15

prised of charged particles (i.e., electrons and ions) which rotate about opposing helical paths along line 11. Antenna 15 is positioned as close as is practical to the location 14 where line 11 intersects the earth's surface. Antenna 15 may be of any known construction for high directionality, for example, a phased array, beam spread angle ( $\theta$ ) type. See "The MST Radar at Poker Flat, Alaska", Radio Science, Vol. 15, No. 2, Mar.-Apr. 1980, pps. 213-223, which is incorporated herein by refer-  
15 20 25

ence. Antenna 15 is coupled to transmitter 16 which generates a beam of high frequency electromagnetic radiation at a wide range of discrete frequencies, e.g., from about 20 to about 1800 kilohertz (kHz). Transmitter 16 is powered by power generator means 17 which is preferably comprised of one or more large, commercial electrical generators. Some embodiments of the present invention require large amounts of power, e.g., up to  $10^9$  to  $10^{11}$  watts, in continuous wave or pulsed power. Generation of the needed power is within the state of the art. Although the electrical gener-  
25 30 35 40 45 50 55

$$v = df$$

where  $f$  is the frequency at which electricity is gener-  
ated. Thus, if  $v = 1.78 \times 10^9$  cm/sec and  $d = 1$  cm then

8 electricity would be generated at a frequency of 1.78 mHz.

Put another way, in Alaska, the right type of fuel (natural gas) is naturally present in large amounts and at just the right magnetic latitudes for the most efficient practice of this invention, a truly unique combination of circumstances. Desirable magnetic latitudes for the practice of this invention interest the earth's surface both northerly and southerly of the equator, particu-  
larly desirable latitudes being those, both northerly and southerly, which correspond in magnitude with the magnetic latitudes that encompass Alaska.

Referring now to FIG. 2 a first embodiment is illus-  
trated where a selected region  $R_1$  of plasma 12 is altered by electron cyclotron resonance heating to accelerate the electrons of plasma 12, which are following helical paths along field line 11.

To accomplish this result, electromagnetic radiation is transmitted at the outset, essentially parallel to line 11 via antenna 15 as right hand circularly polarized radia-  
tion wave 20. Wave 20 has a frequency which will excite electron cyclotron resonance with plasma 12 at its initial or original altitude. This frequency will vary depending on the electron cyclotron resonance of re-  
20 25 30 35 40 45 50 55

gion  $R_1$  which, in turn, can be determined from available data based on the altitudes of region  $R_1$ , the particular field line 11 being used, the strength of the earth's mag-  
netic field, etc. Frequencies of from about 20 to about 7200 kHz, preferably from about 20 to about 1800 kHz can be employed. Also, for any given application, there will be a threshold (minimum power level) which is needed to produce the desired result. The minimum power level is a function of the level of plasma produc-  
tion and movement required, taking into consideration any loss processes that may be dominant in a particular plasma or propagation path.

As electron cyclotron resonance is established in plasma 12, energy is transferred from the electromag-  
netic radiation 20 into plasma 12 to heat and accelerate the electrons therein and, subsequently, ions and neutral particles. As this process continues, neutral particles which are present within  $R_1$  are ionized and absorbed into plasma 12 and this increases the electron and ion densities of plasma 12. As the electron energy is raised to values of about 1 kilo electron volt (keV), the gener-  
ated mirror force (explained below) will direct the ex-  
cited plasma 12 upward along line 11 to form a plume  $R_2$  at an altitude higher than that of  $R_1$ .

Plasma acceleration results from the force on an elec-  
tron produced by a nonuniform static magnetic field ( $B$ ). The force, called the mirror force, is given by

$$F = -\mu \nabla B \quad (2)$$

where  $\mu$  is the electron magnetic moment and  $\nabla B$  is the gradient of the magnetic field,  $\mu$  being further defined as:

$$W_{\perp} / B = m v_{\perp}^2 / 2B$$

where  $W_{\perp}$  is the kinetic energy in the direction perpen-  
dicular to that of the magnetic field lines and  $B$  is the magnetic field strength at the line of force on which the guiding center of the particle is located. The force as represented by equation (2) is the force which is respon-  
sible for a particle obeying equation (1).

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Since the magnetic field is divergent in region R<sub>1</sub>, it can be shown that the plasma will move upwardly from the heating region as shown in FIG. 1 and further it can be shown that

$$\frac{1}{2} M_e V_{e\perp}^2(x) = \frac{1}{2} M_e V_{e\perp}^2(Y) + \frac{1}{2} M_i V_{i\parallel}^2(Y) \quad (3)$$

where the left hand side is the initial electron transverse kinetic energy; the first term on the right is the transverse electron kinetic energy at some point (Y) in the expanded field region, while the final term is the ion kinetic energy parallel to B at point (Y). This last term is what constitutes the desired ion flow. It is produced by an electrostatic field set up by electrons which are accelerated according to Equation (2) in the divergent field region and pulls ions along with them. Equation (3) ignores electron kinetic energy parallel to B because  $V_{e\parallel} \approx V_{i\parallel}$ , so the bulk of parallel kinetic energy resides in the ions because of their greater masses. For example, if an electromagnetic energy flux of from about 1 to about 10 watts per square centimeter is applied to region R, whose altitude is 115 km, a plasma having a density (N<sub>e</sub>) of 10<sup>12</sup> per cubic centimeter will be generated and moved upward to region R<sub>2</sub> which has an altitude of about 1000 km. The movement of electrons in the plasma is due to the mirror force while the ions are moved by ambipolar diffusion (which results from the electrostatic field). This effectively "lifts" a layer of plasma 12 from the ionosphere and/or magnetosphere to a higher elevation R<sub>2</sub>. The total energy required to create a plasma with a base area of 3 square kilometers and a height of 1000 km is about 3 × 10<sup>13</sup> joules.

FIG. 3 is an idealized representation of movement of plasma 12 upon excitation by electron cyclotron resonance within the earth's divergent force field. Electrons (e) are accelerated to velocities required to generate the necessary mirror force to cause their upward movement. At the same time neutral particles (n) which are present along line 11 in region R<sub>1</sub> are ionized and become part of plasma 12. As electrons (e) move upward along line 11, they drag ions (i) and neutrals (n) with them but at an angle θ of about 13 degrees to field line 11. Also, any particulates that may be present in region R<sub>1</sub>, will be swept upwardly with the plasma. As the charged particles of plasma 12 move upward, other particles such as neutrals within or below R<sub>1</sub>, move in to replace the upwardly moving particles. These neutrals, under some conditions, can drag with them charged particles.

For example, as a plasma moves upward, other particles at the same altitude as the plasma move horizontally into the region to replace the rising plasma and to form new plasma. The kinetic energy developed by said other particles as they move horizontally is, for example, on the same order of magnitude as the total zonal kinetic energy of stratospheric winds known to exist.

Referring again to FIG. 2, plasma 12 in region R<sub>1</sub> is moved upward along field line 11. The plasma 12 will then form a plume (cross-hatched area in FIG. 2) which will be relatively stable for prolonged periods of time. The exact period of time will vary widely and be determined by gravitational forces and a combination of radiative and diffusive loss terms. In the previous detailed example, the calculations were based on forming a plume by producing 0<sup>+</sup> energies of 2 ev/particle. About 10 ev per particle would be required to expand plasma 12 to apex point C (FIG. 1). There at least some of the particles of plasma 12 will be trapped and will oscillate between mirror points along field line 11. This

oscillation will then allow additional heating of the trapped plasma 12 by stochastic heating which is associated with trapped and oscillating particles. See "A New Mechanism for Accelerating Electrons in the Outer Ionosphere" by R. A. Helliwell and T. F. Bell, Journal of Geophysical Research, Vol. 65, No. 6, June, 1960. This is preferably carried out at an altitude of at least 500 km.

