Preliminary Plans

for a

NATIONAL INSTITUTE FOR ATMOSPHERIC RESEARCH

Prepared for the

NATIONAL SCIENCE FOUNDATION

Under Grant G 5807

Second Progress Report

of the

University Committee on Atmospheric Research

February 1959

THE UNIVERSITY COMMITTEE ON ATMOSPHERIC RESEARCH

17 February 1959

Dr. Alan T. Waterman, Director
National Science Foundation
Washington 25, D. C.

Dear Dr. Waterman:

I have the honor to transmit herewith, on behalf of the University Committee on Atmospheric Research, our Second Progress Report which has been prepared with the support of grant G 5807 from the National Science Foundation.

This report is based on an analysis of the scientific problems posed by the atmosphere and of the facilities needed to mount an effective attack on them. It represents a distillation of the opinions of some one hundred and fifty research scientists, perhaps half of all those engaged in basic atmospheric research in this country. It is striking that, almost without exception, the working scientists agreed that an effective attack on the major problems of the atmosphere requires a National Institute for Atmospheric Research of the sort described in the report.

Although the report is concerned primarily with the scientific concept of a National Institute it seemed necessary to translate this into a physical plan and from this to make reasonable estimates of costs. This has been done with as much care and accuracy as possible. On the other hand we consider it essential that the actual research program, facilities and buildings be planned by the scientists who will staff the Institute. Such actual plans will differ in detail from those presented in the report but we are confident that the broad concept will remain valid.

We are convinced of the scientific need for a National Institute and firmly believe that the benefits that will eventually arise from a more adequate basic understanding of our atmospheric environment more than justify the expenditure of Federal funds for this purpose. We will await with great interest your reactions to this report.

Sincerely yours,

Henry G. Houghton

Henry G. Houghton
Chairman

Second Progress Report

of the

University Committee on Atmospheric Research

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Roscoe R. Braham, Jr.	University of Chicago
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Thomas F. Malone, Staff Planning Coordinator, The Travelers Insurance Companies

February 1959

PREFACE

This report summarizes the activity and the studies that have taken place over the last year and a half relative to the establishment of a National Institute for Atmospheric Research to be operated by a group of universities and supported by the National Science Foundation. It was first proposed by the Committee on Meteorology of the National Academy of Sciences. Subsequent studies by the University Committee on Atmospheric Research (UCAR), representing fourteen academic institutions with interest in the atmospheric sciences, confirmed the need for the Institute. A series of seventeen research planning conferences was held under the auspices of UCAR with support provided by the National Science Foundation. These conferences covered nearly all aspects of atmospheric research and were attended by some one hundred and fifty scientists familiar with one or more of these aspects.

From the meetings of UCAR and the research planning conferences there has emerged a consensus of the nature of the Institute, the broad fundamental scientific problems of the atmosphere to which it should address itself, and the nature and kind of research facilities which it should provide. From these ideas, tentative plans for the orderly establishment of the Institute over a six-year period have been formulated and estimates made of the budgetary support that will be required.

Although many of the specific details concerning the scientific program, the organization, the operation and the actual budget of the Institute must properly await the appointment of a scientific staff, an attempt has been made to provide information sufficient to reach a decision on the question of support by the National Science Foundation and to initiate steps leading toward the establishment of the Institute.

An extensive Appendix, which includes the Interim Report of the Academy Committee on Meteorology and the First Progress Report of UCAR, has been added to this report so that the reader may have reference to pertinent material without difficulty.

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SUMMARY

A National Institute for Atmospheric Research has been recommended and supported by several representative groups in the scientific community as an essential part of an over-all expansion in atmospheric research in this country. This Institute will be devoted exclusively to basic research and will be operated by a group of universities with primary support from the National Science Foundation. Its principal function will be to enhance the effectiveness of atmospheric research scientists and to bring to bear on the problems of the atmosphere the full competence of the scientific community. It will do this by fostering the vigorous interdisciplinary effort and providing the complex of large facilities and technological support that are required to make significant advances in describing the salient features of the atmosphere and in understanding the important physical processes which determine its behavior.

There are four compelling reasons for establishing a National Institute for Atmospheric Research:

1. The need to mount an attack on the fundamental atmospheric problems on a scale commensurate with their global nature and importance.

2. The fact that the extent of such an attack requires facilities and technological assistance beyond those that can properly be made available at individual universities.

3. The fact that the difficulties of the problems are such that they require the best talents from various disciplines to be

applied to them in a coordinated fashion, on a scale not feasible in a university department.

4. The fact that such an Institute offers the possibility of preserving the natural alliance of research and education without unbalancing the university programs.

The scientific program of the Institute will be focused on the fundamental problems in four principal areas of research:

1. Atmospheric motion.
2. Energy exchange processes in the atmosphere.
3. Water substance in the atmosphere.
4. Physical phenomena in the atmosphere.

Research activity at the Institute will be grouped around three major divisions: Physical Research (including instrumentation), Mathematical Research, and Chemical Research. Scientists from each of these divisions will be concerned with more than one of the principal areas of research listed above.

Major facilities at the Institute will include (1) a group of instrumented airplanes consisting of two light twin-engine planes, two medium twin-engine planes, three DC-6's and two B-57's, (2) a scientific library, (3) a large-scale transistorized electronic computer, (4) a spectroscopic laboratory, (5) microwave and optical radars, together with sferics equipment and infrared equipment for probing the atmosphere with electromagnetic radiation and (6) well-equipped electronics and machine shops. Housing for temporary staff is required.

The estimated personnel requirements for the research program contemplated at the Institute include 108 scientists, 206 technical and professional people and 236 support people. It is further estimated that six years will be required to obtain a full staff of the competence that is desired. The scientific manpower requirements do not present insurmountable problems. About one-half of the scientists will be individuals with training in the atmospheric sciences and about one-half will be drawn from the parent disciplines of physics, mathematics and chemistry, and from engineering. Approximately one-half of the staff will have permanent status and the balance will be on a visiting status. The facilities of the Institute will be open to competent scientists from all disciplines without regard for institutional or organizational affiliation.

Budgetary support of approximately $1,141,000 is estimated as the requirement for Fiscal Year 1960. The yearly budget will gradually increase toward an annual figure between $14,000,000 and $15,000,000 by Fiscal Year 1965. On the basis of preliminary plans for the six-year period from Fiscal Year 1960 to Fiscal Year 1965, inclusive, the total capital costs are estimated to be $33,253,000. On the same basis the total operating expenses are estimated to be $38,042,000.

BACKGROUND OF THE NATIONAL INSTITUTE FOR ATMOSPHERIC RESEARCH

Introduction

During the past eighteen months, scientists from nearly all parts of the world have acted in concert to bring our geophysical environment under a critical observational study. A considerable part of the activities of the International Geophysical Year has been directed toward the exploration of those portions of the atmosphere about which distressingly little had previously been known. The total impact of this major effort will not be clear until the countless thousands of observations have been analyzed and interpreted in the quiet of the scientist's laboratory or study. However, it is already apparent that information of great value has been collected, and the investment of money and manpower in this scientific endeavor has been a profitable one.

During the period when this extensive effort was underway, thoughtful consideration was also being given to the strengths and the weaknesses, to the problems and the requirements of our nation's program of basic research in meteorology. The objective of basic atmospheric research is to increase our knowledge and understanding of the atmosphere and the physical laws which govern its behavior. A searching examination of the present status of research in the atmospheric sciences was initiated in 1956 by the action of the President of the National Academy of Sciences in appointing a Committee on Meteorology. The charge to this committee was a general one. In essence, it was "to view in broad perspective the present position and future requirements of meteorological research and to recommend the general outline of a program which would accelerate progress in this important field." With six of the nine members drawn from the general scientific community and only three members from the field of meteorology, the committee was able to view the problems before it with the desirable degree of detachment.

A series of conferences was held by the committee in 1956 and 1957 with scientists actively working on the problems of the atmosphere and with prominent educators in the general field of geophysics. During the second half of 1957 the tempo of the committee's activities was accelerated by the designation of subcommittees to explore in depth the separate but closely related problems of research and of education and manpower. Personal visits were made by the subcommittee on research to a substantial number of the universities with active programs in atmospheric research.

At a series of committee meetings in late 1957 and in January, 1958, the committee drew up its recommendations. A draft of an Interim Report[1] was discussed with a group of meteorology department heads and other prominent individuals from meteorology and related fields in New York City at the end of January. With their encouragement and endorsement,[2] the report was formally presented on February 5th to the President of the National Academy of Sciences,[3] the Special Assistant

1. Reproduced in Appendix A.
2. Resolution reproduced in Appendix B.
3. Statement reproduced in Appendix C.

to the President for Science and Technology, the Director of the National Science Foundation, the Under Secretary of Commerce responsible for the U. S. Weather Bureau, and to representatives from the Department of Defense and other interested government agencies.[4]

In brief, the committee found that the total effort in basic atmospheric research was quite inadequate when considered in terms of the scientific and economic importance of the meteorological problem and the best interests of the nation. The committee made two principal recommendations with respect to research: (1) that basic research at the universities and kindred institutions be substantially augmented immediately, and (2) that a National Institute for Atmospheric Research be established. Because the matter was clearly one of national interest and the emphasis was on basic research which might not carry with it specific or short-range economic gains, the committee suggested that primary support for this expanded program should come from the Federal Government.

In its deliberations, the committee had noted that progress in atmospheric research was inextricably linked to the problems of education and scientific manpower. The committee made two further principal recommendations dealing with these questions: (1) that the American Meteorological Society substantially expand its program of stimulating interest in meteorology as a field for scientific and professional activity of unusual challenge and opportunity, and (2) that the departments of meteorology at the universities should form an inter-university

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4. Statement by the Chief of the U. S. Weather Bureau reproduced in Appendix D.

committee to consider matters such as curricula, student recruitment, fellowships and textbooks.

The University Committee on Atmospheric Research

Response to these recommendations made by the scientific community-at-large was immediate and vigorous. By the end of February, the universities had organized the University Committee on Atmospheric Research (UCAR) and initiated a series of meetings that were to continue throughout the year. This committee was made up of the chairmen, or their designees, of university departments of meteorology that offered the doctorate in meteorology, and also included a representative of one university active in research on the physics of the high atmosphere.

The objective which UCAR set for itself was very similar to the charge given to the Committee on Meteorology of the National Academy of Sciences, but it was clearly agreed at the outset that any conclusions that might be reached must be arrived at independently of the recommendations made by the Committee on Meteorology. In view of the importance of the decisions which might be made, it was essential that UCAR act in fact, as well as in name, as a committee representing the interest in atmospheric research at the universities.

At UCAR meetings in February, March and May discussion revolved around five principal considerations: (1) the need and urgency for an expansion in basic research on the atmosphere; (2) university research; (3) a national institute for atmospheric research; (4) education and scientific manpower in meteorology; and, as a consequence of decisions reached on these four points, (5) sources of support. The result of the deliberations of the full committee, and studies by several subcommittees, was a Progress Report issued in June.[5]

There was complete concurrence on the urgency for strengthening and expanding basic research if the scientific and economic needs of this country were to be met and the national interests served (see pages E-4 to E-6 in Appendix E). There was also unanimous agreement that the universities must continue to play a leading role in atmospheric research.

With respect to research at the universities, UCAR presented three specific recommendations: (1) that the university programs be strengthened and stabilized immediately by increasing research budgets \$1,500,000 to \$2,000,000; (2) that plans be made by supporting agencies to double the current level of support within three to five years; and (3) that steps be taken to insure long-term stability of support, to reduce fractionation, and to provide greater freedom and flexibility in the use of funds for basic research.

In considering the need for a national institute, UCAR gave thoughtful and deliberate consideration to the following questions: What is the need for such an institute? Why cannot the conceivable needs for an institute be met in existing university and government laboratories? What specific kinds of research require the existence of an institute? Should an institute be more than just a collection of large facilities? If so, what types of research not requiring facilities should be carried on? Are the scientific manpower resources

5. Reproduced in Appendix E.

sufficient to staff an institute with the calibre of scientists necessary for it to contribute effectively in basic research? What can be done to provide a highly competent permanent staff? What proportion of the total staff should be visiting scientists? Would an institute weaken the position of the universities by competing with them for funds and personnel? Would an institute be of assistance in attracting to the study of atmospheric problems the physicists, mathematicians, chemists, astronomers and engineers required for a true interdisciplinary effort? These questions, as well as others, are discussed at length in UCAR's First Progress Report (Appendix E).

In that report, UCAR listed four compelling reasons for the establishment of a National Institute for Atmospheric Research:

"1. The need to mount an attack on the fundamental atmospheric problems on a scale commensurate with their global nature and importance.

"2. The fact that the extent of such an attack requires facilities and technological assistance beyond those that can properly be made available at individual universities.

"3. The fact that the difficulties of the problem are such that they require the best talents from various disciplines to be applied to them in a coordinated fashion, on a scale not feasible in a university department.

"4. The fact that such an institute offers the possibility of preserving the natural alliance of research and education without unbalancing the university programs."

The UCAR report recommended that (1) the universities they represented establish a corporation to obtain support for and to manage the Institute, and (2) staff studies should be initiated to prepare specific proposals for the establishment of the Institute.

In urging an expanded program of atmospheric research UCAR was not unmindful of related, as well as consequent, problems in the area of scientific manpower and education. Although it had the firm conviction that an institute of a high quality of excellence, properly equipped with the facilities required to make scientific efforts fruitful, would be a powerful magnet attracting capable individuals in the scientific community to the challenging scientific problems of the atmosphere, it was keenly aware that vigorous steps would have to be taken at once to guard against the inviting but dangerous assumption that competent scientists "can be found somewhere" to carry on the expanded program at the universities and the scientific work of the Institute.[6] To meet this problem, UCAR proposed that the American Meteorological Society, with support to be sought from the National Science Foundation, establish a program of visiting lectureships, intended to bring to colleges and universities research meteorologists

6. However, instances are already on record of physical science majors who have transferred to meteorology because their imagination has been fired by the prospect of carrying on scientific work in the kind of research environment envisioned for the Institute.

who could stimulate the interest of physical science majors in the exciting problems of the atmosphere and make known to them the opportunities available to graduate students and research scientists. It further described plans for establishing, with support from private foundations, especially attractive graduate fellowships in meteorology that would (1) provide actual opportunities for gifted science majors, and (2) make available a list of qualified and interested applicants who could be offered graduate assistantships from those presently available at the universities.

In concluding this summary of the UCAR deliberations which led to the First Progress Report, it may be remarked that while UCAR was cognizant of the desirability of broadening the base of support for fundamental research in meteorology (and announcing its intention of seeking support from private foundations and industry) it also recognized that the nature of the program it was recommending required support from the Federal Government. Moreover, UCAR felt that the existence of a high degree of national interest in the problems of the atmosphere was ample justification for requesting this support. Because the contemplated expansion was in the area of basic research, it was considered preferable that this support be provided through the National Science Foundation.[7]

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7. Recognizing the possibility that the basic objective of the Academy Committee report (i.e., augmentation of the <u>total</u> research effort in meteorology) might become obscured by the recommendation of substantial support from the National Science Foundation for the Institute, UCAR subsequently sent letters (Appendix F) to the responsible members of other government departments inviting their attention to the spirit and the intent of the Academy Committee's recommendations.

A decisive step toward implementing the recommendation for a National Institute was taken in July, 1958, at a meeting of UCAR attended by administrative representatives from the fourteen universities. Once again, the questions referred to above were explored in extensive discussion. The result of these deliberations was a unanimous Resolution[8] endorsing the establishment of a non-profit corporation for the purpose of fostering support of meteorological research at the universities, organizing and operating a National Institute for Atmospheric Research, and fostering the education and training of the personnel required to carry on an expanded program of atmospheric research. An Agreement for cooperation in atmospheric research was drafted and submitted to the fourteen universities for their approval.[9]

The reaction of the governing bodies at these universities was immediate and enthusiastic. They recognized that the atmospheric sciences constitute an area in which there is a need for a special kind of institute, properly related to the universities, but so organized that it provides the diversified intellectual excellence of a true university, and at the same time makes available to scientists interested in atmospheric studies the large research facilities and technological support required for effective and productive research. At a time when there are many demands on institutions of higher education and the problems of meeting these demands are so great, twelve of these universities announced their decision to band together and assume the responsibility for organizing and operating

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8. Reproduced in Appendix G.
9. Reproduced in Appendix H.

a National Institute for Atmospheric Research.[10] A formal announcement of this decision was made on October 9th at a dinner held in recognition of the service of meteorology to the business and industrial community. This event was sponsored by the New York Board of Trade and was attended by over a thousand leaders in business and industry from the New York City area.[11]

Work was soon started on articles of incorporation and, at a meeting of scientific and administrative representatives of the universities in Ann Arbor, Michigan, on December 5th, unanimous agreement was reached on the details of the corporate structure through which the universities would combine their efforts. Actual incorporation is scheduled to take place early in 1959.

Because of the obvious importance of a scientific manpower to the planned expansion in research activity, a UCAR subcommittee on scientific manpower was meanwhile actively working on plans for obtaining private support for graduate fellowships in meteorology in order to attract gifted individuals into atmospheric research. The Alfred P. Sloan Foundation was quick to recognize an opportunity to make an important contribution to atmospheric research and generously agreed to

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10. Although prevented by legal technicalities from joining the other twelve universities in this move, Florida State University and the University of Washington have continued their vigorous support of the plans of UCAR.

11. Statements by the presidents or chancellors of the twelve universities announcing their support of the Institute were made public on this occasion. These statements are reproduced in Appendix I.

sponsor ten full-time graduate fellowships in the atmospheric sciences for the academic year 1959-60. These fellowships are intended for graduate students with backgrounds in mathematics, physics, chemistry, engineering and other physical sciences who wish to apply their earlier training to the physical problems of the atmosphere. Stipends are $4,000 per calendar year. The universities plan to offer research assistantships to qualified applicants who are not among the first ten selected to receive these fellowships.

