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ROUTING AND RECORD SHEET

SUBJECT: (Optional)

FROM: Luis deFlorez

NO.

DATE: 22 November 1960

TO: (Officer designation, room number, and building)	DATE RECEIVED	DATE FORWARDED	OFFICER'S INITIALS	COMMENTS (Number each comment to show from whom to whom. Draw a line across column after each comment.)
1. DDCI, 203 Admin	11/23			① to ②: Many thanks
2. Adm. de Florez	12/21			
3. Rm 115 - Westent				
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22 November 1960

MEMORANDUM FOR: GENERAL CHARLES P. CABELL

SUBJECT : Climate Control

Attached is a paper prepared by the Research Division of the Travellers Insurance Company on the need for a climate control study program after discussions with Dr. Thomas Malone (Chief of the Division) and his staff. I trust you will find it interesting.

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LUIS deFLOREZ
Research Chairman

Attachment: (1)
As Noted

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THE NEED FOR A CLIMATE CONTROL STUDY PROGRAM

1. Introduction

Control of the weather environment involves the complete spectrum of weather phenomena. As a function of the time and space scale associated with such weather phenomena, different types of human activities are affected ranging from those of the individuals, through the complex operations of large industrial and military organizations and the activities of entire societies. The concept of weather control has meaning only when it is discussed in terms of the specific operations for which it is to be used. The techniques which are and can be used for control of the weather environment vary with the scale of the operation considered and with the specific goals which are to be achieved by such weather control.

Large scale climate control requires the modification of the global weather patterns by altering and interferring with the large-scale physical processes which are associated with the characteristic motions on the scale of the general circulation of the atmosphere. Many proposals have been made regarding means of altering the various physical processes in the atmosphere which might affect these large-scale atmospheric circulations. Most of these proposals have never been subjected to detailed scientific feasibility analyses.

These proposals fall into several general categories. In general they can be categorized by whether they seek to alter processes associated

with the energy and momentum or moisture balance of the atmosphere. For example, proposals have been made to alter the energy balance of large areas by altering the surface albedo. Proposals of this nature involve changing surface albedos by the use of substances of appropriate absorptive or reflective characteristics which differ from the natural surface. An example is the proposal that polar areas be covered with layers of soot. Other proposals are made to alter the energy balance of the atmosphere by injecting dust and other particulate matter into the high atmosphere which might alter the input of solar energy to the atmosphere. Proposals for altering the normal energy cycle of the atmosphere extend also to the alteration of the chemistry of atmospheric substances especially in the high atmosphere which might also effect the radiational balance.

Proposals are made to alter the moisture balance of the atmosphere by the alteration of the evaporation mechanisms. These proposals suggest spreading various kinds of film upon large bodies of water thus cutting down evaporation and interferring with the moisture cycle of the atmosphere. Furthermore, when films are spread upon surfaces to alter their evaporation potential the mechanical effects of the surface are also altered, which might affect the momentum balance of the atmosphere. Proposals are also made for altering the momentum balance of the atmosphere. These proposals generally involve a modification of the surface frictional stresses by changing the frictional drag coefficients over large areas of surface.

2. The Technological Basis for the Reexamination of the Feasibility of Climate Control

Technological developments of the past two decades have provided the understanding, the techniques, and the means necessary for an assault on the problems of climate control. Control of any kind requires capabilities in all three of these areas. Meteorology is just now beginning to acquire such capabilities.

Achievement of an understanding of the large-scale physical processes of the atmosphere has been a continuing process over many decades. However, during the past several years the systematic exploitation of observational information on a global scale has led to a coherent description of the manner in which the large-scale physical processes in the atmosphere operate to provide for the maintenance of the global circulations against the dissipative effects of friction, and the manner in which they operate to transform the solar energy into the kinetic energy of the organized large-scale atmospheric circulations. Theoretical studies have led to an understanding of the reasons why the atmospheric physical processes operate in the observed manner. In combination these studies have led to the formation of the first consistent rudimentary theories for the causes of the fluctuations of the large-scale atmospheric circulations.

The attainment of such a theory holds broad implications for the manner in which climate control studies should be conducted. Much as the

biologist must first achieve an understanding of the causes and processes involved in the generation and communication of diseases before he can consider the problem of disease control, so the meteorologist must achieve an understanding of the causes and processes involved in the fluctuations of the atmospheric circulations which control the regional and global climate. While the meteorologists' understanding is by no means perfect, and much remains to be done, at least the first and most necessary level of understanding has been reached.