The plasma of the typical example might be employed to modify or disrupt microwave transmissions of satellites. If less than total black-out of transmission is desired (e.g., scrambling by phase shifting digital signals), the density of the plasma (N<sub>e</sub>) need only be at least about 10<sup>6</sup> per cubic centimeter for a plasma originating at an altitude of from about 250 to about 400 km and accordingly less energy (i.e., electromagnetic radiation), e.g., 10<sup>8</sup> joules need be provided. Likewise, if the density N<sub>e</sub> is on the order of 10<sup>8</sup>, a properly positioned plume will provide a reflecting surface for VHF waves and can be used to enhance, interfere with, or otherwise modify communication transmissions. It can be seen from the foregoing that by appropriate application of various aspects of this invention at strategic locations and with adequate power sources, a means and method is provided to cause interference with or even total disruption of communications over a very large portion of the earth. This invention could be employed to disrupt not only land based communications, both civilian and military, but also airborne communications and sea communications (both surface and subsurface). This would have significant military implications, particularly as a barrier to or confusing factor for hostile missiles or airplanes. The belt or belts of enhanced ionization produced by the method and apparatus of this invention, particularly if set up over Northern Alaska and Canada, could be employed as an early warning device, as well as a communications disruption medium. Further, the simple ability to produce such a situation in a practical time period can by itself be a deterring force to hostile action. The ideal combination of suitable field lines intersecting the earth's surface at the point where substantial fuel sources are available for generation of very large quantities of electromagnetic power, such as the North Slope of Alaska, provides the wherewithal to accomplish the foregoing in a practical time period, e.g., strategic requirements could necessitate achieving the desired altered regions in time periods of two minutes or less and this is achievable with this invention, especially when the combination of natural gas and magnetohydrodynamic, gas turbine, fuel cell and/or EGD electric generators are employed at the point where the useful field lines intersect the earth's surface. One feature of this invention which satisfies a basic requirement of a weapon system, i.e., continuous checking of operability, is that small amounts of power can be generated for operability checking purposes. Further, in the exploitation of this invention, since the main electromagnetic beam which generates the enhanced ionized belt of this invention can be modulated itself and/or one or more additional electromagnetic radiation waves can be impinged on the ionized region formed by this invention as will be described in greater detail herein after with respect to FIG. 4, a substantial amount of randomly modulated signals of very large power magnitude can be generated in a highly nonlinear mode. This can cause confusion of or interference with or even complete disruption of guidance systems employed by



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 even the most sophisticated of airplanes and missiles. The ability to employ and transmit over very wide areas of the earth a plurality of electromagnetic waves of varying frequencies and to change same at will in a random manner, provides a unique ability to interfere with all modes of communications, land, sea, and/or air, at the same time. Because of the unique juxtaposition of usable fuel source at the point where desirable field lines intersect the earth's surface, such wide ranging and complete communication interference can be achieved in a reasonably short period of time. Because of the mirroring phenomenon discussed hereinabove, it can also be prolonged for substantial time periods so that it would not be a mere transient effect that could simply be waited out by an opposing force. Thus, this invention provides the ability to put unprecedented amounts of power in the earth's atmosphere at strategic locations and to maintain the power injection level, particularly if random pulsing is employed, in a manner far more precise and better controlled than heretofore accomplished by the prior art, particularly by the detonation of nuclear devices of various yields at various altitudes. Where the prior art approaches yielded merely transitory effects, the unique combination of fuel and desirable field lines at the point where the fuel occurs allows the establishment of, compared to prior art approaches, precisely controlled and long-lasting effects which cannot, practically speaking, simply be waited out. Further, by knowing the frequencies of the various electromagnetic beams employed in the practice of this invention, it is possible not only to interfere with third party communications but to take advantage of one or more such beams to carry out a communications network even though the rest of the world's communications are disrupted. Put another way, what is used to disrupt another's communications can be employed by one knowledgeable of this invention as a communications network at the same time. In addition, once one's own communication network is established, the far-reaching extent of the effects of this invention could be employed to pick up communication signals of other for intelligence purposes. Thus, it can be seen that the disrupting effects achievable by this invention can be employed to benefit by the party who is practicing this invention since knowledge of the various electromagnetic waves being employed and how they will vary in frequency and magnitude can be used to an advantage for positive communication and eavesdropping purposes at the same time. However, this invention is not limited to locations where the fuel source naturally exists or where desirable field lines naturally intersect the earth's surface. For example, fuel, particularly hydrocarbon fuel, can be transported by pipeline and the like to the location where the invention is to be practiced.

FIG. 4 illustrates another embodiment wherein a selected region of plasma R<sub>1</sub> which lies within the earth's ionosphere is altered to increase the density thereof whereby a relatively stable layer 30 of relatively dense plasma is maintained within region R<sub>1</sub>. Electromagnetic radiation is transmitted at the outset essentially parallel to field line 11 via antenna 15 as a right hand circularly polarized wave and at a frequency (e.g., 1.78 megahertz when the magnetic field at the desired altitude is 0.66 gauss) capable of exciting electron cyclotron resonance in plasma 12 at the particular altitude of plasma 12. This causes heating of the particles (electrons, ions, neutrals, and particulates) and ionization of the uncharged particles adjacent line 11, all of which

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 are absorbed into plasma 12 to increase the density thereof. The power transmitted, e.g.,  $2 \times 10^6$  watts for up to 2 minutes heating time, is less than that required to generate the mirror force F required to move plasma 12 upward as in the previous embodiment.

While continuing to transmit electromagnetic radiation 20 from antenna 15, a second electromagnetic radiation beam 31, which is at a defined frequency different from the radiation from antenna 15, is transmitted from one or more second sources via antenna 32 into layer 30 and is absorbed into a portion of layer 30 (cross-hatched area in FIG. 4). The electromagnetic radiation wave from antenna 32 is amplitude modulated to match a known mode of oscillation  $f_1$  in layer 30. This creates a resonance in layer 30 which excites a new plasma wave 33 which also has a frequency of  $f_1$  and which then propagates through the ionosphere. Wave 33 can be used to improve or disrupt communications or both depending on what is desired in a particular application. Of course, more than one new wave 33 can be generated and the various new waves can be modulated at will and in a highly nonlinear fashion.

FIG. 5 shows apparatus useful in this invention, particularly when those applications of this invention are employed which require extremely large amounts of power. In FIG. 5 there is shown the earth's surface 40 with a well 41 extending downwardly thereinto until it penetrates hydrocarbon producing reservoir 42. Hydrocarbon reservoir 42 produces natural gas alone or in combination with crude oil. Hydrocarbons are produced from reservoir 42 through well 41 and wellhead 43 to a treating system 44 by way of pipe 45. In treater 44, desirable liquids such as crude oil and gas condensates are separated and recovered by way of pipe 46 while undesirable gases and liquids such as water, H<sub>2</sub>S, and the like are separated by way of pipe 47. Desirable gases such as carbon dioxide are separated by way of pipe 48, and the remaining natural gas stream is removed from treater 44 by way of pipe 49 for storage in conventional tankage means (not shown) for future use and/or use in an electrical generator such as a magnetohydrodynamic, gas turbine, fuel cell or EGD generator 50. Any desired number and combination of different types of electric generators can be employed in the practice of this invention. The natural gas is burned in generator 50 to produce substantial quantities of electricity which is then stored and/or passed by way of wire 51 to a transmitter 52 which generates the electromagnetic radiation to be used in the method of this invention. The electromagnetic radiation is then passed by way of wire 53 to antenna 54 which is located at or near the end of field line 11. Antenna 54 sends circularly polarized radiation wave 20 upwards along field line 11 to carry out the various methods of this invention as described hereinabove.

Of course, the fuel source need not be used in its naturally-occurring state but could first be converted to another second energy source form such as hydrogen, hydrazine and the like, and electricity then generated from said second energy source form.