Positive action to stimulate interest in the atmospheric sciences among physical science majors was taken by The University of Chicago during the summer of 1958. With support from the National Science Foundation a special summer workshop for thirty students was held at the University between June 23 and July 18. The program consisted of lectures, laboratory demonstrations and exercises, and field trips designed to give the student a comprehensive view of the field of geophysics with special attention to meteorology.[12] The calibre of the students attracted by this opportunity was excellent. Preliminary applications for graduate work in meteorology indicate that the program was highly successful in accomplishing its primary objective.

In its capacity as the Advisory Committee on Meteorological Education of the American Meteorological Society, UCAR initiated plans for the visiting lecture program mentioned earlier. This program and other measures to increase scientific manpower in the

12. Excerpts from the announcement of this program are reproduced in Appendix J.

atmospheric sciences will be described in a later section.

Ground work was also being laid by UCAR for strengthening the research effort at the universities. In response to the query from UCAR, assurances were received from the Department of Defense and the Department of Commerce of their appreciation of the vital role of the universities in the total atmospheric research effort.[13] In the summer of 1958, the National Science Foundation announced its intention to expand its support of research at the universities and appointed a Program Director for Atmospheric Sciences in the Division of Mathematical, Physical and Engineering Sciences.

A major task remained: to take the idea of an Institute directly to the working scientists in the field of atmospheric research, to exchange thoughts with them on the concept of such an Institute, to solicit their thinking on the contribution an Institute might make to their research problems, to ascertain the prospects for attracting first-class scientists and mounting a true interdisciplinary effort, and -- if the working scientists looked upon the proposal with favor -- to outline the scientific program which would likely be carried on at the Institute. This work, and the preparation of a tentative budget based on the scientific requirements occupied the fall months of 1958. Before discussing these staff studies, it is in order to mention the concern over atmospheric research expressed in other quarters and to

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13. See copies of letters from Secretary of Commerce Sinclair Weeks and Undersecretary of Defense Paul D. Foote in Appendix F.

indicate pertinent activities of the American Meteorological Society.

Other Interest in the National Institute for Atmospheric Research

Special attention to the importance of increasing basic research in the atmospheric sciences was given at the Fiftieth Annual Conference of Governors in Florida in May 1958. A Resolution was passed by unanimous vote urging a strengthening and acceleration in our national effort in this field and endorsing the proposal that a National Institute for Atmospheric Research be established.[14]

Attention was also directed in Congress to the problem of adequate support for atmospheric research and to the matter of a National Institute by the Subcommittee on Reorganization and International Organizations of the Committee on Government Operations.[15]

Prior to the issuance of the Interim Report of the Committee on Meteorology of the National Academy of Sciences, the potential implication of progress in atmospheric research was given serious consideration by a group of businessmen, educators and government people at a meeting sponsored by the Committee on Economic Development.[16]

The need for new institutional patterns and relationships to meet the requirements imposed by modern research techniques, with special

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14. A copy of the Governors' Resolution is reproduced in Appendix K.

15. See Progress Report on the Science Programs of the Federal Government, Senate Report 2498, September 9, 1958, submitted by Senator Hubert H. Humphrey, Chairman.

16. An excerpt from Introductory Remarks by Vice-President Richard M. Nixon is reproduced in Appendix L.

reference to meteorology, was voiced by the Special Assistant to the President for Science and Technology at a conference on "Research and Development and Its Impact on the Economy" held in Washington, D. C., in May 1958.[17] In its report on Strengthening American Science, President Eisenhower's Science Advisory Committee took special note of the limitations and restrictions under which basic meteorological research has been carried on in this country, and commented on the discrepancy between the money spent for basic research in meteorology and the economic impact of weather.[18] The Council of the American Meteorological Society, at a meeting in Washington, D. C., in May 1958 formally endorsed the findings of the National Academy of Sciences Committee on Meteorology that the research effort at the universities should be expanded and a National Institute for Atmospheric Research should be established.[19]

Related Activities of the American Meteorological Society with Respect to Manpower

Because the matter of the Institute and, in fact, of the general expansion in basic atmospheric research is so intimately related to the problem of scientific manpower, it is appropriate to review briefly the steps taken or underway by the American Meteorological Society to

17. The relevant portion of Dr. Killian's address is reproduced in Appendix M.

18. See Appendix N.

19. Action by the Council is summarized in a letter from the Society Secretary reproduced in Appendix O.

stimulate interest in this field. Quite clearly, channels of communication need to be opened to several groups: mature scientists, college students majoring in physical science, secondary students and the general public.

Interdisciplinary meetings offer one important means of acquainting scientific workers in other areas with atmospheric problems. A start has been made in this direction with a symposium on meteorological instrumentation scheduled for February 1959. This will bring together atmospheric scientists concerned with physical measurements in the atmosphere and individuals skilled in the design and development of sensing probes. This has been arranged in collaboration with the Foundation for Instrumentation Education and Research. It is expected that this symposium will be the first of a series to be held at the rate of about two a year over the next few years. The intent of this series is to interest physicists, astrophysicists, chemists, mathematicians, statisticians, hydrodynamicists and other groups in the fundamental problems encountered in atmospheric research.

To reach college students at schools which do not offer degree courses in meteorology, the Society obtained support from the National Science Foundation to sponsor the visiting lectureship program referred to earlier. An announcement in Science brought a flood of requests, and visits by mature research meteorologists to over a hundred campuses are now planned.

To provide for a continuing flow of highly competent and interested young people into the universities, plans have been drawn up to operate a Pre-College Atmospheric Science Center at the Loomis Institute in Windsor, Connecticut, during the summer of 1959. This will be patterned after the highly successful Pre-College Science Center conducted at Loomis under the sponsorship of the Dorr Foundation in 1957 and 1958. This program will reach about thirty gifted secondary students before they enter college and is designed to broaden their perspective on science in general with special emphasis on the atmosphere as a subject for scientific study.

To bring to the general public a better understanding of the scientific problems of the atmosphere, the Society is collaborating in some fairly well-advanced plans for preparation of a series of twelve or thirteen half-hour adult education films, to be used on educational television stations with a potential viewing audience of eighty to ninety million people.

In addition to this work underway plans are well along for a detailed four-year program that will make available career guidance brochures and serial publications for secondary and college level students, educational monographs and slides, and a variety of educational films for use by schools and colleges.

This brief summary covers a few of the steps taken to implement the recommendation of the Academy Committee addressed to the Society.

UCAR Staff Studies

To lay before the community of scientists engaged in atmospheric research the question of a National Institute for Atmospheric Research, to determine the general outline of the research program that should be carried on at the Institute, and to do the necessary facility and budgetary planning, was clearly a task that required the services of an essentially full-time staff. Dr. Thomas F. Malone, Director of Research for The Travelers Insurance Companies, Professor Roscoe R. Braham, Jr., of The University of Chicago and Dr. William S. von Arx of the Woods Hole Oceanographic Institution were asked to serve in this capacity. Professor Jule Charney of the Massachusetts Institute of Technology devoted part time to participation in the staff activities.

Seventeen two-day conferences were arranged, with each conference devoted to a particular aspect of atmospheric research and attended by from five to fifteen prominent authorities in that aspect.[20] These conferences were started in September and were concluded in December. They were attended by a total of more than one hundred and fifty scientists active in, or interested in, some phase of atmospheric research. Conference topics were:

- Atmospheric Chemistry
- Atmospheric Electricity
- Atmospheric Radiation
- Cloud Physics
- General Circulation
- Hydrodynamic Analysis
- Hydrodynamic Models
- Interaction of Ocean and Atmosphere
- Meteorclogical Instrumentation
- Meteorological Use of Rockets and Satellites
- Ozone
- Severe Storms
- Statistical Methods
- Tropical Meteorology
- Turbulence and Convection
- Upper Atmosphere
- Use of Electromagnetic Radiation as a Meteorological Probe

The participants at each of these conferences were asked to review the state of knowledge in the field under discussion, to consider the role that the Institute might play in basic research in that area, to

20. A list of conferences and the participants is given in Appendix P.

recommend the kind of facilities as well as the type of intellectual attributes the Institute should have to extend the frontiers of knowledge, and to give their opinions on the concept, the function, the organization, the advantages and the disadvantages of an Institute.

The response was enthusiastic and the discussions were far-ranging. There was a remarkable degree of unanimity in the thought that an Institute was needed. The group concerned with hydrodynamic models felt that while very large special facilities were not needed for work in their field, model work should be included in the program of the Institute. The majority of those attending the conference on atmospheric chemistry expressed the thought that the effectiveness of the Institute would be enhanced if it were to be incorporated into the academic community of a single university. Of particular significance was the interest in the Institute evinced by scientists from related fields, whose principal research was only indirectly concerned with atmospheric problems.

The material that follows in this report represents a distillation, a synthesis, and an interpretation of the nearly thirty-four days and many evenings of discussion that went on during the past five months. No formal proceedings have been prepared because of the freedom and informality of the discussions. Care has been taken, however, to be certain that the material that follows reflects faithfully the consensus of the conferences. This has been assured by circulating copies of this report in draft form to the chairmen of the seventeen conferences and soliciting their comments.

Specifically, what was done was to take extensive notes on the recommendations of conference participants and then to convert these rather voluminous records into a plan for the Institute, its scientific program, and the budgetary support that would be required to carry on this program. In preparing specific plans for the Institute, the staff was quite conscious of the fact that, ultimately, decisions on the actual research program and the facilities required for this program will be determined by the scientists who choose to do their work at the Institute. What has been done, in effect, is to set up a "straw" Institute which reflects the expressed needs of the research scientists who participated in the conferences. It is unlikely that another group of individuals concerned with the problems of the atmosphere would suggest radically different requirements, although they would almost certainly differ in detail and in emphasis. The merits of the "straw" Institute are two: it conveys an image of the kind of Institute scientists now engaged in atmospheric research feel is necessary and would be most effective, and it permits some estimate of the budgetary support that would be required.

This report is expressly addressed to the question of the Institute. It should be clearly recognized, however, that the Institute is only one part of the general program for expansion of research on problems of the atmosphere. Sight must not be lost of the fact that everything that follows is predicated on the assumption that the meteorological research effort at the universities will be strengthened. It was not by accident that the Academy Committee on Meteorology gave first priority to the university research program. The wisdom of this ranking was strongly affirmed by UCAR, by the representatives of the university administrations and by the scientists in the series of conferences. Discussion of the Institute, then, is in this context.

THE CONCEPT OF A NATIONAL INSTITUTE FOR ATMOSPHERIC RESEARCH

In considering the contribution that an Institute could make to the total research effort in this country, it is necessary to have in mind the concept of the Institute as it has evolved during extensive discussions by many groups during the past eighteen months.

First, and foremost, it has been urged that the Institute be concerned exclusively with basic research -- the search for new knowledge and understanding. This policy is recommended as a consequence of the general recognition that there is need in atmospheric research for work to progress on a broader basis than that which is possible under the constraints imposed on applied research and development responsive to operational requirements. It is inevitable that applications will arise from research conducted at the Institute, and the potential applications will actually influence to some extent the scientific program at the Institute. But in the long run, it seems certain that applications will be more far-reaching and effective if they come as by-products of undirected efforts to acquire knowledge. Thus the scientific program of the Institute will be centered on a search for the solutions of broad and fundamental problems of the atmosphere, with emphasis on those requiring extensive interdisciplinary participation or facilities beyond the capacities of individual university departments.

Since the principal work at the Institute will concern scholarly investigations, the core of the Institute should be composed of a variety of highly competent research scientists from all parts of the world, which is to say that the Institute must possess all the attributes of an international intellectual center. The intellectual climate of the Institute should be broadly based on a variety of disciplines and technical skills. The scientific problems of the atmosphere do not fall within the usual boundaries of scientific fields; the atmospheric sciences are, by nature, interdisciplinary. For this reason it is felt that the Institute must encourage cross-fertilization of thinking by bringing interested scientists together to learn the scientific languages and techniques of their natural colleagues so that they may work with greater effectiveness. Therefore, in addition to meteorologists it would be appropriate to encourage, for example, classical physicists, mathematicians, chemists, and engineers to participate in the scientific program of the Institute.

It is not sufficient, although quite necessary, that the Institute be characterized by superb intellectual strength. One of the principal justifications for establishing the Institute is to place at the disposal of the scientists the array of powerful research tools that are required to carry on fruitful investigations of the atmosphere. No single major facility is required, but rather it is a complex of large facilities that must frequently be used in coordinated and integrated efforts that is necessary to make significant advances toward a proper understanding of the atmosphere. These include, for example, a flight facility comprised of several different and complementary types of aircraft appropriately instrumented so that they can serve as platforms for sensing devices, a well-equipped instrumentation laboratory to design and construct the specialized sensing devices required for research utilization of aircraft, rockets and satellites, an electronic computer facility to reduce the tremendous volume of observational data to meaningful physical variables, ground-based and airborne equipment for probing the atmosphere by electromagnetic radiation techniques, and the adequate technical and logistical support to assure productive operation of these large and expensive research tools. These same tools, deployed in fragmented, project-type research, operating without the freedom and stability envisioned for the Institute, and lacking the scientific guidance of the diverse and strong theoretical core of the Institute, could certainly not be used nearly as effectively and economically as at the Institute.

The Institute then is to be thought of as a center at which high scientific competence and consummate technological skill can be combined in a free and natural alliance to master our atmospheric environment. Naturally, no forced marriage of these two qualities is considered. Provision must be made for a research environment conducive also to quiet contemplation. Nor is it intended, in citing as examples those facilities which stress airborne probing platforms of various kinds, to imply that the scientific program of the Institute will have a bias toward this particular kind of research. The large-scale electronic computer facility will find wide application in advancing purely theoretical studies and an extremely good library is regarded as one of the essential facilities of the Institute.

The facilities of the Institute are to be available on an equal basis to those qualified scientists who have interest in the fundamental problems of the atmosphere, without regard for institutional or organizational affiliation. In addition to a distinguished staff permanently attached to the Institute, it is expected that an equal number of scientists from universities and from private and government research laboratories will affiliate themselves with the Institute on a transient or semi-permanent basis. Many of the problems of the atmosphere are such that a visiting scientist may profit from residence in the Institute for periods as brief as a few months to as long as several years before returning to his permanent position. It is recognized that the many parts of the scientific program of the Institute will acquire direction and continuity through its permanent staff, but the nature of many of the problems to be solved is such that temporary association with the program of the Institute could have lasting effects as well as being immediately productive both for the Institute and for the visitor. The Institute can play an important role as a stimulus to the general intellectual activity in atmospheric research in this country.

It is expected that the Institute will complement the work of the universities. The function of the university is to extend and disseminate knowledge. One function of the Institute is to enhance the effectiveness of the university scientists concerned directly or indirectly with atmospheric problems. Since there is a traditional alliance between teaching and research, it is to be expected that the Institute will strengthen this alliance and act to preserve a proper balance of these functions in the universities by assisting them in meeting the requirements for large research facilities. It is essential to the success of the Institute that it be integrated into the university community and that participation in its activities be on a university-wide basis and not be narrowly restricted to departments of meteorology. The enthusiasm with which the presidents of the universities endorsed the Institute augurs well in this respect. It is expected that graduate thesis research will be pursued at the Institute when there is a requirement for its facilities and appropriate supervision can be arranged to satisfy the specific requirements of the university concerned. Opportunities for postdoctoral research and study may be extended to promising young men from all countries and all relevant disciplines.

The Institute will be operated under the direct supervision of a scientific Director, acting within the spirit of broad policies set by a Board of Trustees composed of one scientific and one administrative representative from each of the sponsoring universities. It will be physically and administratively independent of any single university. Standards for permanent staff appointments will be the same as those at a university of high standing. Provision for a gradual acquisition of staff has been made to assure a high quality of appointments.

Careful thought has been given to the rate at which an Institute of this kind could be established. A judicious compromise between prudence and a lively sense of urgency over bringing atmospheric research up to a reasonable level suggests that about six years will be required to achieve full-scale research operations at the Institute.

The limiting factor is the rate at which scientific manpower can be acquired.

Many of the fundamental problems of the atmosphere are not likely to be solved without sustained effort. Substantial progress toward a satisfactory understanding of the atmosphere will probably have to be measured in decades rather than in years. It is essential that support for the activities of the Institute be of a stable and long-term nature even though some problems are susceptible of immediate solution given the proper scale of effort. Because the research emphasis will be on basic problems and particularly those beyond the capacities of individual university departments it seems necessary that the principal source of support for the Institute must come from the Federal Government, although support from private and industrial sources will be encouraged. Since the research to be undertaken is basic in nature, it is desirable that federal support come through the National Science Foundation rather than through operational agencies of the government. It is strongly urged that the Institute not serve as a channel for the disposition of federal funds toward the research efforts of the universities.

The central effort of the Institute must concern the advancement of knowledge of the whole atmosphere. This requires the attention of men of the highest competence who are trained in a wide variety of disciplines. The full breadth of such an enterprise can only be partially stated at the present time, but it is the point from which the Institute program must make its departure. The next section will outline this point of departure as it has evolved during discussions over the past year. Detail will be omitted because, as remarked earlier, specific plans properly await the appointment of a nucleus staff.

It remains to be established that proper justification exists for the Institute as it is now conceived. The consensus of each of the groups which has studied the problem -- the Academy Committee, the University Committee on Atmospheric Research, the university administrations, the community of atmospheric scientists -- is that the need for the Institute is urgent. The reasons were succinctly stated in the First Progress Report of UCAR (Appendix E). The national interest is clearly involved on three counts: (1) it is almost a national scandal that weather continues to take its yearly toll of life, wealth, and property without a greater effort to understand the physical processes that govern the atmosphere, (2) the possibility, slight though it may be, that one day a better understanding of the atmosphere might lead to effective large-scale weather control, and (3) the broad implications of the friendly yet thoughtful warning by Dr. Charles H. Malik, President, United Nations General Assembly, in an address at Harvard in September, 1958,[21]

> ..."in the field of scientific and technological research there is a most serious competition with the West. The challenge here appears to be that unless

21. "Turning Back the Communist Challenge", Harvard Business School Bulletin, p. 12, October, 1958.