Given such understanding the meteorologist must have the capability of simulating and testing the natural phenomena he must control. In other physical sciences this is a relatively straightforward matter of laboratory simulation. The circulation phenomena of relevance in global climate are not so readily amenable to laboratory simulation. Fortunately, simple models of the atmospheric circulations of a mathematical nature can and have been intensively studied by meteorologists in connection with theoretical studies of the general circulation and in connection with the problems of numerical weather forecasting. The indispensible tool which has generated such intensive interest in such mathematical formulations of atmospheric models has been the high speed electronic computer, which has become the laboratory of the meteorologist. Rapid technological advances in the data processing and computing art now make it feasible to consider the treatment of simple mathematical models of the atmosphere of considerable sophistication in which important physical processes can be simulated. Such computing machines now place

the meteorologist in the enviable position of other scientists in that the effects of various physical processes can be studied under controlled conditions. In particular, it has now become feasible not only to speculate about the consequences of human intervention in the atmospheric processes but also to simulate, test and study these consequences.

The meteorologist has also attempted to imitate his more fortunate scientific brethren by constructing laboratory models of large-scale atmospheric and oceanic circulations. He has been able to attain considerable success in producing reasonable hydrodynamic analogues of these large-scale atmospheric motions which are also amenable to study under controlled laboratory conditions. This second tool for simulation and testing purposes provides the meteorologist with another indispensible capability which was unavailable to him just one decade ago.

Much of the well justified skepticism about the feasibility of climate control has centered on the available human means for exercising necessary control. While there are many conceivable methods for the control of climate, all of them involve the expenditure of energy in one form or another. Even the vulnerable instabilities of the atmosphere which one would hope to uncover through a systematic program of climate control studies, the so-called "trigger mechanisms", will probably require access to energy sources of immense magnitude for proper exploitation. In this atomic age, we now have available truly immense potential sources of power, and it is highly likely that our lifetime will see the harnessing of hydrogen fusion power, which will provide almost limitless sources of energy. Thus it is no longer possible

to relegate considerations of climate control to the fantasies of science fiction on this account. It has now become necessary for us to recognize the realities and potentialities of modern science for what they are and what they can mean for the possibilities of climate control.

3. Civil and Military Implications

The impace of the successful achievement of methods for the control of climate upon all types of human activities confounds the imagination. Slight amelioration of adverse precipitation or temperature regimes could result in the reclamation of vast territories for agricultural and many other types of human activities. Desert areas which cover a large fraction of the earth's surface are known in many cases to require only slight changes in moisture regimes to make them suitable for large scale agricultural production. Small changes in circulation regimes could bring about the moderation of severe temperature climates to yield additional areas suitable for human habitation. Such changes in circulation regimes can also affect the normal paths of destructive storms like hurricanes, such that their destructive energies could be dissipated in regions far removed from major human activities. Changes in atmospheric circulation regimes would have marked effects upon oceanic circulations with consequent changes in the abundance and location of fertile fishing grounds. Moderate changes in climatic characteristics will have serious repercussions for all aspects of industrial activity.

Militarily, a climatic control capability raises the possibility of a totally new type of warfare. This type of warfare may be termed "Geophysical Warfare" in which our ability to control the weather environment can be used as a weapon. This geophysical weapon will be unique in character in that it can be used in both hot and cold struggles. It can be used to affect an enemy adversely or benefit a friend. As a function of the nature of the control capability, the use of such a

weapon could be a determining factor in the success of national military operations.

As a hot war weapon it would be best to have a strong control capability for specific areas and specific periods of time. Since we are talking about intermediate and long period climate control, this would imply a conflict of considerable duration. Specific military consequences of such a control capability would be in the potential for destruction of an enemy's food production capability thereby weakening his total military power, and also in the derangements of transportation systems and other industrial activities which might result from a marked change in climatic conditions.

As a cold war tool, the capability of climate control would place in the hands of this Government a tool for ameliorating the weather conditions in friendly and uncommitted nations as a means of strengthening bonds with this country. Conversely as a cold war weapon, a climate control capability provides for a unique surreptitious means for weakening a potential enemy so that he does not have the capability to wage a hot war.

The general study of the feasibility of climate control independent of the use of this capability in either hot or cold conflicts provides necessary national insurance if other nations achieve a control capability. Such a capability in either friendly or unfriendly hands represents a threat of weather conditions which might adversely affect the welfare of our nation. As an absolutely necessary countermeasure, this country must have within its scientific arsenal, the knowledge of how to combat any such attempts at control by other nations. Failure to undertake a consistent program at this time which might provide the knowledge necessary to combat such climate control operations on the part of other nations, could lead to

another "Sputnik" situation.

4. General Outline of a Technical Program for Investigating the Feasibility of Climate Control

4.1 Principle areas of technical activity.

Those items marked with asterisks are considered to be the long range continuing activities of prime importance.

4.1.1 Complete literature survey especially focused upon Russian work.

4.1.2 A detailed scientific analysis of all proposals made to date for controlling climate with an evaluation of the economic feasibility as well as the possible scientific consequences, if any.