It can be seen from the foregoing that when desirable field line 11 intersects earth's surface 40 at or near a large naturally-occurring hydrocarbon source 42, exceedingly large amounts of power can be very efficiently produced and transmitted in the direction of field lines. This is particularly so when the fuel source is natural gas and magnetohydrodynamic generators are employed. Further, this can all be accomplished in a

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relatively small physical area when there is the unique coincidence of fuel source 42 and desirable field line 11. Of course, only one set of equipment is shown in FIG. 5 for sake of simplicity. For a large hydrocarbon reservoir 42, a plurality of wells 41 can be employed to feed one or more storage means and/or treaters and as large a number of generators 55 as needed to power one or more transmitters 52 and one or more antennas 54. Since all of the apparatus 44 through 54 can be employed and used essentially at the sight where naturally-occurring fuel source 42 is located, all the necessary electromagnetic radiation 20 is generated essentially at the same location as fuel source 42. This provides for a maximum amount of usable electromagnetic radiation 20 since there are no significant storage or transportation losses to be incurred. In other words, the apparatus is brought to the sight of the fuel source where desirable field line 11 intersects the earth's surface 40 on or near the geographical location of fuel source 42, fuel source 42 being at a desirable magnetic latitude for the practice of this invention, for example, Alaska.

The generation of electricity by motion of a conducting fluid through a magnetic field, i.e., magnetohydrodynamics (MHD), provides a method of electric power generation without moving mechanical parts and when the conducting fluid is a plasma formed by combustion of a fuel such as natural gas, an idealized combination of apparatus is realized since the very clean-burning natural gas forms the conducting plasma in an efficient manner and the thus formed plasma, when passed through a magnetic field, generates electricity in a very efficient manner. Thus, the use of fuel source 42 to generate a plasma by combustion thereof for the generation of electricity essentially at the site of occurrence of the fuel source is unique and ideal when high power levels are required and desirable field lines 11 intersect the earth's surface 40 at or near the site of fuel source 42. A particular advantage for MHD generators is that they can be made to generate large amounts of power with a small volume, light weight device. For example, a 1000 megawatt MHD generator can be construed using superconducting magnets to weigh roughly 42,000 pounds and can be readily air lifted.

This invention has a phenomenal variety of possible ramifications and potential future developments. As alluded to earlier, missile or aircraft destruction, deflection, or confusion could result, particularly when relativistic particles are employed. Also, large regions of the atmosphere could be lifted to an unexpectedly high altitude so that missiles encounter unexpected and unplanned drag forces with resultant destruction or deflection of same. Weather modification is possible by, for example, altering upper atmosphere wind patterns or altering solar absorption patterns by constructing one or more plumes of atmospheric particles which will act as a lens or focusing device. Also as alluded to earlier, molecular modifications of the atmosphere can take place so that positive environmental effects can be achieved. Besides actually changing the molecular composition of an atmospheric region, a particular molecule or molecules can be chosen for increased presence. For example, ozone, nitrogen, etc. concentrations in the atmosphere could be artificially increased. Similarly, environmental enhancement could be achieved by causing the breakup of various chemical entities such as carbon dioxide, carbon monoxide, nitrous oxides, and the like. Transportation of entities can also be realized when advantage is taken of the drag effects caused by

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regions of the atmosphere moving up along diverging field lines. Small micron sized particles can be then transported, and, under certain circumstances and with the availability of sufficient energy, larger particles or objects could be similarly affected. Particles with desired characteristics such as tackiness, reflectivity, absorptivity, etc., can be transported for specific purposes or effects. For example, a plume of tacky particles could be established to increase the drag on a missile or satellite passing therethrough. Even plumes of plasma having substantially less charged particle density than described above will produce drag effects on missiles which will affect a lightweight (dummy) missile in a manner substantially different than a heavy (live) missile and this affect can be used to distinguish between the two types of missiles. A moving plume could also serve as a means for supplying a space station or for focusing vast amount of sunlight on selected portions of the earth. Surveys of global scope could also be realized because the earth's natural magnetic field could be significantly altered in a controlled manner by plasma beta effects resulting in, for example, improved magnetotelluric surveys. Electromagnetic pulse defenses are also possible. The earth's magnetic field could be decreased or disrupted at appropriate altitudes to modify or eliminate the magnetic field in high Compton electron generation (e.g., from high altitude nuclear bursts) regions. High intensity, well controlled electrical fields can be provided in selected locations for various purposes. For example, the plasma sheath surrounding a missile or satellite could be used as a trigger for activating such a high intensity field to destroy the missile or satellite. Further, irregularities can be created in the ionosphere which will interfere with the normal operation of various types of radar, e.g., synthetic aperture radar. The present invention can also be used to create artificial belts of trapped particles which in turn can be studied to determine the stability of such parties. Still further, plumes in accordance with the present invention can be formed to simulate and/or perform the same functions as performed by the detonation of a "heave" type nuclear device without actually having to detonate such a device. Thus it can be seen that the ramifications are numerous, far-reaching, and exceedingly varied in usefulness.

I claim:

1. A method for altering at least one region normally existing above the earth's surface with electromagnetic radiation using naturally-occurring and diverging magnetic field lines of the earth comprising transmitting first electromagnetic radiation at a frequency between 20 and 7200 kHz from the earth's surface, said transmitting being conducted essentially at the outset of transmission substantially parallel to and along at least one of said field lines, adjusting the frequency of said first radiation to a value which will excite electron cyclotron resonance at an initial elevation at least 50 km above the earth's surface, whereby in the region in which said electron cyclotron resonance takes place heating, further ionization, and movement of both charged and neutral particles is effected, said cyclotron resonance excitation of said region is continued until the electron concentration of said region reaches a value of at least  $10^6$  per cubic centimeter and has an ion energy of at least 2 ev.
2. The method of claim 1 including the step of providing artificial particles in said at least one region which are excited by said electron cyclotron resonance.

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3. The method of claim 2 wherein said artificial particles are provided by injecting same into said at least one region from an orbiting satellite.

4. The method of claim 1 wherein said threshold excitation of electron cyclotron resonance is about 1 watt per cubic centimeter and is sufficient to cause movement of a plasma region along said diverging magnetic field lines to an altitude higher than the altitude at which said excitation was initiated.

5. The method of claim 4 wherein said rising plasma region pulls with it a substantial portion of neutral particles of the atmosphere which exist in or near said plasma region.

6. The method of claim 1 wherein there is provided at least one separate source of second electromagnetic radiation, said second radiation having at least one frequency different from said first radiation, impinging said at least one second radiation on said region while said region is undergoing electron cyclotron resonance excitation caused by said first radiation.

7. The method of claim 6 wherein said second radiation has a frequency which is absorbed by said region.

8. The method of claim 6 wherein said region is plasma in the ionosphere and said second radiation excites plasma waves within said ionosphere.

9. The method of claim 8 wherein said electron concentration reaches a value of at least  $10^{12}$  per cubic centimeter.

10. The method of claim 8 wherein said excitation of electron cyclotron resonance is initially carried out within the ionosphere and is continued for a time sufficient to allow said region to rise above said ionosphere.

11. The method of claim 1 wherein said excitation of electron cyclotron resonance is carried out above about 500 kilometers and for a time of from 0.1 to 1200 seconds such that multiple heating of said plasma region is achieved by means of stochastic heating in the magnetosphere.

12. The method of claim 1 wherein said first electromagnetic radiation is right hand circularly polarized in the northern hemisphere and left hand circularly polarized in the southern hemisphere.

13. The method of claim 1 wherein said electromagnetic radiation is generated at the site of a naturally-occurring hydrocarbon fuel source, said fuel source being located in at least one of northerly or southerly magnetic latitudes.

14. The method of claim 13 wherein said fuel source is natural gas and electricity for generating said electromagnetic radiation is obtained by burning said natural gas in at least one of magnetohydrodynamic, gas turbine, fuel cell, and EGD electric generators located at the site where said natural gas naturally occurs in the earth.