> the effort at the formation of scientists and technicians *and at the promotion of pure and applied science is considerably intensified*, the West is heading toward an inferior position in the foreseeable future."... (Italics added)

Funds for a research enterprise, as large as the Institute should be to achieve critical size, are highly unlikely from private sources. Finally, it will be evident from the discussion of Institute personnel in the next section, the scientific manpower requirements are not impossible of attainment and are in consonance with the scientific importance of the problem.

RESEARCH OBJECTIVES OF THE INSTITUTE

The Scientific Problem of Meteorology

One of the most important characteristics of the atmosphere is that it is a thermally active hydrodynamic system, influenced by the earth's rotation and by a combination of internal and cosmic forces. The fluid consists of a mixture of gases in which a number of trace substances play important roles. Many factors operate simultaneously and interact with each other. As a whole the gas fraction is compressible, non-homogeneous, and viscous and is bounded below by geometrically and thermodynamically inhomogeneous surfaces and above by the outer reaches of the solar atmosphere.

The atmospheric envelope rotates with the earth, but does not rest quietly upon it. These minor internal motions of the atmosphere, the winds, are in fact small departures from rather large absolute velocities. Winds are induced by a non-uniform distribution of energy sources and sinks, which in many cases are formed and dissipated at various rates by the internal motions themselves. Air circulation patterns in the atmosphere range in scale from the circumpolar vortex at mid-tropospheric levels, down through the migratory cyclones and anticyclones, hurricanes, tornadoes, and meso-scale wind systems, and on into the convective cloud currents, and finally into small-scale turbulence. One of the central problems is to explain the existence of this spectrum of atmospheric disturbances and the interactions among them. Present knowledge is fragmentary and no unified theory of air motion has yet been developed.

Intimately linked to the phenomenon of air in motion is the matter of energy distribution. Sources and sinks of energy are variable in number and strength and exist mainly in response to the disposition of short-wave solar radiation, the flux of outgoing long-wave radiation, the latent heat involved in phase changes of water substance, and on the flow of sensible heat at the boundary between the lower atmosphere and the oceans or land. Knowledge of the radiative transfer of energy in the free atmosphere suffers acutely from a lack of observation, although the theoretical and observational tools exist to acquire the needed information. The thermodynamics of clouds is but poorly understood. The energy exchange process between the atmosphere and the ocean (which dominates the surface of the earth) is known only very crudely. Until knowledge of the atmospheric energy budget is placed on a secure foundation, it will be extremely difficult to make much headway toward a real understanding, much less the prediction, of air motion or its consequences.

In addition to being thermally active, the atmosphere is the seat of many physical and chemical processes of importance not all of which are clearly understood. For example, the photochemical processes by which the ionization and recombination of gaseous components is achieved are only partly known. The chemical equilibrium of ozone in the upper atmosphere has a profound influence on biological processes on the ground as well as being a possible link between fluctuations in the emission of ultra-violet energy from the sun and atmospheric motion of lower levels. The distribution and decay of natural and artificial radioisotopes, the carbon dioxide and nitrogen cycles in the atmosphere, and the processes by which particulate materials are diffused and removed from the atmosphere are problems which have assumed ecological significance. The phase changes of water substance and the growth of cloud particles to raindrop size offer physical-chemical problems which are clearly of practical as well as scientific interest. The fair weather electrical field in the atmosphere and the mechanism of charge separation which transforms it under stormy conditions is a problem requiring further elucidation. The characteristics of the atmosphere which influence the propagation of electromagnetic radiation over the entire spectrum of wave lengths are of obvious practical significance and of scientific interest in their own right.

The atmosphere forms a major part of the environment to which this life is sensitively responsive. To this extent the atmosphere has the characteristics of a great natural resource. The microclimate influences the intricate balance between plant life and lower forms of animal life. Plant growth and productivity react sharply to a complex combination of temperature and moisture conditions. Human and animal life, and even their evolutionary progress, are influenced by their reactions to the atmospheric environment.

In other respects floods, hurricanes, tornadoes, droughts, frosts, and the problems of air pollution have all, on occasion, influenced modern society. The economic losses accompanying these atmospheric catastrophies can be staggering. But the really tragic part of these occurrences is that they are produced by natural phenomena that we do not clearly understand and cannot predict with the necessary degree of certainty.

On first consideration, the scientific problem of the atmosphere seems to be incredibly complex. However, if it is analyzed and subdivided into an orderly series of problems, it becomes less formidable. There is a logical ordering of the several parts of the atmospheric problem and it is convenient to list the parts as a framework within which it has been suggested that the research at the Institute might be structured. In simplest terms they are these four: description, understanding, prediction and control. For the atmosphere, as for any physical system, the capacity to understand is predicated on the capability to describe; the ability to predict in a really satisfactory manner is dependent on the capacity to understand and in a scientific sense is a measure of that understanding; intelligent control must rest firmly on an ability to predict -- else the efficacy of measures by which control is attempted will remain in doubt because of uncertainty as to the course the atmosphere would have taken if left to its own devices. However, there is not an absolute dependence for the solution of one of these problems on the solution of the problem which precedes it. Some degree of skill in prediction exists without complete understanding, and limited success in local control of weather is recognized even in the absence of an ability to predict with pinpoint precision. In spite of the fact that by far the major portion of meteorological observation is directed to routine quantitative description of successive states of the atmosphere for purposes of weather forecasting, the level of understanding that has been achieved is remarkable and is not to be deprecated because of its shortcomings.

In line with the policy to stress basic research at the Institute, primary attention should be given to the matters of description and understanding. There was general agreement that, in the long run, this is also the most promising avenue along which to approach the admittedly important task of improving weather prediction and of resolving the important question of weather control. While scientific experiments in weather prediction and control are not precluded, were they to be made the primary objectives of the Institute, its scientific program would suffer from hobbling restrictions right at the outset.

The most impressive single conclusion to come out of the seventeen research planning conferences was the fact that the atmospheric sciences today stand on the threshold of an era when great strides forward appear to be within grasp by virtue of a rapidly developing technology which places almost within reach the tools of description and analysis which can, with the proper breadth and depth of thinking, be used to shape a better understanding of man's atmospheric environment.

Research Program of the Institute

In the context of the brief discussion concerning the nature of the atmospheric problem given above and on the basis of the material collected during the series of research planning conferences it is possible to outline in broad terms the general characteristics of the research program currently envisioned for the Institute and to indicate the facilities and other attributes of the Institute which would be required to enable it to play a unique role in the overall atmospheric research effort. From the point of view of providing some structure to the scientific program of the Institute, the research objectives can be classified as being directed toward four broad areas of inquiry. Each area is concerned with one or more fundamental problems in the atmosphere. These four aspects will be discussed in turn.

Atmospheric motion. This includes the entire spectrum of internal wind systems, varying in scale from the general global circulation down to turbulent eddy elements. This research area includes the anticyclonic wind systems, tropical and extratropical cyclones, hurricanes, tornadoes, squall lines and mesoscale wind phenomena. Recommendations for research in this area came principally from the conferences devoted to the general circulation, hydrodynamic analysis, hydrodynamic models, severe storms, statistical methods, tropical meteorology, turbulence and convection, and to some extent from the conference on the use of electromagnetic radiation as a meteorological probe.

From the viewpoint of understanding, the problem of air motion deals with hydrodynamic flow in an open thermodynamic system. There have been important developments in theoretical work in this area during the past decade and the time appears to be propitious for a concerted effort to push forward with the fundamental studies that are expected to yield a vastly improved understanding of air motion.

The intellectual resources required here are competence in mathematics and classical physics. The particular facility that is required is a large-scale electronic computer. Advances in the theoretical treatment have benefited tremendously from the availability of high-speed, large-memory computers and it is considered to be important that a proper balance be maintained between advances in theoretical work and advances in computer technology. There have also been significant developments in the application of modern statistical methods to the problem of air motion, both from the theoretical point of view and as a result of the increasing use of electronic computers. There are extensive requirements for a computer of the most advanced commercial design to be available exclusively for basic research on hydrodynamic and statistical analysis. This urgent need involves the availability of a computer laboratory complete with applied mathematicians and programmers to do the necessary analysis and coding. The likelihood exists that hydrodynamic and statistical methods can be combined to develop a form of statistical mechanics that will be of considerable importance in the analysis and understanding of air motion.

Experimental models have been developed to a high degree of sophistication in recent years, primarily as an analytical tool rather than as an atmospheric analogue. At present there is no urgent need for model facilities that cannot be provided at the universities, but instrumentation and data-reduction facilities are needed. There is general agreement that laboratory model work should be an integral part of a concerted program to attack the fundamental hydrodynamics of the atmosphere.

On the side of description, two extremely promising research tools have been developed in recent years, but neither has found the degree of application in atmospheric research that their capabilities clearly suggest. The first is instrumented aircraft and the second is microwave radar.

The very great potential of instrumented airplanes as diagnostic devices for research studies has been amply demonstrated by the work of the National Hurricane Research Project and there are obvious extensions to the study of mid-latitude wind systems and to tornadoes and mesoscale phenomena which have not been made simply because these large and expensive facilities have not been readily available. A great need exists for a flight facility, a supporting instrumentation development group and a data-processing laboratory provided on a stable, long-term basis. What makes this need particularly urgent at the present time is the fact that knowledge of atmospheric wind systems has arrived at the stage where it is possible to ask meaningful physical questions, design an observational mission involving aircraft to answer those questions, and exploit the full capabilities of aircraft serving as platforms for sensing devices in answering the questions. This circumstance opens up exciting prospects for increasing our understanding of air motion.

The great advantage of radar lies in the fact that it permits a three-dimensional description of the field of motion. To the extent that this motion influences the distribution of precipitation particles, the efficacy of this tool has been established. It is indispensable in observational studies of hurricanes, tornadoes, mesoscale phenomena, and cloud circulations. The need is for equipment especially designed for atmospheric research and for closer liaison between scientists with a primary interest in radar and scientists with a primary interest in the atmosphere. For the most part, radar equipment used in atmospheric research was designed either for an entirely different purpose or for operational use in meteorology. Even the equipment which has been made available lags significantly behind current technological developments in radar.

To these two research tools for describing air motion can be added a third: the use of isotope and radioactive tracer techniques. These methods are particularly useful for studying the gross features of the general circulation and the mechanism and rate of exchange between the stratosphere and the troposphere. The use of decay products of radon as a tool for finding tropospheric air in the stratosphere requires the sampling of large volumes of air in the upper layer and is another aspect of atmospheric research in which aircraft are needed. The attractive possibilities of using tracer techniques have not yet been explored to the extent which is warranted, and work in this direction should accompany other activity in the study of air motion.

Need was expressed in the conferences for a fluid dynamics laboratory in which a low-speed horizontal wind tunnel with a large test section could be set up for research in turbulence. A 100-meter instrumented tower which could serve as a standard for the development of research equipment in low-level turbulence studies is another example of the kind of facility recommended for the Institute.

Finally, it may be mentioned that certain problems of the upper atmosphere, for example, those concerned with the ionosphere and the auroral glow zone, are beginning to require more attention to the motion at these levels. It is likely that a fruitful cross-fertilization of ideas and techniques could be achieved between the hydrodynamicists working on the atmospheric motions in the troposphere and the physicists concerned with magnetohydrodynamics in the upper portions of the atmosphere.

Energy Exchange Processes in the Atmosphere. Studies encompassed by this area include the nature, distribution and flux of particle energy, short-wave radiation, long-wave radiation, turbulent mass transport and the exchange of sensible heat between the atmosphere and the underlying surface, as well as the latent heat involved in the phase transformation of water. Recommendations for research in this area came from the conferences on atmospheric radiation, hydrodynamic analysis, the general circulation, interaction of sea and atmosphere, meteorological use of rockets and satellites, ozone, tropical meteorology and the upper atmosphere. Advances in this field were held to be essential to progress in the study of air motion.

There are four important reasons for designating atmospheric heat budget as one of the broad, fundamental problems that should be attacked at the Institute. In the first place, the development of mathematical models of atmospheric motion has now reached the stage at which it is feasible to introduce the energy equation in explicit form. To do this with any degree of reality compounds the analytical problem tremendously, and much more information is required than is now available on the distribution of heat sources and sinks in the atmosphere. To acquire this knowledge, a major effort addressed to the problem of the atmospheric heat budget is required. In the second place, the imminent advent of meteorological satellites will place in the hands of the atmospheric scientist a new and remarkably powerful tool for viewing the heat balance problem in its global entirety. To exploit the information which will become available and to develop the techniques of measurement and data reduction and interpretation which will be necessary is going to require a larger effort than now exists. Thirdly, since the ocean surface underlies the atmosphere over nearly three-quarters of the world, it is clear that a quantitative explanation of the heat budget of the atmosphere must be, to a substantial extent, a joint endeavor of atmospheric scientists and oceanographers. The expanding interest and activity in oceanographic research make the the present time propitious for a far more comprehensive study of the energy exchange at the boundary separating the gaseous part of the earth's envelope from the liquid part. Finally, the physical linkage between the heat budget and the general circulation of the atmosphere is such a close one that any hope of effective climate control is likely to lie in alteration of some aspect of the heat budget. One of the most promising methods for the scientific analysis of climatic variation and the possibilities of controlling this variation is to experiment with mathematical models of atmospheric motion under a variety of distributions of energy inputs. But before this can seriously be attempted, it is essential that fundamental knowledge of heat transfer processes in the atmosphere be extended.

The intellectual resources required for this work draw upon the disciplines of physics, chemistry and mathematics. Solutions to the problems of atmospheric radiation require competence in classical physics, particularly in spectroscopy. Knowledge of chemistry is needed in dealing with the energy balance of the ozone layer and the upper atmosphere. Physical and mathematical skills are required in treating the matter of the turbulent transport of heat between the atmosphere and its underlying surface -- land or water.

Research facilities that are needed here include a spectroscopic laboratory for the study of absorption and emission characteristics of atmospheric constituents, instrumented aircraft to make radiation measurements and to obtain horizontal and vertical profiles of the ozone distribution, a large-scale computer for theoretical calculations and reduction of observational data, and an instrumentation laboratory for equipment development. Quite clearly, rockets and satellites will play an important role as platforms for radiation sensing devices, but it was recommended that the Institute should work in cooperation with agencies that already have rocket and satellite facilities and should concentrate on the design of scientific experiments to be conducted with these vehicles, on the development of the sensing devices and on the analysis and interpretation of the observations from these probes. These are areas in which there are important needs at the present time.

A particularly important part of the heat budget problem is found in tropical latitudes. It was pointed out that the flight facility of the Institute could help fill a large gap in our knowledge in this area by conducting "expedition" type experiments designed to yield significant information over this portion of the globe from which data coverage now is distressingly sparse.

The role of latent heat in the atmospheric heat budget overlaps into the third broad problem area of the Institute and will be mentioned in the next section.

Water Substance in the Atmosphere. The objective here is: to understand the fundamental physical and chemical properties of water in the liquid, solid and gaseous phases; to understand the micro- and macrophysical meteorological processes responsible for the generation, internal structure, and dissipation of clouds; to understand the micro- and macrophysical processes responsible for the formation, structure and efficiency of all forms of precipitation; and to understand the thermodynamic interaction between a cloud or a cloud system and the surrounding atmosphere. Recommendations for research in this area came from the conferences on atmospheric radiation, atmospheric electricity, cloud physics, interaction of ocean and atmosphere, severe storms, tropical meteorology, and use of electromagnetic radiation as a meteorological probe.

There are several reasons for emphasizing this subject as a broad problem area for fundamental research at the Institute. In the first place, the role of water substance in the atmosphere is a crucial one. It has a profound influence on the distribution of energy sources and sinks by virtue of its effect on radiation processes and because it is continually releasing or taking up heat from the atmosphere as it changes phase. Secondly, knowledge about water substance in the atmosphere has advanced to the stage at which further progress will be accelerated or slowed by the extent to which recourse can be had to actual observational data obtained from direct measurements in the atmosphere. Thirdly, these observational studies are now both practicable and feasible with the use of instrumented aircraft, radar and modern data-processing equipment. Finally, from national economic considerations, the water resources problem is already a critical one and will become even more critical during the next few decades. Recent experimentation has raised the cautious hope that man may one day be able to exert some influence in the management of this natural resource. It is abundantly clear, however, that this hope will not be realized until fundamental knowledge about water substance in the atmosphere is substantially expanded.

Airborne field studies are required to establish the nature, abundance and size distribution of condensation and freezing nuclei, the droplet-size distribution, liquid water content, temperature and electrical effects in cloud systems, the wind field, the albedo and the radiation budget above, below, in and around clouds and cloud systems, and thermodynamic interactions between clouds and their environment, and the phase, drop-size distribution and total liquid water content of precipitation elements in and below clouds, and the interaction between the electrical field in and about clouds and the precipitation process. There is more involved here, however, than merely sending aircraft up to take measurements. There are deficiencies in currently available instrumentation that need the attention of a group of high competence.

These deficiencies are not fundamental and the technology exists to correct them. This technology has simply not been applied because of the disjointed way in which much of cloud physics work has been carried on. Moreover, the development of sensing systems must take place with regard for compatibility between the data-gathering procedures and the computing facilities for reduction of these data.

To complement and supplement the information obtained by sensing probes mounted on airplanes, both ground-based and airborne radar are required. Currently available radar systems leave much to be desired from the standpoint of cloud physics studies, but here again the technology exists to improve their performance materially.

For laboratory studies, a cold chamber, a vertical wind tunnel, facilities for the construction of kinematic cloud models and equipment to measure the radiation characteristics of water substance over a range of pressures, are included among the basic research requirements.

A relatively neglected area that deserves more attention is the study of the hydrologic cycle by the analysis of isotope ratios. But first, answers must be obtained for questions such as whether or not the changes in the ratios of O^{16}/O^{18} and H/D follow the same equilibrium distillation process in nature that they do under special laboratory conditions. The pressing need in the field of isotope tracer analysis is to bring together the chemist and the cloud physicist.