*4.1.3 An expanded effort to collect, systematize, and analyze observational material for the entire globe extending to the highest accessible levels to obtain a more detailed and clearer description of the fundamental physical processes operating in the earth's atmosphere.

*4.1.4 An expanded effort to develop mathematical models of the atmosphere capable of including those pertinent physical processes which are felt to be important in the fluctuations of the large-scale atmospheric motions.

*4.1.5 A consistent long range program of comparative numerical integrations of mathematical models to determine the consequences of interferring with any physical processes in the atmosphere.

4.1.6 A much expanded program in associated sciences, especially in the field of numerical analysis to enable us to conduct extended numerical integrations.

*4.1.7 An extended effort to undertake studies of radiational processes in the atmosphere which will provide necessary information for incorporation into

mathematical models suitable for numerical integration.

*4. 1. 8 An expanded effort to establish experimental laboratory facilities for the construction of experimental models suitable for simulating and testing various theories about atmospheric circulations which may be important for climate control.

4. 1. 9 A long range program of investigations of the interaction between ocean and atmosphere to determine the nature of these interactions.

4. 1. 10 A program of investigation into pertinent micrometeorological processes especially as they refer to the fictional dissipation of kinetic energy and the transfer of momentum and energy at the earth-atmosphere interface.

A Possible Program for the Study of Climate Control Problems

1.0 Introduction

It is proposed that a group of scientists be assembled to conduct experiments on the feasibility of climate control. The objective of this research will be to develop methods necessary to analyze and test the theoretical and economic feasibility of ideas which have been and will be proposed to control climate.

There is a clear need to undertake the following types of studies on a systematic long range basis.

a. The evaluation of present knowledge which may be pertinent to the problem.

b. The supplementary research not adequately being performed be present research organizations.

c. Theoretical climate control experiments as justified by the state of the art.

It should be clearly emphasized that the chances of attaining feasible climate control methods are extremely small. The potential value to the nation is so great, however, as to warrant the initiation of the activities proposed below.

2.0 Surveillance and Evaluation of the Existing State of the Art.

There are many research efforts in this country and abroad which have important bearing on the problems of climate control. This research encompasses numerical general circulation and short range

forecast experiments, observational studies of the large scale atmosphere physical processes involving momentum, energy and moisture exchanges, experimental research on laboratory atmospheric analogues, and pertinent technological advances in non meteorological sciences concerned with the availability of energy sources, delivery and distribution systems, and materials.

An active program of surveillance and evaluation of the existing state of the art as represented by the research described above for its applicability to climate control problems is required. This work should commence with a literature survey of pertinent and related research. This surveillance program will permit the isolation of promising developments which require further engineering and testing and will define any supplementary research required to further climate control objectives. This should be a continuing effort to monitor all pertinent research so that at all times the state of the art is fully exploited for purposes of examining the feasibilities of climate control.

3.0 Supplementary Research

It is envisioned that the activities of the group will include research necessary to supplement the work of other groups. Additional research may be required to describe more fully the climatology of certain pertinent physical processes in the atmosphere. Information on space and time spectra will be required of the various atmospheric energy and momentum exchange processes. This research will aid in the

formulation of realistic physical models of the atmosphere. It is likewise needed to test the suitability of various models for the purpose of numerical climate control experiments.

Extensive research into the formulation of mathematical models of the atmosphere which are suitable for long period integrations will be required. These models will be integrated numerically on an electronic computer and tested for agreement with the climatology of pertinent physical processes. Depending upon the test results, the numerical integration methods and the mathematical models may require modification in order to achieve a formulation which is suitable to numerical climate control experiments.

4.0 Climate Control Experiments

A series of systematic numerical climate control experiments will be performed with suitable atmospheric models to analyze and test the theoretical and economic feasibility of ideas which have or will be proposed to control climate. These experiments will be designed to assess the climatic change which would result from changes due to artificially introduced energy and momentum sources and sinks. Innumerable ways have been proposed for varying these sources and sinks, such as changing radiation absorptions and reflection characteristics controlling evaporation from free water bodies, altering surface stresses, etc.

5.0 Personnel and Program Costs

Until such time as it is clear that the state of the art can permit

extensive climate control numerical experimentation, the research effort should be concentrated on items 2.0 and 3.0. When the model development under item 3.0 has progressed to a satisfactory point, a large increase in electronic computer time would be required for item 4.0.

Personnel required to pursue this program would be:

2 Senior Research Associates (dynamic meteorology)

1 Senior Research Associate (physicist)

1 Senior Research Associate (mathematician)

2 Research Associates (dynamic meteorology)

3 Research Associates (mathematicians, analysists, and programmers),

plus supporting help.

Total salary support and overhead costs estimated on the basis of $25,000.00 per professional would be $225,000/year. Initially, computer rental for 200 hours/year would total approximately $75,000.00/year. Computer costs would greatly increase for any substantial effort under item 4.0.