15. The method of claim 14 wherein said site of natural gas is within the magnetic latitudes that encompass Alaska.

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## APPENDIX 12

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**PRAVDA**<sup>RU</sup>  
online since January 27th, 1999

## USA and Russia supposedly develop secret meteorological weapons

30.09.2005 ■ Source: ■ URL: <http://english.pravda.ru/science/tech/8992-hurricanes-0>

### American meteorologist Scott Stevens has recently brought accusations against Russia

Mr. Stevens claims that Russian military specialists were behind the fury of Hurricane Katrina that devastated New Orleans. According to him, Russia has built secret equipment for causing a detrimental impact on the weather way back in the Soviet era.

U.S. media quickly spread the news around. Both Russia and the U.S. were long rumored to have been involved in the development of meteorological weapon. But those rumors seemed too wild to searching a grain of truth hidden underneath. In the meantime, some Russian politicians say the experiments have been conducted and still conducted on either side of the ocean. Following death and destruction caused by Katrina, The Americans promptly unearthed the controversial interview by Vladimir Zhirinovsky in which he threatened to unleash floods all over the United States when "our scientists slightly change the earth's gravitational field." Nobody got scared watching the drunken boss of the Liberal Democratic Party promise doom's day for the United States. But once Katrina struck and the southern part of the U.S. got drowned, the improbable rumors about Russia's meteorological weapon came to light again.



American meteorologists are not the only ones who blame the neighbors for using the "hurricane gun." Unconfirmed and patchy reports on questionable experiments with weather conducted by the U.S. and Soviet Union stirred up a number of political scandals in many countries of the world. Following a large-scale flooding in Europe in 2002, some European politicians put the blame on the "U.S. military" for disrupting EU economy. In 2002, Committee for Defense of the Russian Duma raised the issue about a detrimental impact on climate caused by experiments involving disturbance of the earth's ionosphere and magnetosphere. The deputies focused their attention on HAARP system that is still under construction in Alaska.

There is a special facility located at a military installation some 400 km north of Anchorage. A huge area of tundra features thousands of 25-m antennas pointing to the sky. The facility is called High Frequency Active Auroral Research Program (HAARP). U.S. Marines patrol the vicinity of the base. No commercial or military aircraft are allowed to fly over the base. Air-defense systems Patriot were installed around the base following the 9/11 terrorist attacks.

U.S. Navy and U.S. Air Force combined efforts building the facility. Open information sources indicate that the facility is used for causing active influence on the earth's ionosphere and magnetosphere. The results could be fantastic, according to scientific journals. Scientific journals claim that HAARP is capable of causing artificial aurora borealis, it can also jam radar stations of early ballistic missile detection systems, communicate with submarines in the ocean and even detect secret underground complexes of the enemy. Radio-frequency emission is capable of piercing through the ground and examine hideaways and tunnels, it can burn out electronics and destroy space satellites. The equipment can also impact the atmosphere and thus cause changes in weather. HAARP is allegedly used for causing natural disasters similar to Hurricanes Katrina and Rita.

Three years ago the Duma deputies held a heated discussion of issues related to HAARP. They even drew up an appeal to the President Putin and the UN. They demanded to set up an international commission for the investigation of the experiments conducted in Alaska.

Speaking to *Nezavisimaya Gazeta*, specialist for active influence on the atmosphere of the Federal Service of Hydrometeorology and Environmental Monitoring Valery Stasenko said HAARP is a "very serious issue." "It is not for nothing that the term 'space weather' has become quite popular lately.

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The term stands for interrelation between the solar activity, magnetosphere and ionosphere perturbations and developments in the atmosphere. Perturbations in the magnetosphere and ionosphere can really impact climate. Using powerful equipment for deliberately bringing about perturbations, one can impact weather too, even on a global scale. I believe the deputies were right in finally raising the issue regarding the experiments in the U.S.," said Mr. Stasenko.

Russian politicians are head over heels debating plans of U.S. imperialists and their bloodthirsty military, man-made disasters and floods. They are probably totally unaware that Russia has long build it own facility similar to HAARP. The facility Sura is as powerful as HAARP. It is located in Russia's central area, in a remote and desolate place some 150 km from the city of Nizhny Novgorod. One of the leading scientific research institutions of the USSR, Research Institute of Radiophysical Studies, owns the facility.

"There are only three facilities like this in the world, one is in Alaska, the very HAARP, one in Norway, and one in Russia," said Nikolai Snegirev, director of the above institute. The facility was commissioned in 1981. "Using this unique facility, researchers achieved extremely interesting results regarding the ionosphere behavior. They discovered the effect of generation of low-frequency emission at the modulation of ionosphere current. At the beginning, Soviet Defense Department mostly footed the bill for similar research projects. Alas, no research like that has been conducted at the facility since the collapse of the Soviet Union. These days we are involved in the international projects for research of the ionosphere," said Mr. Snegirev.

Sura looks quite seasoned and a little bit rusty. Against all odds, it still works. There are straight lines of 20-m antennas standing in an area of 9 hectares. A giant emitter the size of a country hut sits in the center of the field, the emitter is used for studying acoustic developments in the atmosphere.

Researchers at the Sura can not yet conjure hurricanes similar to Katrina and Rita. At least they say they can not. However, they conduct research (on a smaller scale than in the U.S.) of interrelation between the natural disasters and perturbations in the ionosphere and magnetosphere.

"It is possible to impact weather. However, neither Russians nor Americans are capable at the moment of creating something like Hurricanes Katrina or Rita. The capacity of the facilities is too low. The Americans are going to switch HAARP into its design capacity. Still, it will not be enough for effectively causing natural disasters," said Yuri Tokarev, head of department of solar and terrestrial relations of the Research Institute of Radiophysical Studies.

Technologies of the secret research institutes that used too be classified and inaccessible become available to non-military researchers. One of the devices was recently tested thanks to support of the Russian Academy of Natural Sciences.

"We produced lots of interesting results during the first test of the ionic generator," said Academician Mikhail Shahramanyan. "A stream of oxygen ions was going up and could either result in a local rupture of the clouds or bring out overcast sky, depending on a work mode of the device. We managed to form cumulonimbus overcast sky over Erevan in April 2004. We used two GIONK type devices when the sky was clear. According to protocols verified by independent observers, between April 15 to April 16 in Erevan precipitation totaled to 25mm-27mm," said Academician Shahramanyan.

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## APPENDIX 13

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**Weather as a Force Multiplier:  
Owning the Weather in 2025**



A Research Paper  
Presented To

*Air Force 2025*

by

Col Tamzy J. House  
Lt Col James B. Near, Jr.  
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August 1996



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### Disclaimer

*2025* is a study designed to comply with a directive from the chief of staff of the Air Force to examine the concepts, capabilities, and technologies the United States will require to remain the dominant air and space force in the future. Presented on 17 June 1996, this report was produced in the Department of Defense school environment of academic freedom and in the interest of advancing concepts related to national defense. The views expressed in this report are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States government.

This report contains fictional representations of future situations/scenarios. Any similarities to real people or events, other than those specifically cited, are unintentional and are for purposes of illustration only.

This publication has been reviewed by security and policy review authorities, is unclassified, and is cleared for public release.