Fundamental theoretical investigations are needed of the basic physics of water in all its forms, the physical-chemical aspects of nucleation, and the physics of cloud droplet growth. The requirements for a large-scale electronic computer in theoretical studies of cloud droplet growth are as severe as in any other area of the atmospheric sciences.

Experimental field studies concerned with modification of precipitation processes in the atmosphere have been recommended as a part of the Institute's research program in this area, but the purpose of these experiments should be to elucidate the physics of the precipitation mechanism rather than simply to see if it is possible to augment the rainfall at the ground.

From the brief account of some of the major scientific problems connected with the study of water substance in the atmosphere, it is apparent that a vigorous interdisciplinary effort is required in this field just as it is in the previous two broad problem areas.

Physical Phenomena in the Atmosphere. There are phenomena in the atmosphere of great interest and importance which do not play as direct a part in atmosphere motion as do radiation phenomena and water substance. These include, for example, electrical, chemical, optical and acoustical phenomena and certain physical processes in the upper atmosphere. Study in some of these fields has been carried on somewhat independently of the main stream of atmospheric research, yet these phenomena are integral parts of the scientific problem of the atmosphere and it is generally agreed that they should be included in any comprehensive research program aimed at a better understanding of the atmosphere.

Over and above their fundamental scientific importance, there are three reasons why provision should be made for inclusion of problems in this general area in the scientific program of the Institute. The first is, as pointed out in the conference on the upper atmosphere, the world-wide activities of the International Geophysical Year have resulted in the amassing of an astounding volume of extremely valuable scientific data. The reduction, analysis and interpretation of these data are going to require the competence of a strong interdisciplinary group equipped with excellent facilities for large-scale data processing. While it would be highly undesirable to concentrate all of the effort in analyzing IGY data in one place (and would not be possible even if it were attempted), the Institute, as an international intellectual center with a marked interdisciplinary flavor and a first-rate computational laboratory, could serve as a focal point for bringing together and coordinating the several disciplines involved and make an important contribution to the effective utilization of these data -- many of which are concerned with atmospheric phenomena which fall into the general category under discussion. Secondly, man's activities in consuming fossil fuels during the past hundred years, and in detonating nuclear weapons during the past decade have been on a scale sufficient to make it worthwhile to examine the effects these activiti have had upon the atmosphere. Reference is made here to the still unsolved question of whether the carbon dioxide content of the atmosphere is increasing as a result of combustion processes and the even more elusive question as to possible changes in the earth's electrical field as a result of nuclear explosions. Thirdly, by nature most of these problems fall exactly into the realm of basic research and many of them require facilities on the scale envisioned for the Institute as well as an interdisciplinary approach. A few examples will be cited here.

It was pointed out by the participants in the conference on the upper atmosphere that a pressing need in auroral and airglow research is for laboratory and library research to obtain a better understanding of the fundamental physics which is involved. It was further emphasized that this will require bringing together in one place people from many disciplines which have not yet been drawn into these investigations. The physical properties of the atmosphere between the limit of balloon soundings and the ionosphere are just beginning to be measured by rockets, but there is no concerted effort to exploit the information obtained from these vehicles. Measurements in this region may be of critical importance in establishing possible effects of solar disturbances on tropospheric weather. Another problem of the upper atmosphere that has been described as being neglected is the determination of the variables of state above 100 kilometers.

The study of atmospheric electricity has lacked facilities for the field investigations on a scale to determine more than the gross features of the earth's electrical field and its temporal variations. Moreover, there was agreement from participants of the conference on atmospheric electricity and the conference on the upper atmosphere that the broad field of study concerned with electrical phenomena in the atmosphere has suffered seriously from a traditional but scientifically indefensible division into upper and lower atmospheric phenomena.

The thunderstorm and associated phenomena were described as the "most important problem in atmospheric electricity" yet it was agreed that existing basic knowledge of atmospheric electrical effects and the instrumentation for making the basic measurements are so inadequate that, at the present time, it would be difficult to justify a large field project for the sole purpose of studying electrical effects in thunderstorms. It was felt that the Institute could be of great help in this area by developing adequate instrumentation for such a study. The need for field studies of this kind can be inferred from the fact that there is at the present time no generally accepted explanation for a process so basic as the separation of charge in an incipient thunderstorm.

There has even been evidence presented that the role of electrical phenomena in the atmosphere may not be as passive as heretofore believed. The possibility cannot be completely discounted that electrical effects may be of some influence in the precipitation process. Should this be verified, another intriguing possibility would be opened up for exerting some degree of control over the weather by influencing the electrical field in the atmosphere.

The establishment of "bench mark" stations to measure long-period changes of the electric field in a representative number of atmospheric columns is urgently needed in order to investigate long-term effects of nuclear explosions on the earth's electrical field. A related question which needs attention concerns the effect of nuclear weapons tests on the isotope balance in the stratosphere. An answer to this question is difficult because knowledge is so limited about the natural production of isotopes in the atmosphere. Research on this fundamental scientific problem also involves securing samples of air from columns extending into the stratosphere.

Other fundamental problems that require attention in the field of atmospheric chemistry include: the isotopes of water, the carbon dioxide and nitrogen cycles, the properties of oxygen, the general geochemical balance in the atmosphere, the escape of substances from the atmosphere and the origin of the atmosphere.

The sampling of chemical and electrical problems given above is merely intended to be suggestive of a class of problems which have been suggested as the kind that would provide a desirable breadth and depth to the program of fundamental research at the Institute. Some of these investigations require large-scale facilities, such as computers and aircraft, or technological support, for example, development of instrumentation. Others need the refreshing thinking that can result from interdisciplinary collaboration. Either need qualifies a problem for consideration at the Institute. While one of the principal justifications for the Institute is to make available badly needed but expensive facilities, an equally important reason for its establishment is to foster the cross-fertilization of disciplines. Both factors are recognized as being essential to the advancement of atmospheric research.

ORGANIZATION OF THE INSTITUTE

Institute Laboratories

It is not the intent of this report to set forth an organizational chart for the Institute, but it is desirable to indicate in broad terms the general structure that has emerged from the thinking of many people as the one that would be most likely to enable a group of scientists, professional and technical people and supporting staff to pursue productive research in the four general areas discussed in the preceding section.

It is worthwhile at this point to recall the primary objective of the Institute, namely, to <u>describe</u> and to <u>understand</u> phenomena in the four broad areas of investigation cited above. These objectives require three basic steps: observation, reduction of data, and the intellectual effort required to design the experiment and to analyze and interpret the results. In addition, of course, theoretical studies which have no immediate relation to the experimental program are an essential part of the total research activity. The total resources of the Institute may reasonably be divided into two kinds: people and facilities. Care must be taken in further subdivision, lest an undesirable degree of compartmentalization be artificially imposed. Traditionally, meteorologists have been grouped by primary interest into a half dozen or so different kinds of meteorologists. This is considered to be undesirable at an Institute at which the goal is to achieve the fundamental unity of the atmospheric sciences while respecting the identity of the basic disciplines which have a part to play in atmospheric research. Since some grouping of people is necessary, it has seemed desirable to do this by basic disciplines. This suggests that a physical laboratory, a mathematical laboratory and a chemical laboratory comprise a suitable structure for the organization of the Institute. In response to the urgent need for emphasis on instrumentation, provision has been made in the physical laboratory for basic research on instrumentation. Progress in this area, however, will involve all three laboratories.

It is unlikely that this subdivision will result in establishing impediments to an interdisciplinary effort, since all three laboratories will be concerned in varying degrees with the four fundamental problem areas outlined in the preceding section. In addition they will share in common the facilities to be described below.

These facilities represent the basic tools required in the four general problem areas selected as fields for fundamental investigation at the Institute. The largest single facility is the group of aircraft for which there is an almost universal need in the descriptive aspects of atmospheric research. Only the major facilities will be described here and it should be emphasized that facility requirements will depend on the interests of scientists actually engaged in research at the Institute and that even their requirements will change as their work progresses. It is almost certain, however, that these major facilities will be needed and that this need will continue for quite a number of years.

Institute Facilities

<u>Flight Facility</u>. Airplanes are needed at the National Institute for Atmospheric Research to provide airborne platforms suitable for (1) carrying out scientific measurements of atmospheric variables, and (2) conducting experiments aimed at furthering our understanding of the atmosphere. Research in many areas is lagging because of a lack of such facilities. In the development of meteorology, research centered around the lower levels of the mid-latitude troposphere, principally because data for such studies were available from routine data-gathering networks of civil and military weather services. These networks are most concentrated in mid-latitudes because these are the regions of heaviest air traffic -- the principal reason for the establishment of the networks.

Data obtained from the standard weather network are inadequate for many kinds of atmospheric research. Many atmospheric problems of vast scientific and economic importance involve phenomena of such nature as to effectively slip through the regular net of observing stations. Most of the problems of common interest fall into this category. Operationally motivated data-gathering systems cannot conceivably provide data of sufficient density over small areas, of sufficiently high repetition rate, and of such specialized nature as to meet the needs for research and action in these areas. Only specialized research planes can do this.

Another kind of need for research flight facilities arises as a consequence of our ever-expanding knowledge of the atmosphere. Meteorologists have reached the stage in many areas of research where it is necessary to conduct experiments in the atmosphere, experiments aimed at altering the natural course of development of some atmospheric phenomenon, and experiments aimed at furthering knowledge through the asking of "key" questions of the atmosphere. It is obvious that this vital "next step" in the development of atmospheric sciences depends upon specialized research facilities, among which the research planes will play a leading role.

What are some of the problem areas requiring research flight facilities? Several examples can be cited (see Supplement I for details):

a. Microphysics and microchemistry of clouds and precipitation including cloud modification.

b. Heat balance studies of the earth and the associated details of radiative transfer of energy through the atmosphere.

c. Severe storms, such as thunderstorms, tornadoes, and damaging hail and wind storms.

d. General circulation of the atmosphere, including climate.

e. Atmospheric ozone.

f. Atmospheric chemistry.

g. Atmospheric electricity, including the role of electrical effects in precipitation and other weather phenomena.

h. Convection and turbulence.

i. Tropical meteorology, including hurricanes.

j. Micrometeorology, including air pollution.

These types of problems will inevitably be represented in the scientific program of the Institute, and they suggest some of the kinds of research which will be aided immediately by the formation of the Institute. As the Institute matures and as knowledge of the atmosphere expands, programs of even greater impact will be undertaken.

Historically, flight support for meteorological research has come from military agencies. Because of the high cost of instrumenting, operating and maintaining airplanes, scientists have been dependent upon the Air Force and Navy for such support. Generally speaking, only those kinds of research for which the military can supply the required flight support have been attempted. This research has taken the form of "projects" which range widely in size and scope. Notable among the large efforts are the Thunderstorm Project of 1946-1949 and the Artificial Cloud Nucleation (ACN) Projects of 1952-1955. Since 1956, the Weather Bureau has been operating the Hurricane Project.

Although the one-shot project approach has been successful in expanding basic understanding of particular features of the atmosphere, these projects have been rather unsuccessful in enlisting the best scientific talents, largely because the year to year funding has not provided the long-term financial stability required for the best research.

Research groups at Government laboratories are theoretically capable of handling basic problems on a stable long term basis. However, the scientists and administrators from these laboratories have repeatedly advised that their emphasis must be on problems having operational significance with the consequence that fundamental research has been severely restricted.

Still another difficulty has resulted from tieing atmospheric research to the military agencies. The mission of the Military Establishment is the defense of this country. Their airplanes, and their methods of operating and maintaining them, reflect this mission. As a consequence, the airplanes which have been made available to atmospheric scientists, for the most part, have been rather unsuited to the tasks of research. Looking toward the future it appears that the picture is likely to get worse before it gets better. The present trend is toward bigger, faster, higher-flying airplanes which will be even less suitable for research in the lower atmosphere. The ever increasing costs of operating and maintaining these new planes will make it even more difficult to divert them into basic research.

It is absolutely essential that a flight facility be established for the sole purpose of providing support for basic research in the atmosphere. It is essential that this facility be under the complete control of, and available to university scientists, that it be capable of making measurements and carrying out experiments whenever, wherever, and in whatever manner needed to solve a particular problem.

Problems in meteorology demand a complex of airplane types. Many of them demand a multiple-plane capability of long range and/or high altitude. From these planes the scientists will make measurements and carry out experiments involving several altitude levels and long flight paths. Details of the individual flight paths will vary with the research problems, but in general they will be such as to obtain data detailed in space and time to supplement that obtained from the weather networks. The data obtained from these flights will involve tens of thousands of data points per hour of flight. It is totally beyond the capability of existing meteorological research institutions to provide these planes, and to cope with the volume of data coming from them.

Many other problems, such as cloud physics studies, severe storm research, cloud seeding, etc., can best be tackled by relatively small planes with limited but highly specialized instrumentation. Theoretically these planes are within the capability of existing meteorological laboratories, but experience has shown that unstable financial support for research has made it impossible for many of the university laboratories to acquire them on an adequate basis.

The proposed minimal flight facility for the National Institute is as follows:

2 each Cessna 310's (or equivalent)	ready	for	research	Fiscal	Year	61
2 each Convairs (or equivalent)	"	"	"	"	"	62
3 each DC-6's	"	"	"	"	"	64
2 each B-57's	"	"	"	"	"	64

This proposal is based upon planes available in 1958 -- it is likely that the actual complement of planes at the Institute will differ somewhat from this list. It is not considered wise for the Institute to invest in single engine light planes because of their limited size and electrical power for scientific equipment, and their restriction to daytime CFR conditions. Any need for these planes at the Institute should be met through local rental.

The cost and phasing schedule for the proposed flight facility is shown on the following page. These costs reflect 1958 experience in operating the kinds of planes in question.

Several research problems of great importance are beyond the capability of the proposed flight facility. This is unavoidable. The vastness of the atmosphere inevitably means that there will always be problems which will tax the capabilities of planes of most advanced design. Whenever the Institute becomes engaged in such research, arrangements for flight support will have to be worked out with the military agency best able to furnish this support. However, the vast majority of the present problems of the atmosphere will be accessible with the proposed flight facility. The Institute does not propose to carry out routine, operational-type weather reconnaissance. The National Institute for Atmospheric Research should be devoted to basic research without the responsibility for operational problems.

These airplanes will be permanently instrumented for measuring those variables which are common to almost all kinds of atmospheric problems. In addition, power supplies and recorder systems will be large enough and flexible enough to accommodate additional instruments needed for certain special studies. The variables to be measured on all flights include wind direction and speed at flight level, air temperature, atmospheric pressure, height above surface, air water vapor content, "D" value, cloud water content, and radar cloud coverage. (The light twins will not be equipped for some of these measurements.) Among variables which will be measured only on special flights one can list precipitation water content, cloud droplet spectra, pre-

Budget and Phasing of Flight Facility

Fiscal Year	1960	1961	1962	1963	1964	1965
Staff-hiring	Flight facility manager and assistant	2 Instrument men & 2 Flight scientists	4 Instrument men & 4 Flight scientists	5 Instrument men & 2 Flight scientists	5 Instrument men & 9 Flight scientists	
Aircraft						
Light twin		Purchase and Instrument 2 each	-----------------Full Scale Research Operations-----------------			
Heavy twin			Purchase and Instrument 2 each	----------Full Scale Research Operations---------		
DC-6				Acquire & Instrument 3 each	--Full Scale Research Operations--	
B-57				Acquire & Instrument 2 each	--Full Scale Research Operations--	
Expenditures (Thousands of Dollars)*						
Capital						
Plane purchase		$200	$ 800			
Scientific instrumentation		20	800	$2,500 Instrumentation of DC-6's & B-57's		
Operations**						
310 type		130	260	260	$ 260	$ 260
Convair type			250	585	585	585
DC-6's (including lease costs)				500	2,470	2,470
B-57's					1,040	1,040
Total		$350	$2,110	$3,845	$ 4,355	$ 4,355
Cumulative total		$350	$2,460	$6,305	$10,660	$15,015

*Based on 1958 figures.

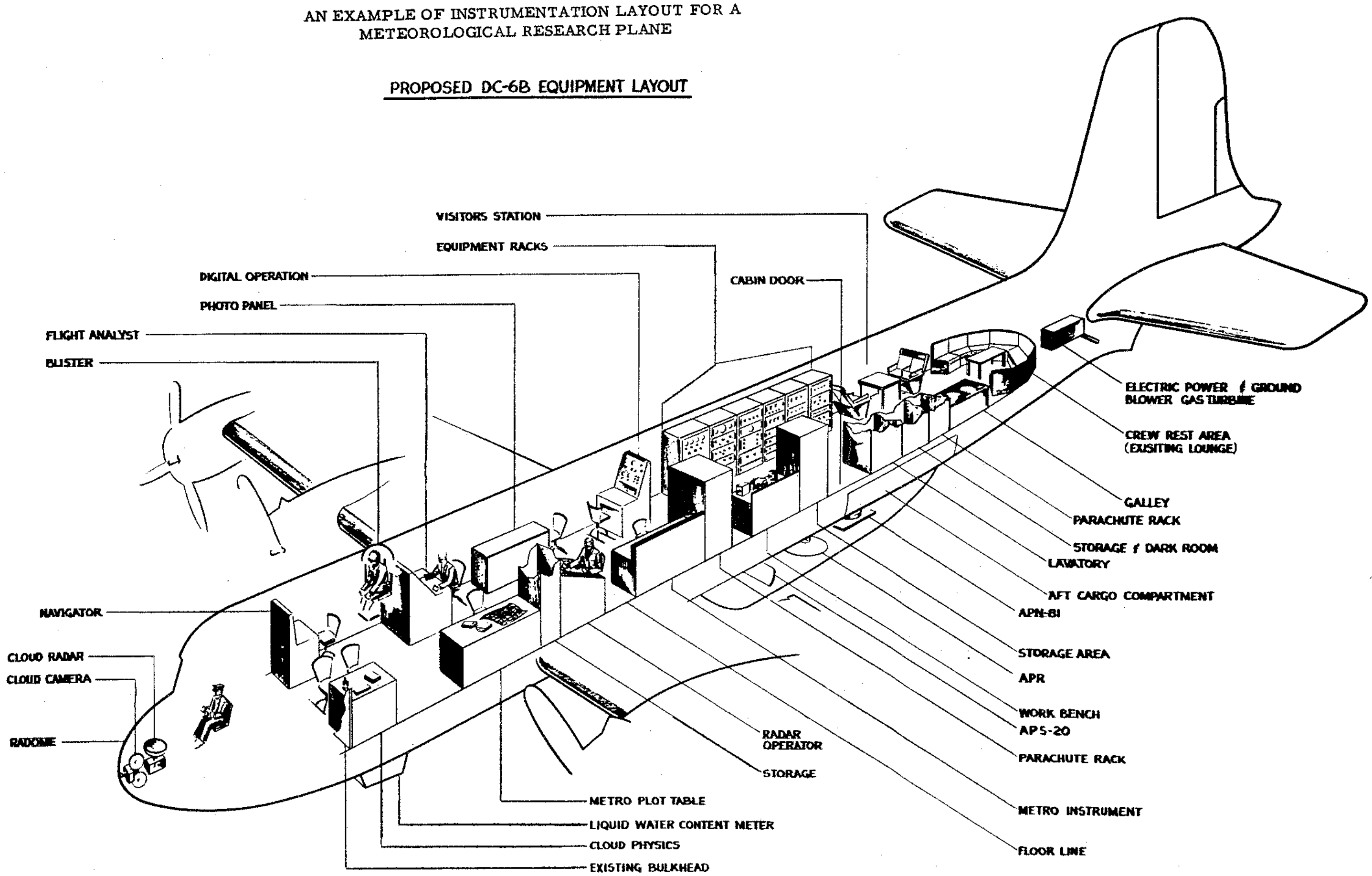
**Costs based on 750 hours of operation per plane per year. Includes 30% above basic 1958 costs to allow for operations away from principal base. Maintenance expenses are included.

cipitation particle spectra, air turbulence and strong vertical motions, radar cloud structure, atmospheric electricity, condensation nuclei, atmospheric particulates, ice nuclei, land-sea surface temperatures, cloud and surface albedo, and visibility. From time to time still other variables will have to be measured with specialized instruments installed for the purpose. In order to use the measured data, it will be essential to measure and record certain reference data including plane latitude and longitude, heading, airspeed, airplane attitude, and airplane altitude. Time synchronization between various instruments will be provided through the incorporation of timing signals on the magnetic tapes used for recording the data. The magnetic tape format will be designed to permit direct data input into the ground data evaluating and computing system.

The airplane instrumentation envisaged for the National Institute is similar in many respects to that currently in use on the National Hurricane Research Project. Figures 1 and 2, supplied through the courtesy of the United States Weather Bureau, illustrate one way in which these complex instrumental devices can be installed inside an airplane to create a flying meteorological laboratory.

It is proposed that the Institute acquire the two light and two heavy twin-engine planes through purchase. These should be available for research in Fiscal Years 1961 and 1962 respectively. The three four-engine cargo planes will be leased from a private concern. It is proposed that the two B-57's be obtained from the Air Force on a bailment basis. The operation and maintenance of the NIAR airplanes

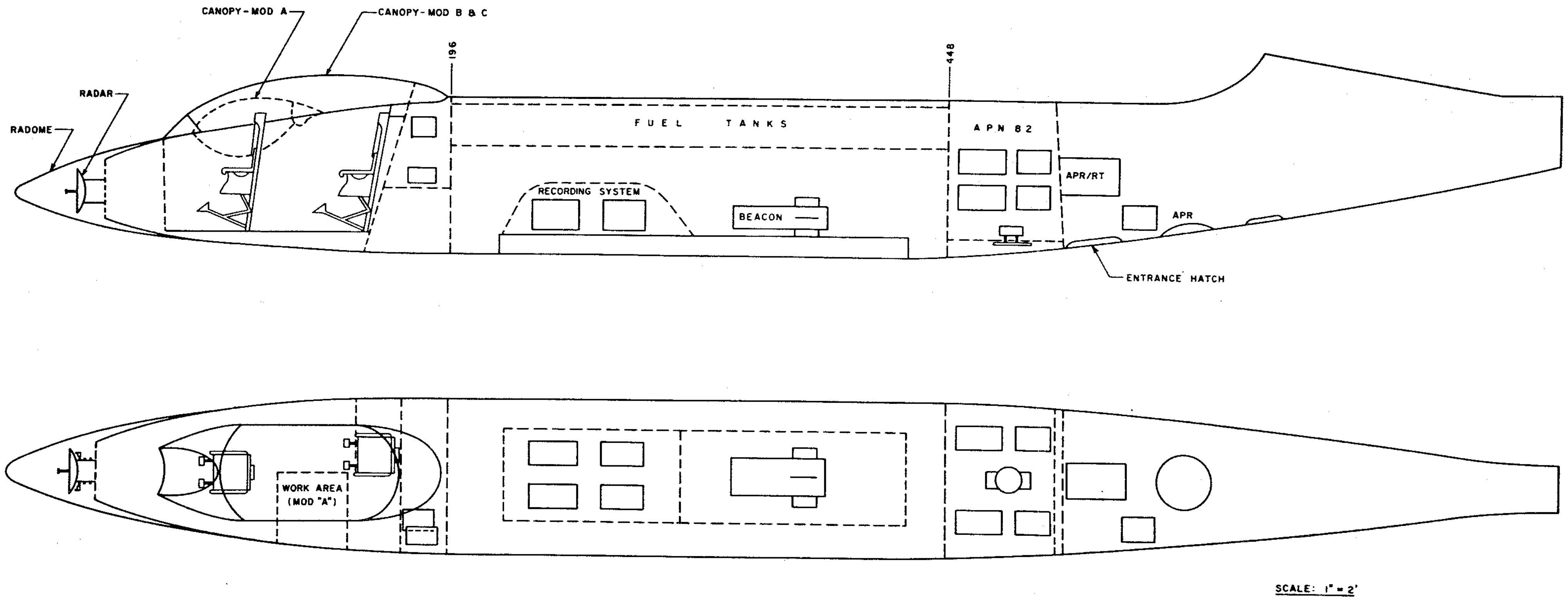
AN EXAMPLE OF INSTRUMENTATION LAYOUT FOR A METEOROLOGICAL RESEARCH PLANE



Courtesy -- U. S. Weather Bureau
General Precision Labs

FIGURE 1

AN EXAMPLE OF INSTRUMENTATION LAYOUT FOR A METEOROLOGICAL RESEARCH PLANE



PROPOSED B-57 EQUIPMENT LAYOUT

Courtesy -- U. S. Weather Bureau
General Precision Labs

FIGURE 2

should be handled on a contract basis with a commercial concern skilled in such operations. Several commercial airlines and private pilots have indicated an interest in such an arrangement.

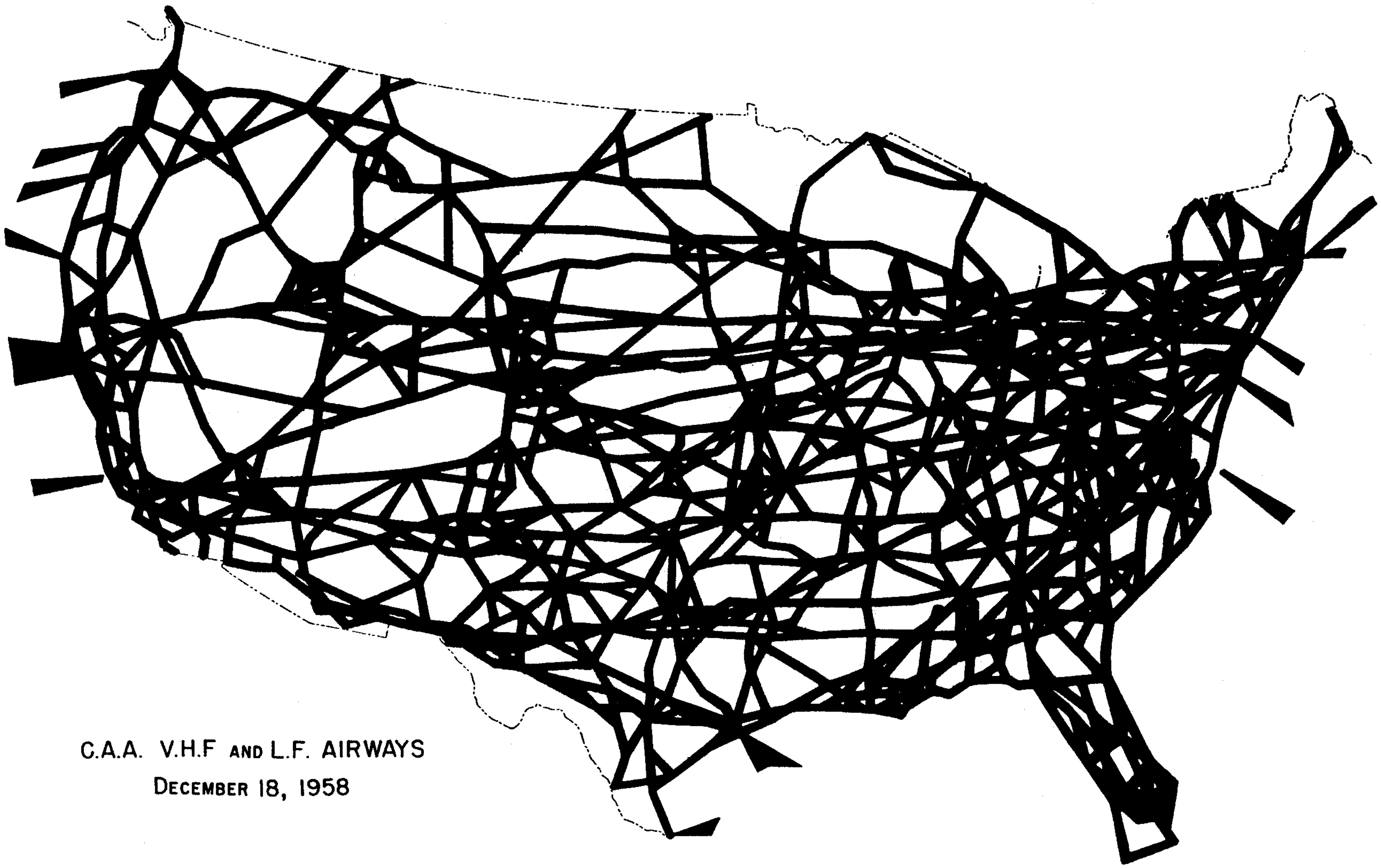
The manner in which the flight facility is integrated into the other efforts of the National Institute is of great importance. The object in having a flight facility is to provide university scientists with a modest but useful capability for making measurements and for carrying out experiments in the atmosphere. But the airplanes alone do not meet this objective. The airplane effort must lean heavily upon the Institute's instrument development group, the radar and electronics shops and the data analysis and computer facilities. In addition, the scientists using the airplanes need the opportunity for contact with the other scientific disciplines which will characterize the Institute, and the laboratory scientists will have need for occasional airplane support.

This need for close physical relationship between the flight facility and the remainder of the Institute poses some difficult problems. Because of noise and general congestion, it is not considered wise to locate the Institute immediately adjacent to a large airport. The costs of construction and maintenance make consideration of a private airport for the Institute out of question. The remaining alternative is to locate the Institute conveniently close to an established airport. In view of the developments taking place in the military weather reconnaissance programs, this airport should be capable of handling jet type airplanes. Discussions with scientists who have conducted extensive flight research programs in the atmosphere suggest that there should be less than thirty minutes travel time between the planes and the Institute if there is to be an effective liaison between the two efforts. In the opinion of the scientists now using aircraft, the effectiveness of a flight facility <u>within</u> the Institute will be largely lost if this distance requires more travel time than the order of an hour.

On the other hand, no single location will provide examples of all types of atmospheric phenomena. The planes necessarily will spend substantial fractions of the time (perhaps 1/2 to 2/3) on an expeditionary basis away from home base. The time spent at the Institute will be spent in instrumentation research, repair and calibration of instruments, removing special equipments of one kind and installing others, in addition to the atmospheric research which can be carried out locally.

Many very important problems, such as those posed by tornadoes, squall lines, thunderstorms, hurricanes and cloud modification, can be solved only by research carried out from airplanes. To carry out this research, the scientist must be able to fly at the time, place and altitude dictated by the problem and not be traffic control. As a consequence, in the past, this type of research has tended to be stricted to the non-controlled off-airway areas. The difficulty of finding such areas is illustrated in Figure 3 which shows the extent of controlled areas in 1958.

Lacking a suitable flight facility, atmospheric scientists have



C.A.A. V.H.F AND L.F. AIRWAYS
DECEMBER 18, 1958

FIGURE 3

thus far closed their eyes to this problem. However, the creation of a flight facility for atmospheric research will make it necessary to explore every avenue for ways of making the atmosphere accessible to scientific exploration with a minimum of disturbance to the other users of the airways.

Computer Facility. One of the most important tools for atmospheric research to be developed in recent years is the high-speed, large-storage electronic computer. It finds great application in the solution of the mathematical equations describing physical processes in the atmosphere and in processing the incredibly large amounts of data collected in observational research programs. The need for computational facilities at the present time has almost outstripped the part-time availability of machines at those universities and research laboratories where such equipment are located.

There already exists a need for a computer devoted exclusively to basic research on atmospheric problems. With the expansion in atmospheric research, and the increasing sophistication of methodology, this need is going to increase substantially. It is already apparent that the reduction and analysis of data from meteorological satellites is going to impose even greater requirements for computational facilities.

To meet the needs of scientists at the universities and other meteorological research centers and to constitute an integral part of the research facilities at the Institute, it is essential that a computational laboratory equipped with a large-scale computer of the IBM 7090 or Philco Transac 2000 class be available at the Institute. A computer of this type, in the opinion of participants at the conferences, would be capable of fulfilling the immediately foreseeable needs. A staff of about forty-four people would be consistant with the estimated work load.

Problems that would require an even larger computer were discussed at the research planning conferences. It was felt that arrangements to rent time on bigger computers would be the best way to take care of these occasional requirements until the demand for this scale of equipment is sufficiently great to justify purchase, construction or full-time rental of a larger machine. During the interim period while permanent quarters for the Institute are being completed, research needs can be met by rental of time on a computer as needed.

Rental fees for the kind of computational facilities recommended here are fairly well established. Charges for a transistorized computer operating on more than one shift, together with the accessory equipment, tape, paper and cards is estimated to be approximately $1,116,000 annually.

Library Facility. Experience has shown that the use of literature by research scientists reflects the state of the library facilities available to them as much as, if not more than, it reflects their requirements for literature. A library of a high degree of excellence is universally accepted as a factor of major importance in setting the intellectual tone of a closely knit community of scientists. A strong recommendation for a complete, first-rate library in the atmospheric sciences at the Institute is supported by the fact that, in addition to serving the needs of the Institute staff in accordance with the consensus of the conference participants, it would provide to the community of atmospheric scientists a greatly needed facility which is not generally available in this country.

The general objectives of the Institute require a substantial library with broad coverage in the following fields: general science, including academy publications; mathematics, including statistics, probability theory and logic; physics in all its phases; chemistry, excluding many biological phases; earth sciences, with special attention to the physical and mathematical aspects; astrophysics and astronomy; geodesy, including planetary and space navigation; and the engineering literature related to the basic disciplines. Cross-disciplinary categories, such as abstracts and bibliographies, dictionairies and collected works, will also have to be provided. Extensive coverage of the scientific literature in languages other than English is essential.

A basic science library with back holdings of approximately 300,000 volumes and with a current acquisition rate of about 6,000 books and 2,000 serial titles each year is strongly urged. Approximately eighty per cent of the back holdings will be serial titles and the balance will be books. Approximately eight years will be required to bring the back holdings up to 300,000 volumes, but with a vigorous program of library build-up, and with proper selection, it should be possible to provide a useful library service at the end of two years. It is no small undertaking to set up a first-class scientific library in eight years -- a task which usually extends over several generations -- but with an enthusiastic and adequate staff this objective is realistic. The success of this part of the Institute will depend in no small measure on the selection of the Chief Librarian. A total library staff of about forty-five people will likely be required. (More details on the library are given in Supplement II.)

The cost of acquiring the back-holdings over a period of eight years is estimated at $4,000,000 (250,000 serial volumes at $15 each, and 50,000 books at $5 each) at an annual expenditure rate of approximately $500,000. Current acquisitions will cost $70,000 annually (2,000 periodicals at $15 each and 6,000 books at approximately $6.50 per book). The annual rate of expenditure for books and periodicals will average about $570,000, but only for the first eight years.

Radiation Probing Facility. An essential component of the complex of facilities needed at the Institute is a completely equipped station for probing the atmosphere by techniques which use one or more bands in the spectrum of electromagnetic radiation. The types of probing systems fall into four general classes: (1) microwave radar, (2) sferics, (3) optical radar (pulsed searchlight), and (4) infrared. In each of these classes, further development of equipment will be required to make it most suitable for atmospheric research, but it is considered to be desirable that this development work take place concurrently with the use of the equipment in an integrated research program. For example, advances in scattering theory will help to determine the direction in which the development of radar equipment should proceed. As new knowledge concerning atmospheric processes is acquired, new requirements for probing systems will arise.

The largest single set of equipment involves microwave radar. In Supplement III there are listed a few of the research areas in which this tool can be expected to make substantial contributions. Needed equipment has been broken down into two classes (see Supplement III): basic requirements which are estimated to cost about $1,308,000, and an all-purpose meteorological research radar which would cost in the neighborhood of $3,000,000. Film analysis and test equipment is estimated at slightly more than $100,000.