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Table 1

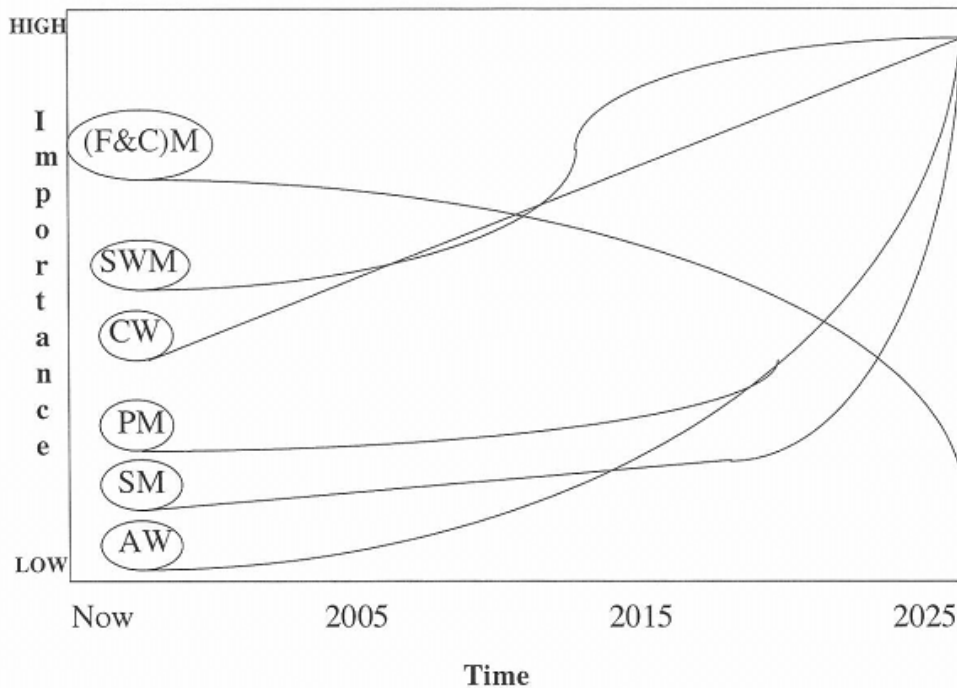
Operational Capabilities Matrix

<b>DEGRADE ENEMY FORCES</b>	<b>ENHANCE FRIENDLY FORCES</b>
<b>Precipitation Enhancement</b> <ul style="list-style-type: none"><li>- Flood Lines of Communication</li><li>- Reduce PGM/Recce Effectiveness</li><li>- Decrease Comfort Level/Morale</li></ul>	<b>Precipitation Avoidance</b> <ul style="list-style-type: none"><li>- Maintain/Improve LOC</li><li>- Maintain Visibility</li><li>- Maintain Comfort Level/Morale</li></ul>
<b>Storm Enhancement</b> <ul style="list-style-type: none"><li>- Deny Operations</li></ul>	<b>Storm Modification</b> <ul style="list-style-type: none"><li>- Choose Battlespace Environment</li></ul>
<b>Precipitation Denial</b> <ul style="list-style-type: none"><li>- Deny Fresh Water</li><li>- Induce Drought</li></ul>	<b>Space Weather</b> <ul style="list-style-type: none"><li>- Improve Communication Reliability</li><li>- Intercept Enemy Transmissions</li><li>- Revitalize Space Assets</li></ul>
<b>Space Weather</b> <ul style="list-style-type: none"><li>- Disrupt Communications/Radar</li><li>- Disable/Destroy Space Assets</li></ul>	<b>Fog and Cloud Generation</b> <ul style="list-style-type: none"><li>- Increase Concealment</li></ul>
<b>Fog and Cloud Removal</b> <ul style="list-style-type: none"><li>- Deny Concealment</li><li>- Increase Vulnerability to PGM/Recce</li></ul>	<b>Fog and Cloud Removal</b> <ul style="list-style-type: none"><li>- Maintain Airfield Operations</li><li>- Enhance PGM Effectiveness</li></ul>
<b>Detect Hostile Weather Activities</b>	<b>Defend against Enemy Capabilities</b>

Current technologies that will mature over the next 30 years will offer anyone who has the necessary resources the ability to modify weather patterns and their corresponding effects, at least on the local scale. Current demographic, economic, and environmental trends will create global stresses that provide the impetus necessary for many countries or groups to turn this weather-modification ability into a capability.

In the United States, weather-modification will likely become a part of national security policy with both domestic and international applications. Our government will pursue such a policy, depending on its interests, at various levels. These levels could include unilateral actions, participation in a security framework such as NATO, membership in an international organization such as the UN, or participation in a coalition. Assuming that in 2025 our national security strategy includes weather-modification, its use in our national military strategy will naturally follow. Besides the significant benefits an operational capability would provide, another motivation to pursue weather-modification is to deter and counter potential adversaries.

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**Figure 5-1. A Core Competency Road Map to Weather Modification in 2025.**

<b>Legend</b>			
PM	Precipitation Modification	(F&C)M	Fog and Cloud Modification
SM	Storm Modification	CW	Counter Weather
SWM	Space Weather-modification	AW	Artificial Weather

Even today's most technologically advanced militaries would usually prefer to fight in clear weather and blue skies. But as war-fighting technologies proliferate, the side with the technological advantage will prefer to fight in weather that gives them an edge. The US Army has already alluded to this approach in their concept of "owning the weather."<sup>1</sup> Accordingly, storm modification will become more valuable over time. The importance of precipitation modification is also likely to increase as usable water sources become more scarce in volatile parts of the world.

As more countries pursue, develop, and exploit increasing types and degrees of weather-modification technologies, we must be able to detect their efforts and counter their activities when necessary. As depicted, the technologies and capabilities associated with such a counter weather role will become increasingly important.

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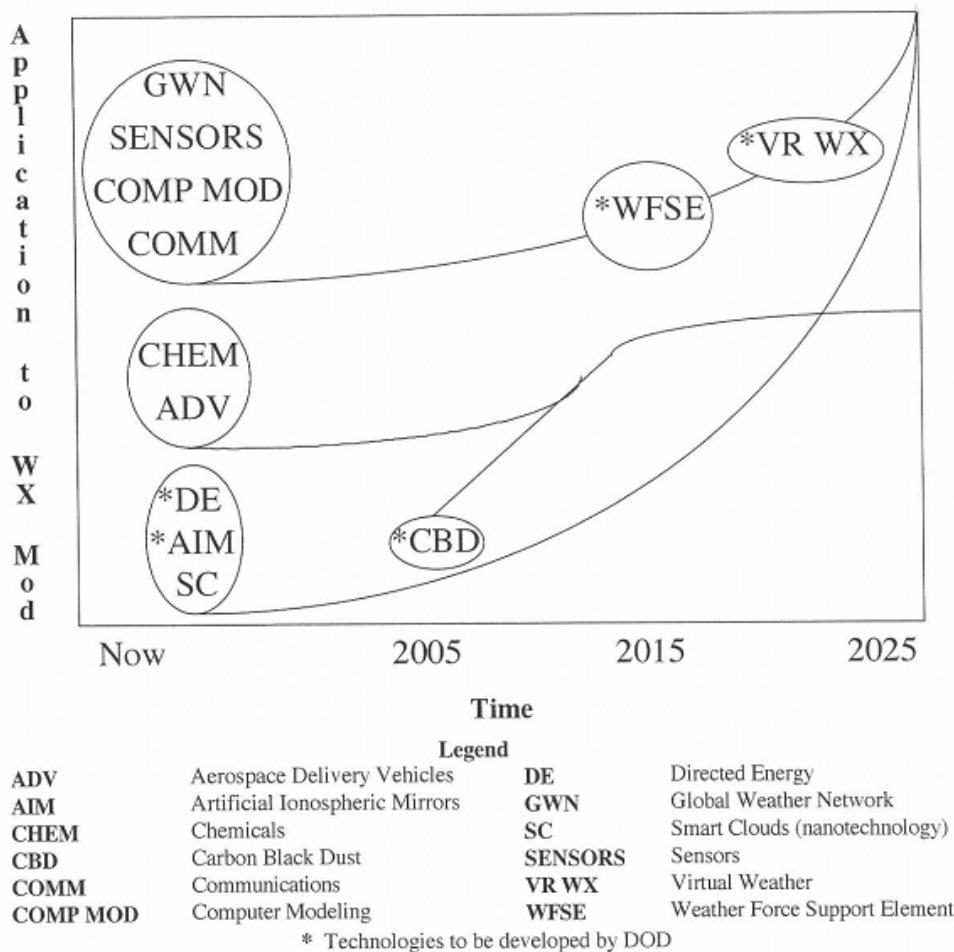


Figure 5-2. A Systems Development Road Map to Weather Modification in 2025.