The use of sferics equipment as a tool for analyzing the electomagnetic radiation emanating from lightning discharges and for locating the source of these electrical phenomena has not received the attention it deserves. To stimulate activity in this area of research and to round out the complement of devices employing electromagnetic radiation techniques, a sferics installation has been proposed at the Institute. Cooperative arrangements with other research centers will have to be worked out since four stations are required for effective utilization of most sferics techniques. The cost of major equipment is estimated to be between $400,000 and $500,000 (see Supplement III).

Optical radar, involving pulsed searchlight techniques to examine the fine structure of the atmosphere, requires equipment which needs to be developed. The cost of engineering studies and building the equipment is estimated to be about $200,000.

To complete the set of facilities required for a complete station, and to meet the equipment needs for a program to investigate the atmospheric heat budget, instrumentation for working in the infrared part of the electromagnetic spectrum is recommended. Major items of equipment are listed in Supplement III. The total cost of these is estimated to be about $1,000,000. This includes a low-pressure absorption tube for studying absorption characteristics of atmospheric constituents in the infrared. Further design and engineering studies are required to establish a satisfactory cost estimate for this piece of equipment.

Shop Facilities. To provide proper support for experimental research and work in instrumentation, it is necessary to plan for both machine and electronics shops of about equal size and a complement of accessory shops capable of handling a variety of materials. From the number of scientists engaged in experimental work and from conventional ratios of scientists to skilled artisans, a shop staff of approximately fifty-four people is envisioned (see Supplement IV, page IV-7 for estimates of the distribution of skills among shop personnel). Investments of $400,000 for acquisition of machine shop equipment, $400,000 for accessory machines and attachments, and $270,000 for acquisition of equipment for working plastics, glass, wood, ceramics, sheet metal and electrical materials are appropriate for a shop complex of this size. Test and analysis equipment and the essential tools for a well-equipped electronics shop is estimated to cost $500,000 at the outset. The cost of specialized electronics equipment has been omitted. The cost of basic stocks for the machine and electronics shops is estimated at about $800,000.

SCIENTIFIC MANPOWER

During the research planning conferences certain recommendations were made for characteristic representations of different disciplines in the Institute staff. It was also recommended that approximately half of the scientists working at the Institute be on a visiting basis, that is, on sabbatical leave from universities, on leave of absence from their regular employment for periods of months or years, or be invited guests of the Institute. This kind of exchange was seen as a fruitful way to add to the variety of talents available at the Institute and to disseminate the influence of the Institute as broadly as possible throughout the scientific community. The inducement offered to these visitors is composed of both the extraordinary facilities provided for research and study and the attraction of a distinguished resident staff.

In terms of the level of activity now regarded as necessary to make a material contribution to the atmospheric research effort and the diversity of talent needed to do so, it appears that approximately 108 research scientists may be required in the Institute. About one-half of these will have had training in the earth sciences. In the remaining half, the three major disciplines of physics, mathematics and chemistry will be represented. This degree of diversity places a relatively light burden on the existing manpower resources in any one discipline. But since the number of pre-eminent men in any field is small the recruitment of first quality scientists must proceed with careful regard for excellence.

Approximately fifty-four scientists, including at least two scientists with marked creative ability from each of the major disciplines, will form the core of the Institute. An equal number of well-qualified visiting scientists will provide a total scientific staff of approximately 108. It is expected that about fifty of this total will be mature scientists. The remainder may be composed of research scientists of associate and some assistant grades so as to provide opportunities for younger post-doctoral and pre-doctoral students of many disciplines to become acquainted with atmospheric problems.

To assist in planning the Institute and to determine its manpower requirements in realistic terms, the numbers of people required with different kinds of talents have been listed in broad categories. It should be recognized in reading through this list that there are wide personal differences in the scientific interests of individuals who quite justly profess to be, for example, physical meteorologists, instrumentation engineers, or applied mathematicians. The list is consequently more schematic than any actual roster. Moreover it should be regarded as suggestive rather than definitive and should <u>not</u> be regarded in any way as placing constraints on the actual selection of individuals. Nevertheless, it reflects a balance of disciplines relating to atmospheric research and provides a minimum but perhaps sufficient number of persons in each discipline to enable them to maintain their disciplinary identity. The technical and supporting manpower requirements have been added in accordance with the experience of existing research laboratories to bring the total complement of the Institute into realistically balanced proportions.

Mathematical Research

Seniors	4	
Theoretical Physicists	4	
Probabilists	2	
Statisticians	5	
Numerical Analysts	2	
Applied Mathematicians	5	
Dynamical Meteorologists	7	
Synoptic Meteorologists	5	
Mathematical Assistants	10	
Secretaries and Clerical	20	
		64

Physical Research

Seniors	4	
Physical Meteorologists	5	
Oceanographers	2	
Experimental Physicists	6	
Instrumentation Engineers	12	
Electronic Engineers	10	
Radar Physicists	5	
Radar Technicians	15	
Radiation Physicists	5	
Solid State Physicists	3	
Physical Assistants	30	
Secretaries and Clerical	20	
		117

Chemical Research

Seniors	2	
Photochemists	4	
Biochemists	2	
Isotope Chemists	5	
Nucleation Chemists	3	
Chemical Meteorologists	3	
Chemical Assistants	12	
Secretaries and Clerical	10	
		41

Computer Facility

Laboratory chief	1	
Supervisory	3	
Programmers	30	
Mathematical assistants	10	
		44

Library Facility

Reference staff	12	
Library services staff	12	
Clerks, secretaries	16	
Warehousemen	2	
Microfilm technician	1	
Bindery technicians	2	
		45

Flight Facility

Flight operations manager	1	
Operations assistant	1	
Flight instrument engineers	16	
Scientific flight crew	17	
		35

Shop Facility

Machinists	20	
Electronic technicians	10	
Optical technicians	2	
Moulding & plastic tech.	2	
Welder	1	
Sheet metal worker	1	
Glass blower	1	
Cabinet maker	1	
Pattern maker	1	
Photo-technicians	3	
Draftsmen	3	
Motor mechanics	2	
Stockkeepers	3	
Utility men	4	
		54

Administration		
Laboratory Operation		
Director	1	
Personnel	3	
Purchasing	3	
Payroll	4	
Accounting	7	
Report reproduction service	12	
Communications (telephone, mail, radio, teletype and facsimile)	8	
Shipping and receiving	3	
Medical	2	
Kitchen staff	9	
Housing	2	
Receptionists	2	
Secretaries and clerical	12	
		68
Physical Plant Operation		
Building Service		
Supervisor	1	
Cleaners and window washers	22	
Watchmen and police	10	
Heating and vent. mechanics	6	
Shipping and receiving	1	
Matrons	2	
Stockman	1	
		43
Utilities Plant		
Chief Engineer	1	
Operating and repair engineers	7	
		8
Tradesmen		
Foreman	1	
Electricians	2	
Plumbers	2	
Pipe fitters	2	
Painters	3	
Carpenters	2	
		12
Grounds, Moving and Truckers		
Gardeners	2	
Groundsmen (licensed drivers)	2	
Laborers (some licensed drivers)	6	
		10
Plant Office		
Superintendent	1	
Draftsman	1	
Secretary and clerical	7	
		9
TOTAL		550

ANALYSIS OF STAFF REQUIREMENTS

	Scientists	Technical and Professional	Support	Total
Mathematical Research	34	10	20	64
Physical Research*	52	45	20	117
Chemical Research	19	12	10	41
Facilities Staff				
Shops	--	45	9	54
Computer	1	33	10	44
Library	1	17	27	45
Flight	--	35	--	35
Administration				
Research	1	8	59	68
Plant Operations	--	1	81	82
Total	108	206	236	550

*Includes Instrumentation Research

SUMMARY OF STAFF BUILD-UP

	Fiscal 1960	Fiscal 1961	Fiscal 1962	Fiscal 1963	Fiscal 1964	Fiscal 1965
Scientists	8	25	45	65	85	108
Technical & Professional	8	30	70	130	200	206
Support People	5	20	40	60	150	236
Total	21	75	155	255	435	550

To answer the basic question of whether or not the availability of scientific manpower imposes serious limitations on the feasibility of establishing the Institute, it is convenient to refer to the Summary of Staff Build-Up on page 72. The staff requirements in each category of personnel are listed there as nearly as they can be estimated for the next six years.

If it is recalled that approximately one-half of the scientists will be drawn from the atmospheric sciences and that about one-half of these will be visiting scientists, it is evident that between twenty-five and thirty permanent staff members trained in the atmospheric sciences will be required by Fiscal Year 1965. The universities offering degrees in meteorology are now graduating about ten men with their doctorates each year. With the Sloan Fellowship program and other measures to stimulate interest in the atmospheric sciences in effect, and with the expansion in activity in the atmospheric sciences at the universities over the next six years, this number should increase. Even if it remained static, there would still be graduated over this period of time about twice as many scientists as would be needed as permanent staff members from the atmospheric sciences at the Institute. Now it is not reasonable, nor would it be desirable, to staff the Institute with young doctoral candidates. The point is that there would be replacements for those who chose to carry on their research at the Institute. It has been estimated that the universities can double their present graduate output without significant additions to their staff and facilities (see First Progress Report of the

University Committee on Atmospheric Research, Appendix E). There is little doubt that the existence of the Institute and the research opportunities it will provide will help to increase graduate enrollment at the universities.

If the scientific manpower requirements can be met in meteorology where the problem is acute, it is hardly being unrealistic to believe that the requirements from other disciplines can be handled without jeopardy to scientific activity in other areas. Physics, mathematics and chemistry would have to provide among them about twenty-five or thirty scientists as permanent staff members over a six year period. This is scarcely likely to upset the manpower requirements in those disciplines. One might ask if our country can do other than invest this much manpower in a problem which is now coming to be recognized as being of some importance. Certainly the availability of many challenging research opportunities will be an attraction to these scientists.

Since the Institute is thought of as partaking of the characteristics of an international center, it is likely that a number of highly competent scientists from other countries can be interested in participating in the research activity. Expressions of personal interest from individuals who meet these qualifications have already been received.

THE INSTITUTE BUILDING

The seventeen planning conferences held during the fall months of 1958 under the auspices of the University Committee for Atmospheric Research have provided a view of the research needs to be met by the Institute. Since this need is composed of many scientific parts and human relationships to be brought to fruition most ideally in one laboratory, it seemed necessary to visualize this laboratory and for practical reasons, to estimate the time and money needed to bring it into existence. Both the specific requests for space and facilities, and the general requirements given during the course of these conferences has been translated into designs consistent with the advice of men experienced in the construction and management of several well known university, government and industrial research laboratories. To this has been added thoughtful concern for the human service that the Institute structure must perform.

The studies have been handicapped by a lack of knowledge of the site and of the actual personnel requirements. This limitation has forced consideration of an expansible structure capable of being erected on any reasonable site and in any climate, as a self-sufficient entity. The choice of a site may permit considerable relaxation of this high degree of self-sufficiency.

To provide flexibility of growth from small beginnings, the building has been conceived in terms of a game of dominos, in which symmetry is deliberately avoided to remove the necessity for matching any necessary expansion with an unnecessary member for architectural balance. Still the concept is far from amorphous.

A concept of the Institute has been considered in which the spaces for contemplative effort are carefully arranged with respect to those for the more overt pursuits. The design also provides for some expansion. (See isometric drawing on next page and floor plans in Supplement IV.)

Studies of existing laboratories have shown that in mathematical and physical research a total of from 8 to 14 people, but most often 10, are required to provide proper support for each innovating scientist. These others include the administrative complement, laboratory assistants, programmers, machinists, electronics technicians, librarians, secretaries, kitchen staff, maintenance men, and so on. A 550-man total staff has been suggested (see pages 69-72) which means that about 50 innovating scientists may lead an Institute staff of some 100 research scientists, together with 200 technical assistants and 200 other supporting personnel.

For effective scientific effort, a minimum of 150 and an optimum area of 200 square feet of space should be available for assignment to each person, and some 300 square feet of active gross area per person be provided in all. The assignable floor space provided for scientific and technical office-laboratories in the Institute totals approximately 104,000 feet in a gross area of 156,000 square feet. This area provides working room for a scientific and technical staff numbering 520, which allows for nearly 33 per cent expansion above immediate needs.

In addition to research space, the Institute is provided with a library, an auditorium seating 550 persons, an adequate cafeteria, seminar and classrooms, space for an electronic computer, special laboratories for research in fluid mechanics, electromagnetic radiation and instrumentation, together with shops, service tunnels and the necessary administrative spaces. These features total some 215,000 square feet. The initial gross area of 371,000 square feet could be made to accommodate twice the initial scientific staff by adding not more than 100,000 square feet of assignable research space in the future.

The research laboratory-offices are arranged on both sides of the main and branching corridors. Laboratory or office space is assignable in modules. Modules measure 9 feet along the corridor with a 16-foot depth to the window wall in the office modules on one side (144-ft^2), and a 27-foot depth in the laboratory modules on the other (243-ft^2). The 9-foot module provides a number of comfortably proportioned shapes and window placements. Offices composed on the 9 x 16 foot module might measure 16 x 18, 16 x 27, and so on. Laboratory or office-laboratory spaces on the 9 x 27 foot module might measure 18 x 27, 27 x 27, 27 x 36, and so on as required, and be subdivided with alcoves if necessary.

It is expected that a number of modules would be assigned to a scientifically coherent group and that subdivision of the space would be made at their own discretion. Partitioning can be of the kind best suited to the needs of the scientific group concerned. However, it is desirable that the coherent blocks of space be delineated by fire stops of semipermanent masonry.

The laboratory roof is to be paved, provided with power outlets, ducts for temporary wires or pipes, and fitted with flush pad eyes at regular intervals so that a variety of equipment can be mounted upon it temporarily. The roof structure is designed to sustain distributed loadings of 100 lb/ft^2, but can be made to carry greater concentrated loads by tieing into the main structural verticals.

Adequate spaces have been provided on an experimental court or bay for the machine and electronics shops together with smaller spaces for auxiliary shops, stock, and assembly rooms, which relate logically to each other and to both the instrumentation and experimental physics laboratory. It is necessary to allow for a 20-man machine shop, an electronics shop of equal size and lesser auxiliary shop services.

Estimates of construction costs have been made by the George A. Fuller Company, the Delbrook Engineering Company, and by the firm of Anderson, Beckwith and Haible, all of Boston, Massachusetts. These estimates are given in terms of New England prices. For the Denver area apply a factor 0.97 and for the Los Angeles area apply a factor 1.05. The estimates are given in accordance with the following assumptions, inclusions and exclusions:

<u>Assumptions made in preparing the building and construction budget</u>

1. Reasonably level site for the building complex.
2. Climate requiring both heating and air-cooling.
3. Average soil bearing for foundations.
4. Overhead sprinklers required over half the building area.
5. Laboratory floors designed to sustain 100#/sq.ft. live loads.

Items included in building budget

1. Site work.

2. Construction of research and utilities buildings.

3. Laboratory services connected to laboratories.

4. Furnishings for office, laboratories and shops.

5. Utilities and emergency services.

6. Escalation expectancy at 3% per year.

7. Apartments and staff housing.

Items excluded from building budget

1. Cost of land.

2. Cost of basic water supply (wells or conduit from project to source of supply).

3. Storm drainage beyond utilities building.

4. Roads and utilities lines beyond limits of developed area shown.

5. Laboratory apparatus and shop equipment.

The total and unit costs of construction for the main laboratory as specified are as follows:

	Total Cost	Unit Cost of Enclosed Space (370,980 ft^2)	Unit Cost of Total Useful Space* (381,380 ft^2)
Laboratory building with basic utilities	$ 7,932,070	$21.38/$ft^2$	$20.80/$ft^2$
Finished laboratory with all designed services, and basic furnishings	$14,676,474	$39.56/$ft^2$	$38.48/$ft^2$

*Useful space includes that portion of the roof specially paved for the installation of experimental equipment.

These estimates are consistent with the unit cost of similar laboratory construction.

On the advice of competent authority it is estimated that one year will be required to provide architectural and engineering specifications for the Institute buildings and that construction can be completed in the ensuring 21 months. Limited occupancy may be possible in the 17th month of the construction period.

SITE CONSIDERATIONS

No single decisive factor dictating the location of the Institute came out of the research planning conferences. However, the scientific program recommended for the Institute suggests several site criteria that are worthy of consideration. There are also a number of human and cultural concerns which should be considered along with the purely scientific objectives. No attempt will be made here to pass definitive judgment on these criteria. They will be mentioned merely as a point of departure for the detailed site selection study which will be required.

The radar facility should be fairly remote from television and microwave communications links which may produce electronic noise to interfere with measurements. The multifrequency high-power radars planned for the Institute are likely to interfere with local communication channels. Maximum utilization of the radar equipment for research purposes would be favored in a region of changeable weather patterns characterized by a large variety of precipitation phenomena. Special problems, such as the studies of thunderstorms, tornadoes, hailstorms, lightning, could conceivably be met by field stations.

The ultra-violet, visible and infrared spectophotometric equipment require stable foundations and a clear sweep of the local horizon. Several kinds of radiation studies can best be conducted in a region of variable cloudiness and large fluctuations in total water vapor content. A site near sea level would permit measurements to be obtained which would complement observations at higher altitudes.

A site free from air pollution was also suggested by scientists concerned with atmospheric electricity and radiation. To be useful as a "bench mark" station (see page 47) the site should remain free of local air pollution and permit access to the upper atmosphere.

To integrate the flight facility into the research effort, it is desirable to have the Institute located within thirty minutes driving time of an airport capable of handling the flight facility. Ideally, this airport should be located in a region of relatively low air traffic density to permit a maximum of local research flying. This airport should also be large enough to handle the jet airplanes of the new Air Force Weather Reconnaissance program to permit maximum cooperation with the military weather services. A more complete discussion of these aspects of the site problem is given on pages 59-61.

In addition to the site criteria arising from the scientific program of the Institute, there are considerations which will be very important to the success of the Institute. These are the human conveniences of accessibility to good transportation (planes, rail), proximity to an intellectual and cultural center (especially to a university active in the physical and earth sciences), the quality of housing, schools and hospitals in the local community and the possibility of finding good transient housing for visiting scientists. The latter is a key factor since the Institute is conceived as a logical extension of the university capabilities in atmospheric science and will involve large numbers of visiting scientists.

Still other considerations include local availability of technical and semiskilled manpower, the cost and availability of suitable tracts of land, adjacency to industrial and mercantile centers and to other scientific activities. The location must also bear a proper relationship to the scientific community which will participate in the program of the Institute.

BUDGET FOR THE INSTITUTE

In order to provide an estimate of the budgetary support that will be required, it has been necessary to project a schedule for the orderly establishment of the Institute. This schedule is given below. It is expected that it will be subject to modification as the Institute takes form. In particular, it will be very important that the acquisition of research facilities should not generate such pressure to obtain people that sacrifice in quality of staff might result.

Schedule for Establishment of the Institute

Fiscal Year 1960	Appoint director. Appoint several key scientists and technical and professional staff members and extend invitations to others. Select site. Develop engineering specifications for Institute building and major facilities. Hire architect and solicit bids for construction of Institute buildings. Begin acquisition of office and research equipment. Begin research activity using rented airplanes and computers in rented quarters.
Fiscal Year 1961	Continue staff appointments, including senior scientific and necessary administrative staff, shop foreman, and building and grounds superintendent. Acquire land, prepare site for construction, begin construction of Institute buildings and major facilities. Purchase and instrument 2 light-twin airplanes. Begin acquisition of library and shop tools. Continue acquisition of office and research equipment. Expand research activity using Institute airplanes and rented computers in rented quarters.
Fiscal Year 1962	Continue staff appointments and intensify research activities Continue building construction, including visiting staff housing. Begin installation of major research facilities.

Equip service departments, continue library acquisitions.
Purchase and instrument 2 heavy-twin airplanes.
Continue acquisition of research equipment.
Arrange for rental of computer for Institute.

Fiscal Year 1963	Continue staff appointments and expand research activity in Institute building. Construction of building completed. Continue acquisition of laboratory and office equipment and library, and continue installation of major research facilities. Acquire and instrument three DC-6 airplanes and two B-57 airplanes.
Fiscal Year 1964	Continue expansion of staff. Installation of major facilities completed. Continue library acquisition program. Full-scale activity in fundamental research begins.
Fiscal Year 1965	Full-scale operations. Continue library acquisition program.

Operating expenses and capital costs presented on the following pages have been obtained from actual experience in similar organizations, scaled to the size of the Institute, from specific estimates (as in the case of the building), or from generally recognized cost figures.

A management allowance for the corporation which will operate the Institute has been included on a graduated scale as compensation for necessary expenses in managing the Institute.

Operating expenses for the Instrumentation Laboratory have been included in the budget for the Physical Laboratory. Funds have been budgeted for research operations in the laboratories to provide for expenses such as rental of light aircraft, field experiments involving meso-meteorological networks, design and acquisition of meteorological instrumentation for satellites, meteorological rockets, high-altitude balloons, and ocean ship time.

Budget Summary - Fiscal Year 1960

	Operating Expenses	Capital Costs
Salaries and Wages (1/2 year)	$ 120,000	
8 scientists		
8 technical and professional		
5 support people		
Staff and employees security program	18,000	
Scientific Operations		
Flight facility		
Aircraft operation		
(occasional rental of light planes)	10,000	
Insurance on flight personnel	1,000	
Computer facility		
Rental on outside machine	40,000	
Laboratory operations		
Acquisition of laboratory equipment		$10,000
Physical laboratory research	30,000	
Mathematical laboratory research	20,000	
Research facility planning	150,000	
Travel and transportation	25,000	
Plant Operations		
Rent	10,000	
Office equipment		5,000
Architectural planning (Inst. Bldg.)	700,000	
Management Allowance (10% of salaries and wages)	12,000	
Total	$1,136,000	$15,000

Budget Summary - Fiscal Year 1961

	Operating Expenses	Capital Costs
Salaries and Wages	$ 640,000	
25 scientists		
30 technical and professional		
20 support people		
Workmen's compensation and liability	5,000	
Staff and employees security program	96,000	
Scientific Operations		
Flight facility		
Acquisition of aircraft (2 instrumented Cessna 310's)		$ 220,000
Aircraft operation	130,000	
Insurance on flight personnel	1,000	
Insurance on aircraft	30,000	
Liability insurance	3,000	
Rental of space at airport	1,000	
Per diem for flight personnel	10,000	
Computer facility		
Rental on outside machine	350,000	
Library facility		
Acquisition of back volumes		500,000
Shop facilities		
Acquisition of equipment		50,000
Laboratory operations		
Acquisition of microwave radar gear		560,000
Physical laboratory research	120,000	
Mathematical laboratory research	40,000	
Chemical laboratory research	40,000	
Research facility planning	200,000	
Travel and transportation	40,000	
Plant Operations		
Rent	45,000	
Office equipment		15,000
Architectural planning (Inst. Bldg.)	470,000	
Architectural planning (Housing for visiting staff)	78,000	
Land acquisition		250,000
Road construction		100,000
Institute Building construction costs		12,400,000
Electric power lines to Institute		20,000
Sewer and water to Institute property		125,000
Management Allowance (8% of salaries and wages)	51,000	
Total	$2,350,000	$14,240,000

Budget Summary - Fiscal Year 1962

	Operating Expenses	Capital Costs
Salaries and Wages	$1,300,000	
45 scientists		
70 technical and professional		
40 support people		
Workmen's compensation and liability	10,000	
Staff and employees security program	195,000	
Scientific Operations		
Flight facility		
Acquisition of aircraft (2 instrumented Convairs)		$1,600,000
Aircraft operation	510,000	
Insurance on flight personnel	2,000	
Insurance on aircraft	150,000	
Liability insurance	5,000	
Rental of space at airport	3,000	
Per diem for flight personnel	25,000	
Computer facility		
Rental on outside machine	500,000	
Library facility		
Acquisition of back volumes		500,000
Acquisition of current material	25,000	
Shop facility		
Acquisition of major machine shop equipment		400,000
Acquisition of electronics shop equipment		500,000
Laboratory operations		
Acquisition of laboratory equipment		200,000
Acquisition of microwave radar		852,000
Physical laboratory research	240,000	
Mathematical laboratory research	80,000	
Chemical laboratory research	80,000	
Travel and transportation	75,000	
Plant Operations		
Rent	93,000	
Office equipment		20,000
Preparation of property for use	50,000	100,000
Institute building costs		2,276,000
Construction of housing for visiting staff (10 year-round and 10 summer family units, 100 person residence hall)		973,000
Management Allowance (5% of salaries and wages)	65,000	
Total	$3,408,000	$7,421,000

Budget Summary - Fiscal Year 1963

	Operating Expenses	Capital Costs
Salaries and Wages	$2,120,000	
65 scientists		
130 technical and professional		
60 support people		
Workmen's compensation and liability	16,000	
Staff and employees security program	318,000	
Scientific Operations		
Flight facility		
Acquisition of aircraft (3 DC-6's and 2 B-57's, instrumented)		$2,500,000
Aircraft operation	1,345,000	
Insurance on flight personnel	3,000	
Insurance on aircraft	150,000	
Liability insurance	7,000	
Rental of space at airport	5,000	
Per diem for flight personnel	25,000	
Airport landing fees	5,000	
Computer facility		
Operation of computer	1,116,000	
Library facility		
Acquisition of back volumes		500,000
Acquisition of current material	70,000	
Shop facility		
Acquisition of auxiliary machine tools		350,000
Acquisition of inventory stock		350,000
Acquisition of equipment for pattern making, plastics, sheet metal, welding, glass, ceramics, and electrical shop		220,000
Laboratory operations		
Acquisition of microwave radar		1,500,000
Acquisition of sferics equipment		500,000
Acquisition of spectrographic equipment		1,000,000
Acquisition of optical radar		100,000
Acquisition of instrumented tower 100 meters high		250,000
Acquisition of general laboratory equipment		260,000
Physical laboratory research	300,000	
Mathematical laboratory research	100,000	
Chemical laboratory research	100,000	
Travel and transportation	115,000	
Plant Operations		
Administrative & building service equipment		247,000
Furnishing for staff housing		150,000
Management Allowance (4% of salaries and wages)	85,000	
Total	$6,380,000	$7,927,000

Budget Summary - Fiscal Year 1964

	Operating Expenses	Capital Costs
Salaries and Wages	$ 3,370,000	
85 scientists		
200 technical and professional		
150 support people		
Workmen's compensation and liability	25,000	
Staff and employees security program	505,000	
Scientific Operations		
Flight facility		
Aircraft operation	4,355,000	
Insurance for flight personnel	8,000	
Insurance on aircraft	150,000	
Liability insurance	10,000	
Rental of space at airport	6,000	
Per diem for flight personnel	79,000	
Airport landing fees	32,000	
Computer facility		
Operation of computer	1,116,000	
Library facility		
Acquisition of back volumes		$ 500,000
Acquisition of current material	70,000	
Shop facility		
Acquisition of machine and electronics shop inventory		450,000
Repair and replacement in electronics shop	50,000	
Repair and replacement in machine shop	30,000	
Laboratory operations		
Acquisition of microwave radar		1,500,000
Acquisition of laboratory equipment		200,000
Physical laboratory research	500,000	
Mathematical laboratory research	200,000	
Chemical laboratory research	200,000	
Travel and transportation	165,000	
Plant Operations	500,000	
Management Allowance (3% of salaries and wages)	101,000	
Total	$11,472,000	$2,650,000

Budget Summary - Fiscal Year 1965

	Operating Expenses	Capital Costs
Salaries and Wages	$ 4,124,000	
108 scientists		
206 technical and professional		
236 support people		
Workmen's compensation and liability	30,000	
Staff and employees security program	619,000	
Scientific Operations		
Flight facility		
Aircraft operation	4,355,000	
Insurance for flight personnel	10,000	
Insurance on aircraft	150,000	
Liability insurance	10,000	
Rental of space at airport	6,000	
Per diem for flight personnel	79,000	
Airport landing fees	32,000	
Computer facility		
Operation of computer	1,116,000	
Library facility		
Acquisition of back volumes		$ 500,000
Acquisition of current material	70,000	
Shop facility		
Repair, replacement and inventory for machine shop	125,000	
Repair, replacement and inventory for electronic shop	200,000	
Laboratory operations		
Spectroscopy laboratory	20,000	
Chemical, physical and mathematical laboratory research	1,500,000	500,000
Travel and transportation	200,000	
Plant Operations	547,000	
Management Allowance (2½% of salaries and wages)	103,000	
Total	$13,296,000	$1,000,000

Budget Summary - Fiscal Years 1960-1965

Fiscal Year	Staff	Expenditures Operating	Expenditures Capital
1960	8 Scientists 8 Technical & Professional 5 Support people 21	$ 1,136,000	$ 15,000
1961	25 Scientists 30 Technical & Professional 20 Support people 75	2,350,000	14,240,000
1962	45 Scientists 70 Technical & Professional 40 Support people 155	3,408,000	7,421,000
1963	65 Scientists 130 Technical & Professional 60 Support people 255	6,380,000	7,927,000
1964	85 Scientists 200 Technical & Professional 150 Support people 435	11,472,000	2,650,000
1965	108 Scientists 206 Technical & Professional 236 Support people 550	13,296,000	1,000,000
	Total	$38,042,000	$33,253,000

SUPPLEMENT I

FLIGHT FACILITY FOR THE NATIONAL INSTITUTE FOR ATMOSPHERIC RESEARCH

General Statement

A requirement for a flight facility at the National Institute for Atmospheric Research stems primarily from a need for airborne platforms suitable for (1) carrying out scientific measurements of atmospheric variables, and (2) conducting experiments aimed at furthering our understanding of the atmosphere. The kind of flight facility required is determined largely by the kinds of research problems which have to be solved and the relative priority placed upon them. Therefore, this discussion of NIAR flight facilities logically begins with a summary of the scientific problems which require such facilities for their solution.

This summary was compiled on the basis of discussions during the seventeen conferences devoted to a consideration of the Institute. There was a remarkable agreement among the conference members that a facility available for the sole purpose of providing flight support to basic research in the atmosphere is absolutely essential. It is imperative that this facility be under the complete control of the scientists, and that it be capable of making measurements and carrying out experiments whenever, wherever, and in whatever manner needed to solve a particular problem. These points are probably generally accepted. The problems arise when one tries to devise a workable arrangement for providing the research scientist with the flight support which is so essential to his work. On the basis of months of study of the needs of the scientists, of the possibility that these needs can be met through existing government agencies, of the way in which other countries have organized for scientific research, and on the basis of a critical review of our present research capability in the United States, there is a clear consensus that a flight facility within the framework of the proposed National Institute represents the best way yet proposed for bolstering this aspect of basic research in the atmosphere.

Areas of Atmospheric Research Requiring Special Flight Facilities

Cloud Physics and Radar. Cloud Physics studies involving airplanes tend to be of limited geographical extent and to involve a limited number of highly specialized measurements. Examples from this area might be the microphysics of cloud and precipitation particles, studies of atmospheric nuclei, weather modification studies, studies of the energetics of clouds, and special studies of various atmospheric physical parameters such as refractive index. These problems require a variety of airplane capabilities, although most of the work can be done with light to heavy twin engine planes, perhaps assisted occasionally with light flivver planes.

Radiation Studies. The principal need for flight support in the radiation area is to permit simultaneous measurements of the albedo of clouds and the microphysical parameters characterizing the clouds. Also needed are measurements of various radiation parameters as a function of altitude, type of terrain, synoptic situation, etc. Airplanes satisfying these requirements range from a heavy twin to a large multi-engine cargo plane. For high resolution spectral studies a pure jet is required to minimize the problems of vibrations affecting the very sensitive measuring equipments.

Severe Storms. The severe storms problem presents flight requirements which are difficult to meet with any simple combination of airplanes. The cloud physics part of severe storm research, that is, the investigation of the internal structure of severe storm clouds and the relationship of these clouds to their environment, can be studied with groups of twin engine planes. Since severe storms characteristically reach to great heights, jet airplanes such as the B-57 or B-47 would be required for sampling the upper reaches of the storm clouds. Turbulence parameters inside of the severe thunderstorms and squall lines can best be studied by rugged fighter type military planes. Existing techniques for deducing turbulence parameters from the response of an airplane flying through the turbulence are best applied to airplanes of very rigid wing construction. Such airplanes would be of limited usefulness in other kinds of atmospheric studies.

Studies of the General Circulation. The basic problem of the general circulation of the atmosphere is to develop an understanding of the motions of the atmosphere. One of the fundamental difficulties in this area at the present time is a lack of observational detail from vast areas of the globe. It is to be anticipated that additional data will be available from standard observing networks, augmented by the increased weather reconnaissance efforts of the air weather service within the next several years. However, the operationally motivated weather reconnaissance systems can never hope to cover the entire globe, and such airplanes cannot be made available for detailed study of specific parts of the atmospheric circulation pattern which may be of particular importance to the scientist. For this reason, the Institute must have a flight facility capable of such studies. The minimum facility for these studies would be a group similar to that which has been used most successfully in recent years by the U.S. Weather Bureau in the Hurricane Research Project. Airplanes meeting these general requirements are DC-6's and DC-7's for low and intermediate altitudes, and B-47's and B-57's for obtaining data above 30,000 feet.

Ozone. Principal needs of the ozone scientists are for complete vertical soundings of the ozone distribution from 15,000 to 100,000 feet. No operational airplane completely fulfills this altitude range, but it is anticipated that the planes to be used in the Air Force Weather Reconnaissance System, AN/AMQ-15, will be equipped for such measurements. Highly specialized airplanes required for this research will inevitably have to be borrowed from the military services. A substantial part of the ozone problem can be solved by flying high-resolution spectrographic equipment at medium altitudes -- above the majority of the water vapor in the atmosphere. For this purpose a pure jet flying at 30,000 to 50,000 feet would appear to be ideal. The B-57 apparently meets these requirements.

Atmospheric Chemistry. The flight facility requirement in atmospheric chemistry stems from the necessity for making measurements of atmospheric particulates and gases at various points in space and time. Measurements include particulates such as natural atmospheric dusts, sea salt particles, industrial smokes, and artificially induced radioactive materials. Gaseous constituents of particular interest are carbon-dioxide, sulfurous compounds, various hydrocarbon wastes from industrial activities and automotive exhaust, ozone, water vapor and other trace elements. The airplanes meeting these requirements range from light twins for low level work to pure jets and rocket planes for high level measurements. A B-57 type plane would be particularly useful to this program, inasmuch as it would permit collection above and below the tropopause, thus enabling scientists to tackle the question of stratospheric holdup of bomb debris and to study the circulation of air through the tropopause.

Atmospheric Electricity. Problems in atmospheric electricity range from detailed studies of lightning and charge generation within individual thunderstorms to large scale studies of the earth's surface-ionospheric electrical system. In view of the wide range of scale of problems involved, no single airplane is suitable for making these measurements. Detailed studies of individual clouds and the electrification process associated therewith require twin engine airplanes ranging in size up to a Convair. Detailed motion studies and turbulence studies within such clouds require rigid-wing military airplanes of the fighter type for the reasons mentioned in the discussion of severe storms given above. General studies of thunderstorm conditions over a large area require larger airplanes -- such as the DC-6 and DC-7. Since tops of thunderstorms reach heights of 60,000 and 70,000 feet, the uppermost regions are above the altitude capability of even the best jet planes available today. However, scientists should have the best available airplanes for making studies in the upper reaches of these clouds. Since the atmospheric electricity problem is a global one, studies in this area should be coordinated with the projected new Weather Reconnaissance System, AN/AMQ-15.