**Conclusions**

The world's finite resources and continued needs will drive the desire to protect people and property and more efficiently use our crop lands, forests, and range lands. The ability to modify the weather may be desirable both for economic and defense reasons. The global weather system has been described as a series of spheres or bubbles. Pushing down on one causes another to pop up.<sup>2</sup> We need to know when another power "pushes" on a sphere in their region, and how that will affect either our own territory or areas of economic and political interest to the US.

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## **APPENDIX 14**

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**United States Patent** [19]  
**Chang et al.**

[11] **Patent Number:** 5,003,186  
[45] **Date of Patent:** Mar. 26, 1991

[54] **STRATOSPHERIC WELSBACH SEEDING FOR REDUCTION OF GLOBAL WARMING**

[75] **Inventors:** David B. Chang, Tustin; I-Fu Shih, Los Alamitos, both of Calif.

[73] **Assignee:** Hughes Aircraft Company, Los Angeles, Calif.

[21] **Appl. No.:** 513,145

[22] **Filed:** Apr. 23, 1990

[51] **Int. Cl.:** G21K 1/00

[52] **U.S. Cl.:** 250/505.1; 250/504 R; 250/503.1; 244/158 R

[58] **Field of Search:** 250/505.1, 504 R, 503.1, 250/493.1; 244/136, 158 R

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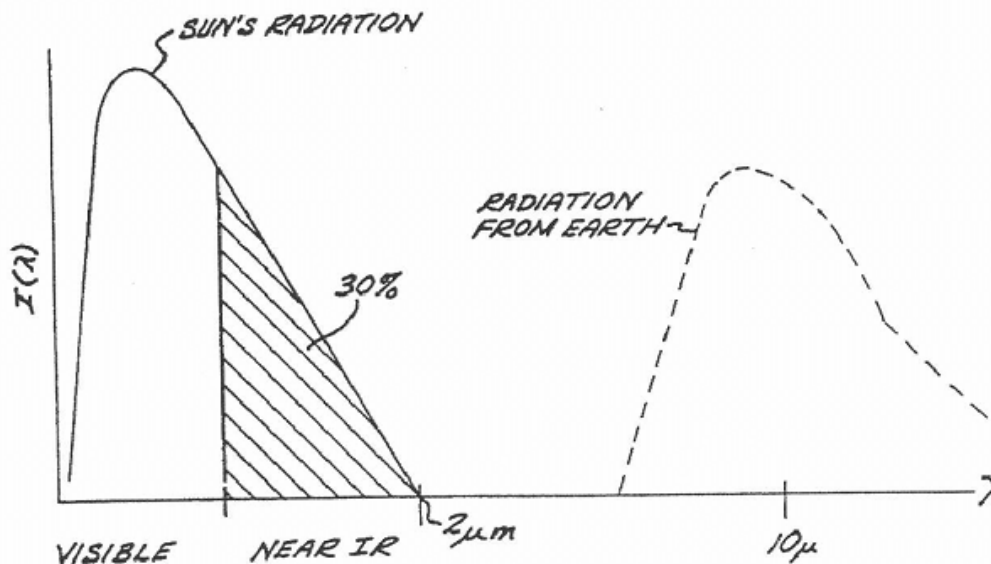
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*Primary Examiner*—Jack I. Berman  
*Attorney, Agent, or Firm*—Michael W. Sales; Wanda Denson-Low

[57] **ABSTRACT**

A method is described for reducing atmospheric or global warming resulting from the presence of heat-trapping gases in the atmosphere, i.e., from the greenhouse effect. Such gases are relatively transparent to sunshine, but absorb strongly the long-wavelength infrared radiation released by the earth. The method includes the step of seeding the layer of heat-trapping gases in the atmosphere with particles of materials characterized by wavelength-dependent emissivity. Such materials include Welsbach materials and the oxides of metals which have high emissivity (and thus low reflectivities) in the visible and 8–12 micron infrared wavelength regions.

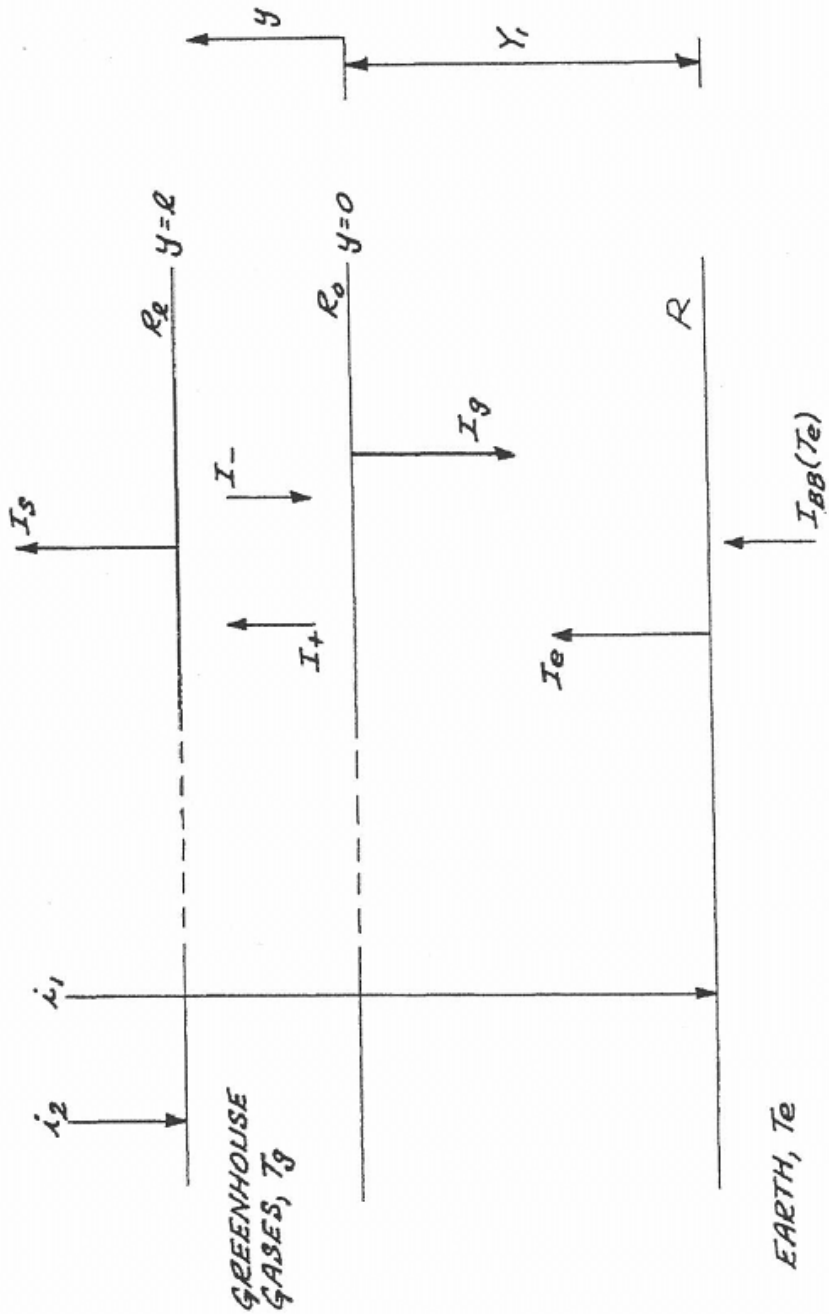
**18 Claims, 2 Drawing Sheets**





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FIG. 1



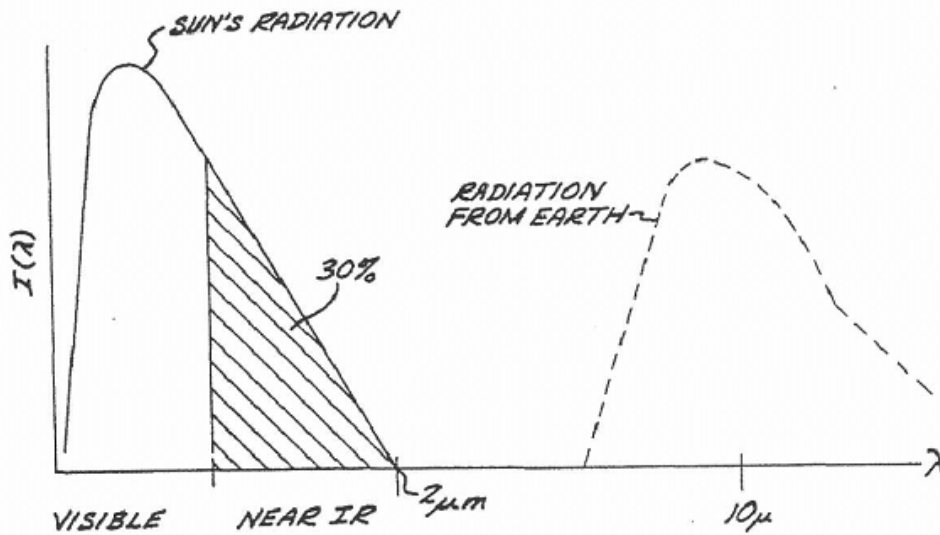
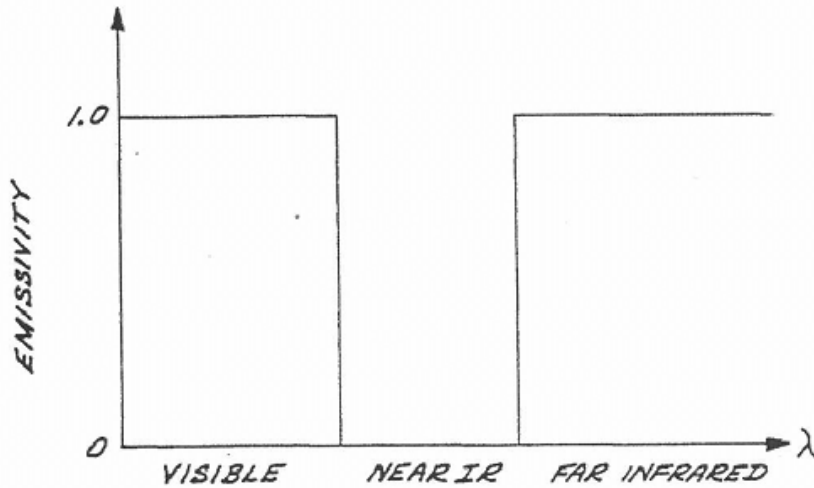


FIG. 2

FIG. 3



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STRATOSPHERIC WELSBACH SEEDING FOR REDUCTION OF GLOBAL WARMING

BACKGROUND OF THE INVENTION

This invention relates to a method for the reduction of global warming resulting from the greenhouse effect, and in particular to a method which involves the seeding of the earth's stratosphere with Welsbach-like materials.

Global warming has been a great concern of many environmental scientists. Scientists believe that the greenhouse effect is responsible for global warming. Greatly increased amounts of heat-trapping gases have been generated since the Industrial Revolution. These gases, such as CO2, CFC, and methane, accumulate in the atmosphere and allow sunlight to stream in freely but block heat from escaping (greenhouse effect). These gases are relatively transparent to sunshine but absorb strongly the long-wavelength infrared radiation released by the earth.

Most current approaches to reduce global warming are to restrict the release of various greenhouse gases, such as CO2, CFC, and methane. These imply the need to establish new regulations and the need to monitor various gases and to enforce the regulations.

One proposed solution to the problem of global warming involves the seeding of the atmosphere with metallic particles. One technique proposed to seed the metallic particles was to add the tiny particles to the fuel of jet airliners, so that the particles would be emitted from the jet engine exhaust while the airliner was at its cruising altitude. While this method would increase the reflection of visible light incident from space, the metallic particles would trap the long wavelength blackbody radiation released from the earth. This could result in net increase in global warming.

It is therefore an object of the present invention to provide a method for reduction of global warming due to the greenhouse effect which permits heat to escape through the atmosphere.

SUMMARY OF THE INVENTION

A method is disclosed for reducing atmospheric warming due to the greenhouse effect resulting from a greenhouse gases layer. The method comprises the step of seeding the greenhouse gas layer with a quantity of tiny particles of materials characterized by wavelength-dependent emissivity or reflectivity, in that said materials have high emissivities in the visible and far infrared wavelength regions and low emissivity in the near infrared wavelength region. Such materials can include the class of materials known as Welsbach materials. The oxides of metal, e.g., aluminum oxide, are also suitable for the purpose. The greenhouse gases layer typically extends between about seven and thirteen kilometers above the earth's surface. The seeding of the stratosphere occurs within this layer. The particles suspended in the stratosphere as a result of the seeding provide a mechanism for converting the blackbody radiation emitted by the earth at near infrared wavelengths into radiation in the visible and far infrared wavelength so that this heat energy may be reradiated out into space, thereby reducing the global warming due to the greenhouse effect.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the present invention will become more apparent from the following detailed description of an exemplary embodiment thereof, as illustrated in the accompanying drawings, in which:

FIG. 1 illustrates a model for the heat trapping phenomenon, i.e., the greenhouse effect.

FIG. 2 is a graph illustrating the intensity of sunlight incident on earth and of the earth's blackbody radiation as a function of wavelength.

FIG. 3 is a graph illustrating an ideal emissivity versus wavelength function for the desired particle material.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows a model for the heat-trapping (greenhouse effect) phenomenon. It is assumed that the greenhouse gases are concentrated at altitudes between y=0 (at some altitude Y1, above the earth's surface) and y=l. Regardless of the sunshine reflected back into space, i1 and i2 denote the shortwavelength sunlight energies that are absorbed by the earth's surface and the greenhouse gases, respectively. Available data shows that i1=0.45 is0l and i2=0.25 is0l, where is0l is the total flux from the sun. The short wavelength sunlight heats up the greenhouse gases and the earth surface, and this energy is eventually reradiated out in the long wavelength infrared region.

FIG. 2 is a graph illustrating the intensity of sunlight and the earth's blackbody radiation as a function of wavelength. As illustrated, some 30% of the sunlight energy is in the near infrared region. The earth's blackbody radiation, on the other hand, is at the far infrared wavelength.

Referring again to FIG. 1, I\_s, I\_+, I\_-, I\_g and I\_e represent the fluxes in the infrared wavelength region, where I\_s and I\_g are the fluxes reradiated by the greenhouse gases toward the sky and ground, respectively; I\_e is the flux reradiated by the earth; and I\_+ and I\_- are fluxes within the gases radiating toward the space and ground, respectively. I\_+ and I\_- are functions of y, e.g., I\_+(0) is the I\_+ flux at y=0. Considering the principles of energy conservation and continuity at boundaries, the following relationships are obtained:

I\_s = i\_1 + i\_2 (1)

I\_s = I\_+(1)(1 - R\_l) (2)

I\_-(1) = I\_+(1)R\_l (3)

I\_+(0) = I\_-(0)R\_0 + I\_g(1 - R\_0) (4)

I\_g = I\_-(0)(1 - R\_0) + I\_e R\_0 (5)

I\_e = I\_BB(T\_e)(1 - R) + i\_g R (6)

I\_e = i\_1 + I\_g (7)

where  $R_0$ ,  $R_1$  and  $R$  are the reflectivities at the  $y=0$  and  $y=1$  boundaries and at the earth's surface.  $I_{BB}(T_e)$  is the blackbody radiation flux at the earth's temperature  $T_e$ . Within the greenhouse gases' layer, the energy equations are

$$(dI_+/dy) = I_{BB}(T_g) - \alpha I_+ \quad (8)$$

$$-(dI_-/dy) = I_{BB}(T_g) - \alpha I_- \quad (9)$$

where  $I_{BB}(T_g)$  is the blackbody radiation flux at the greenhouse gases' temperature  $T_g$ , and  $\alpha$  is the absorption coefficient of the gases. The solutions of equations 8 and 9 are given by equations 10 and 11:

$$I_+(y) = (I_{BB}/\alpha) + Ce^{\alpha y} \quad (10)$$

$$I_-(y) = (I_{BB}/\alpha) + De^{-\alpha y} \quad (11)$$

To illustrate the effects of  $R_0$  and  $R_1$  on the greenhouse effect, the extreme case is considered wherein a high concentration of greenhouse gases has strong absorption in the infrared region; that is, for  $y=1$ ,  $e^{-\alpha l}$  approaches 0. Then, using Equations 3 and 4, the relationships of Equations 12 and 13 are obtained.

$$C = (I_e - (I_{BB}/\alpha)(1 - R_0)) \quad (12)$$

$$D = 0$$

From Equations 5 and 7,

$$I_e = i_1 + I_-(0)(1 - R_0) + I_e R_0$$

or

$$I_e = (i_1/(1 - R_0)) + (I_{BB}/\alpha) \quad (14)$$

From Equations 2 and 1,

$$I_e = (I_{BB}/\alpha)(1 - R) = i_1 + i_2$$

or

$$(I_{BB}/\alpha) = (i_1 + i_2)/(1 - R) \quad (15)$$

Combining Equations 14 and 15, the relationship of Equation 16 is obtained.

$$I_e = i_1/(1 - R_0) + (i_1 + i_2)/(1 - R) \quad (16)$$

Finally, Equation 6 gives the blackbody radiation from the earth's surface in terms of  $i_1$  and  $i_2$  and the three reflectivities:

$$I_e = I_{BB}(T_e)(1 - R) + (I_e - i_1)R$$

$$I_{BB}(T_e) = I_e + (R/(1 - R))i_1$$

or

$$I_{BB}(T_e) = i_1/(1 - R_0) + (i_1 + i_2)/(1 - R) + (R/(1 - R))i_1 \quad (17)$$

To achieve a lower temperature of the earth, (considering  $i_1$ ,  $i_2$  and  $R$  as constants), it is desirable to make  $R$  and  $R_1$  as small as possible.

Known refractory materials have a thermal emissivity function which is strongly wavelength dependent. For example, the materials may have high emissivity (and absorption) at the far infrared wavelengths, high emissivity in the visible wavelength range, and very low emissivity at intermediate wavelengths. If a material having those emissivity characteristics and a black body are exposed to IR energy of equal intensity, the selective thermal radiator will emit visible radiation with higher efficiency (if radiation cooling predominates), i.e., the selective thermal radiator will appear brighter than the black body. This effect is known as the Welsbach effect and is extensively used in commercial gas lantern mantles.

Welsbach materials have the characteristic of wavelength-dependent emissivity (or reflectivity). For example, thorium oxide ( $\text{ThO}_2$ ) has high emissivities in the visible and far IR regions but it has low emissivity in the near IR region. So, in accordance with the invention, the layer of greenhouse gases is seeded with Welsbach or Welsbach-like materials which have high emissivities (and thus low reflectivities) in the visible and 8-12 micrometer infrared regions, which has the effect of reducing  $R_0$  and  $R_1$  while introducing no effect in the visible range.

A desired material for the stratospheric seeding has a reflection coefficient close to unity for near IR radiation, and a reflection coefficient close to zero (or emissivity close to unity) for far IR radiation. FIG. 3 is a graph illustrating an ideal emissivity versus wavelength function for the desired material. Another class of materials having the desired property includes the oxides of metals. For example, aluminum oxide ( $\text{Al}_2\text{O}_3$ ) is one metal oxide suitable for the purpose and which is relatively inexpensive.

It is presently believed that particle sizes in the ten to one hundred micron range would be suitable for the seeding purposes. Larger particles would tend to settle to the earth more quickly.

The particles in the required size range can be obtained with conventional methods of grinding and meshing.

It is believed that the number of particles  $n_d$  per unit area in the particle layer should be defined by Equation 18:

$$n_d l \geq 1/\sigma_{abs} \quad (18)$$

where  $l$  is the thickness of the particle layer and  $\sigma_{abs}$  is the absorption coefficient of the particles at the long IR wavelengths. One crude estimate of the density of particles is given by Equation (19):

$$n_d l \geq (cmw)/(4\pi e^2) \quad (19)$$

where  $c$  is the speed of light,  $m$  is the average particle mass,  $e$  is the electron charge, and  $w$  is the absorption line width in  $\text{sec}^{-1}$ .

The greenhouse gases are typically in the earth's stratosphere at an altitude of seven to thirteen kilometers. This suggests that the particle seeding should be done at an altitude on the order of 10 kilometers. The particles may be seeded by dispersal from seeding aircraft; one exemplary technique may be via the jet fuel as suggested by prior work regarding the metallic parti-

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cles. Once the tiny particles have been dispersed into the atmosphere, the particles may remain in suspension for up to one year.

It is understood that the above-described embodiment is merely illustrative of the possible specific embodiments which may represent principles of the present invention. Other arrangements may readily be devised in accordance with these principles by those skilled in the art without departing from the scope and spirit of the invention.

What is claimed is:

1. A method of reducing atmospheric warming due to the greenhouse effect resulting from a layer of gases in the atmosphere which absorb strongly near infrared wavelength radiation, comprising the step of dispersing tiny particles of a material within the gases' layer, the particle material characterized by wavelength-dependent emissivity or reflectivity, in that said material has high emissivities with respect to radiation in the visible and far infrared wavelength spectra, and low emissivity in the near infrared wavelength spectrum, whereby said tiny particles provide a means for converting infrared heat energy into far infrared radiation which is radiated into space.
2. The method of claim wherein said material comprises one or more of the oxides of metals.
3. The method of claim 1 wherein said material comprises aluminum oxide.
4. The method of claim 1 wherein said material comprises thorium oxide.
5. The method of claim 1 wherein said particles are dispersed by seeding the stratosphere with a quantity of said particles at altitudes in the range of seven to thirteen kilometers above the earth's surface.
6. The method of claim 1 wherein the size of said particles is in the range of ten to one hundred microns.
7. The method of claim wherein said material comprises a refractory material.
8. The method of claim 1 wherein said material is a Welsbach material.
9. The method of claim 1 wherein the number of said dispersed particles per unit area in the particle layer is

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greater than or equal to  $1/\sigma_{abs}l$ , where  $l$  is the thickness of the particle layer and  $\sigma_{abs}$  is the absorption coefficient of the particles at the far infrared wavelengths.

10. A method for reducing atmospheric warming due to the greenhouse effect resulting from a greenhouse gases layer, comprising the following step: seeding the greenhouse gases' layer with a quantity of tiny particles of a material characterized by wavelength-dependent emissivity or reflectivity, in that said materials have high emissivities in the visible and far infrared wavelength spectra and low emissivity in the near infrared wavelength spectrum, whereby said particles are suspended within said gases' layer and provide a means for converting radiative energy at near infrared wavelengths into radiation at the far infrared wavelengths, permitting some of the converted radiation to escape into space.
11. The method of claim 10 wherein said material comprises one or more of the oxides of metals.
12. The method of claim 10 wherein said material comprises aluminum oxide.
13. The method of claim 10 wherein said material is thorium oxide.
14. The method of claim 10 wherein said seeding is performed at altitudes in the range of seven to thirteen kilometers above the earth's surface.
15. The method of claim 10 wherein said material comprises a refractory material.
16. The method of claim 10 wherein said particle size is in range of ten to one hundred microns.
17. The method of claim 10 wherein said material is a Welsbach material.
18. The method of claim 10 wherein the number of said dispersed particles per unit area in the particle layer is greater than or equal to  $1/\sigma_{abs}l$ , where  $l$  is the thickness of the particle layer and  $\sigma_{abs}$  is the absorption coefficient of the particles at the far infrared wavelengths.

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