Convection and Turbulence. Convection is defined as vertical motion in the atmosphere, whereas random-like chaotic motions are known as turbulence. Convection and turbulence regimes range in scale from the size of the smallest clouds and dust devils over the heated desert terrain to large scale but very slow vertical motions associated with cyclonic activity in the weather system. Turbulence is characteristic of all altitudes from the surface of the earth through the greatest heights thus far explored. For these reasons a wide range of airplane facilities is required. Twin engine airplanes are suitable for making measurements in individual convective clouds, and in systems of such clouds. The small-scale vertical motions associated with large-scale weather systems can best be measured by the sensitive wind equipment installed on DC-6 or DC-7 type airplanes. Rigid-wing military fighter-type airplanes are required for making measurements of turbulence, and clear air turbulence in the upper atmosphere must be explored with jet type airplanes reaching to the limit of available airplane capabilities. These studies must also be integrated into the AN/AMQ-15 program when that program becomes a reality.

Tropical Meteorology. The problems of tropical meteorology are characterized by the necessity for long-range flights over ocean regions. Typical of problems in this area is that of the hurricane, easterly waves, the turbulent weather motion systems in the upper regions over low latitudes, and the intertropical convergence zone. Such studies will require airplanes capable of long sustained flights over water. For studies in the low and middle levels in the tropics, DC-6 and DC-7 type airplanes are very suitable. Upper level regions of necessity involve jet airplanes of the B-47 and B-57 type. Studies of individual clouds, studies of the interaction between sea and air, the effect of sea surface temperature anomalies upon cloud distributions, etc., can be studied with light twins, as well as DC-6 and DC-7 type airplanes. Many of the local problems, such as the development of clouds over islands, and the role of such clouds in the energy budgets of the tropical regions can be studied with rather small planes. In view of the wide-scale nature of the problems of the tropical regions, it is inevitable that studies in these regions must be integrated into the general AN/AMQ-15 program.

Kind of Flight Facility Needed

Many of the problems demand a multiplane capability of long range and high performance. From these planes the scientists will make measurements of more or less conventional kinds simultaneously at several levels and over long flight paths. The details of the individual flight paths will be indicated by the various research problems, but in general they will be planned to obtain data detailed in space and in time to supplement those obtained from the operational networks. The data obtained from these planes per hour of flight will consist of tens of thousands of data points which must be reduced, analyzed and synthesized in order to abstract from them an understanding of the basic atmospheric processes.

It is totally beyond the capability of existing meteorological research institutions to provide these high altitude long range airplanes, and the high output rate of data from such planes in turn require data handling facilities, data processers and computers, which likewise are beyond the capability of existing university establishments.

Many of the problems of cloud physics, severe storms, cloud seeding, atmospheric electricity, air pollution, etc., can best be tackled with relatively small planes with limited but highly specialized instrumentation.

Theoretically, these airplanes are within the capability of existing meteorological laboratories; however, experience has repeatedly shown that the financial support for such research has not permitted the instrumentation and retention of suitable airplanes for long periods of time. The specialized equipment required for detailed measurements of individual cloud particles within clouds, of the very localized regions of severe winds and hail, etc., in severe storms are frequently too complex to permit installing them or transferring them to another airplane, as has been the custom in the past. In order to get on with the problems of research in the atmosphere, it is essential that medium performance planes, instrumented for atmospheric measurements, be available on a continuing basis to atmospheric scientists. It is proposed to locate such planes at the National Institute. The scientists at the university laboratories will be able to carry out their field experiments through the device of becoming a visiting scientist at the Institute for a specified period of time, after which they may return to their respective universities where interpretation of the data will be carried out.

Kinds and Numbers of Planes Required. From a consideration of the kinds of problems to be solved, and from a realization that the effective number of planes available will always be less than the total number on hand because of mechanical outages, an estimate of the minimum useful flight facility has been made. This estimate is in terms of planes available in 1958. It is quite likely that the actual complement of planes at the National Institute will differ somewhat from this list.

The proposed minimum flight facility for the National Institute of Atmospheric Research is as follows:

2 - Cessna 310 or Beech 18 (or equivalent)
2 - Convairs
3 - DC-6's
2 - B-57's

It is not considered wise for the National Institute to include single engine light planes in its flight facility. Although there are many ways in which these planes can be useful in atmospheric research, they suffer four serious drawbacks, viz., they are largely restricted to daytime operation, they are not particularly useful in instrument flight conditions, they are restricted from over-water flying, and in addition, they have very little, if any, power available for scientific instrumentation. In addition, the problems for which they are useful tend to be very local and require a minimum of instrumentation and personnel, which means that these planes are readily available to existing university laboratories on a rental basis. Similarly, any need for these planes at the National Institute can best be met through local rental.

Several of the problems outlined earlier are beyond the capability of the proposed flight facility of the Institute. This is unavoidable. The vastness of the atmosphere inevitably means that there will always be some problems which will tax the capabilities of planes of most advanced design. Whenever the Institute becomes engaged in such research it will be necessary to work out some arrangement with the military agency best able to furnish the required support. However, the vast majority of the present problems of the atmosphere will be accessible to the scientists with the numbers and kinds of airplanes listed above.

The flight capability proposed for the Institute makes no provision whatsoever for routine, operational weather reconnaissance. Such activities are considered to be the responsibility of the United States Weather Bureau and the Department of Defense agencies. The National Institute for Atmospheric Research should be devoted to basic research without responsibility of operational problems.

Airplane Instrumentation. The airplanes of the Institute will be permanently equipped for making certain basic measurements which experience has shown to be necessary for almost all kinds of atmospheric research. In addition, the power supply and recorder systems must be large and flexible enough to accommodate additional instruments needed for certain special studies. For maximum value the entire system from sensors, through amplifiers and recorders, to the data handling devices and high-speed computers must be integrated into a single compatible system. Details of this system cannot be specified at this date, since it is closely tied up with final selection of a high speed computer for the Institute, and to a lesser extent to the final selections of airplane types. There is no question, however, but that suitable systems can be developed. This is an area in which there is a large measure of skill in this country -- several very fine flying laboratories have been created and destroyed in our "hit and run" research activities in the past.

Although details of the airplane system must await engineering studies, it is desirable to list the variables of the atmosphere which must be measured in order to deal with the atmospheric problem. The following list represents those of such general importance as to warrant measurement on almost all research flights:

Basic Atmospheric Variables Measured on All Flights	Possible Methods of Measurement
Wind direction and speed	Doppler radar (e.g., ANP/81)
Air temperature	Thermocouples or thermistors suitably housed to measure total temperature and to eliminate effects of cloud water.
Atmospheric pressure	Differential pressure devices
Height above surface	Radio-radar-altimeter
Water vapor content	Dew-point (frost-point) hygrometer or infrared absorption devices
"D" value (departure of pressure height from standard)	Radar altimeter coupled to differential pressure device (APR-5 Canadian Applied Research Laboratory)
Cloud water content	Hot wire
Radar cloud coverage	AN/APS - 20E or equivalent

In addition, there are many variables which will be measured only on certain research flights. Some of these variables require instruments of such size and complexity as to require permanent installation. Others can be handled by equipment installed and removed as the research requires. Most of the measurements for cloud physics, atmospheric chemistry and severe storms research fall into the later categories. A list representative of these variables is given on the following page.

Special Atmospheric Variables Measured on Certain Flights	Possible Methods of Measurement
Precipitation water content	Conductometric water meter
Cloud droplet spectra	Continuous droplet sampler
Precipitation spectra	Foil samplers
Air turbulence and strong vertical motions	Integrated vertical accelerations, corrected for response characteristics of airplane (methods developed by NACA would not be installed on light twins)
Radar cloud structure	3 cm, narrow-beam, moderate power, height-finding radar.
Atmospheric electricity	Field mills sensing in three dimensions
Condensation nuclei	Light scattering in closed cells (methods of Rich, Gen. Elec.)
Atmospheric particulates	Impactors, filters, etc.
Ice nuclei	Cold box counters
Land-sea surface temperatures	Infrared bolometers
Cloud and surface albedo, visibility and sky brightness	Various kinds of spectrophotometric devices

In order to use the measurements of these variables it will be essential to measure and record certain reference data including latitude and longitude, airplane heading, airspeed, altitude, airplane attitude, etc. A beacon transponder (APX-6 or equivalent) is desirable to permit following the planes with ground based radars. The navigation and instrument flight equipment of these planes must be second to none. To be useful in solving the problems of the atmosphere, these planes must be capable of carrying the scientists through the worst of weather conditions. The problems of bad weather present first magnitude scientific problems and to the man-on-the-street represent the essence of all meteorological problems.

From time to time still other scientific equipment will have to be mounted on the Institute airplanes. It is inevitable that this list must include nuclei-generating equipment for cloud studies, chaff dispensing equipment for wind studies, special cameras for stereographic studies, and facilities for releasing special devices such as dropsondes and hurricane beacons. The initial installation of equipment must be sufficiently flexible to permit these additions as the need arises.

A crucial part of the airplane instrumentation system is the method chosen for data recording. Magnetic tape provides the only acceptable means for recording and storing within the planes the large amount of data that will be collected on some studies. Data on magnetic tape is readily fed into ground computer equipment. The number of items to be sensed is often sufficient to require simultaneous recording on more than one tape. This is not a disadvantage, since it will permit separating the basic variables of the structure of the atmosphere from the special variables measured only on certain flights. For most studies the sampling rates required in the two classes of data are totally different. For studies of the structure of the atmosphere a sample every few miles is entirely adequate, but in cloud physics studies a space resolution of a few feet is required. In addition to the recording equipment it will also be necessary to install equipment permitting direct reading of selected portions of the data. Only in this way can the scientists follow the progress of an individual flight and plan the subsequent flight.

Proposed Source of NIAR Planes and Methods of Operation and Maintenance

There are several alternative ways whereby the National Institute for Atmospheric Research might obtain flight support for research in the atmosphere. Inasmuch as airplanes are expensive, both in initial procurement and in operation and maintenance, the question of the exact nature of the Institute's flight facility has been given a great deal of careful study. Data concerning the availability and suitability of airplanes of various types, and the costs of operating these airplanes were obtained from a series of conferences and questionnaires addressed to scientists and administrators, both in government and in private industry, who have had broad experience in carrying out research programs involving airplanes.

In general, there is unanimous opinion concerning the nature of the facilities at the proposed Institute. It was agreed that most of the research could best be carried out with airplanes available from non-military sources and that there were overwhelming advantages in having them operated and maintained by non-military groups. Obviously some problems, such as those involving great heights, require airplanes of such highly specialized performance as to be available only from military sources. Any research in these areas carried out at the Institute will have to represent a joint effort between scientists and the military establishment.

Where is the dividing line between planes obtained from military and non-military sources? As discussed above, the needs of the Institute for flight facilities center around six specific kinds of planes. A single engine light plane finds frequent use in studies of a very localized nature. Light twin engine airplanes, such as a Cessna 310 or equivalent, and heavy twins such as the Convairs are needed for many local and regional studies. Four engine cargo-type airplanes are needed for long range scientific missions throughout the greater part of the troposphere. A DC-6 apparently meets these requirements quite adequately. A high altitude long range capability is required for exploring the upper troposphere and the lower stratosphere. The military B-47 and B-57 bombers apparently are the only airplanes presently available which meet these requirements. Lastly, a small heavily stressed fighter type plane is needed for studying the severely turbulent parts of thunderstorms, squall-lines and other related severe weather.

The first four of the above types are readily available from commercial sources, and on the basis of evidence assembled during the planning phases of the Institute, it is recommended that these needs at the Institute be met through non-military channels. The single engine light plane is readily available. However, because of its small size, the limited electrical power available, the limited load-carrying capacity, and the fact that they are restricted to daylight and CFR flying inevitably means that the needs of the Institute for them will be nominal. It is proposed that such needs be met through local rental of airplane time. It is recommended that the Institute purchase outright two light twins (as Cessna 310) and two heavy twins (as Convairs) to meet the needs for low and medium level, local and regional studies. These should be ready for full scale research by Fiscal Year 1961 and Fiscal Year 1962 respectively.

It is the advice of those with whom the study group have counselled that airplanes of the size of the DC-6 probably should not be purchased outright by the Institute. These are available on a lease basis from private sources, but the possibility of bailment from the Air Force should be explored. It is estimated that Fiscal Year 1964 represents a reasonable estimate of the time when personnel at the Institute will be ready to operate three DC-6's on a full-time basis.

The high altitude long range research airplanes cannot conveniently be obtained from non-military channels. The only available airplanes today meeting the altitude requirement are the Air Force

B-47's and B-57's. It is proposed that the Institute obtain two B-57's on bailment from the military. These airplanes are to be operated and maintained by the Institute.

The measurements of turbulence in heavy thunderstorms and severe weather which require a fighter type rigid-wing airplane will not represent a continuing research effort at the Institute, and it is recommended that such airplanes be obtained on a bailment basis, or on a cooperative arrangement with the Air Force at such time as research in this area gets under way. It is envisaged that this kind of research will be accomplished in a relatively short period of time, and it is not considered advisable to have such airplanes in the permanent flight facility for the Institute.

It is the unanimous opinion of experts who have been called upon during the planning phases for the Institute that the operation and maintenance of the airplanes should be handled on a contract basis with a commercial concern skilled in such operations. Several commercial airlines and private pilots have indicated an interest in such arrangements. It is not considered advisable for the Institute to attempt to maintain the personnel and facilities required for routine operation and maintenance of these airplanes. Contract services for operation and maintenance are envisaged in the budget figures presented in this report.

A summary of personnel, aircraft, and expenditures required for this program and a schedule of build-up is given on the following page.

Budget and Phasing of Flight Facility

Fiscal Year	1960	1961	1962	1963	1964	1965
Staff-hiring	Flight facility manager and assistant	2 Instrument men & 2 Flight scientists	4 Instrument men & 4 Flight scientists	5 Instrument men & 2 Flight scientists	5 Instrument men & 9 Flight scientists	
Aircraft						
Light twin		Purchase and Instrument 2 each	----------------Full Scale Research Operations----------------			
Heavy twin			Purchase and Instrument 2 each	----------Full Scale Research Operations---------		
DC-6				Acquire & Instrument 3 each	--Full Scale Research Operations--	
B-57				Acquire & Instrument 2 each	--Full Scale Research Operations--	
Expenditures (Thousands of Dollars)*						
Capital						
Plane purchase		$200	$ 800			
Scientific instrumentation		20	800	$2,500 Instrumentation of DC-6's & B-57's		
Operations**						
310 type		130	260	260	$ 260	$ 260
Convair type			250	585	585	585
DC-6's (including lease costs)				500	2,470	2,470
B-57's					1,040	1,040
Total		$350	$2,110	$3,845	$ 4,355	$ 4,355
Cumulative total		$350	$2,460	$6,305	$10,660	$15,015

*Based on 1958 figures.
**Costs based on 750 hours of operation per plane per year. Includes 30% above basic 1958 costs for operations from a single base to allow for operations away from principal base. Maintenance expenses are included.

SUPPLEMENT II

LIBRARY SUPPLEMENT

by

Ole V. Groos

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Precis

The library is considered as a basic science library, with back holdings of about 300,000 volumes, and an annual addition of 2,000 periodicals and 6,000 newly-published books. A staff of about 45 people will be required.

Total budget for acquisitions during the first 6 years will be about $2,735,000. Of this, $2,500,000 ($500,000 for 5 years) will be for back volumes and $235,000 ($25,000 for the third year and $70,000 for the fourth through the sixth year) will be for annual new volumes. Acquisition expenses for current material will stabilize at $70,000 per year, but a capital investment of $500,000 per year for three additional years after Fiscal Year 1965 would be required to complete the library.

Scope and Cost of Collections

Experience has shown that the research scientist's use of literature reflects the state of the library facilities available to them, as much as, if not more than, it reflects their requirements for literature. They use what is available and at hand, whether they are looking for specific references or have items called to their attention. This also applies to the "non-readers" who, in communication with their colleagues, receive information derived from the library's holdings. A library is therefore essential to a research staff whose mission is to make new advances rather than to repeat what has been achieved earlier elsewhere.

The determining condition for the scope of the library's holdings is taken as the mission assigned the Institute. The mission is to provide a center where meteorologists and specialists in the basic disciplines of mathematics, physics and chemistry can apply themselves to the problems of the atmosphere. The Institute will also have the function of providing common national facilities, including a library, which no participating university could afford to support alone.

In necessarily general terms, such an Institute would require a substantial library with broad coverage in each of the following fields:

general science (including academy publications), mathematics (including statistics and logic), astronomy (emphasizing astrophysics), geodesy (including planetary and space navigation), physics (in all its phases), chemistry (excluding most biological phases), earth sciences (with special emphasis on mathematical and physical aspects), and the engineering literature backing these disciplines. An analysis of the frequency with which over five hundred serial publications were quoted in the Compendium of Meteorology, and a review of titles held in whole or in part by the Air Force Cambridge Research Center, provided an estimate of the overall size of the library that would be required. Cross-disciplinary categories, such as abstracts and bibliographies, dictionaries, collected works, will also have to be provided.

About 80 per cent of such a collection will be in the form of periodicals or other serials. This fact determines the general cost, and also makes it possible to build the collection up in a relatively short time, due to the fact that a single serial title may include a hundred or more volumes covering decades of publication. The value of the serial holdings of a research library rests on the completeness of each title. There will be many cases, however, in which a complete set cannot be found on the international market, even where the library is in a most-favored category with the major dealers. The policy of the Institute library, in such cases, should be to have the dealers supply the missing parts in microfilm, and then to have this reproduced by Xerox Copyflow, or similar method, and then bound. The average volume cost can be set at approximately $15, and the total number of serial volumes in the projected collection at 250,000.

Backing the core serials will be a monograph collection which can be set at approximately 50,000 volumes. The unit cost should not exceed $5, although current volumes will be closer to $10 each. Easiest to procure will be those titles still in print. Hardest to procure will be out-of-print foreign items. The best initial attack on the latter problem will be to buy whole subject collections, or whole libraries, where the average cost may be as low as $2 per item. Preferred customers may be given the right to return and exchange up to 40 per cent of the items in a lot purchase, although this is not likely to be the case in the early part of the build-up. Out-of-print domestic items should probably be procured through the University Microfilm Copyflow service, if not picked up in earlier lots, at a page cost of approximately four to five cents per page.

The material discussed to this point may be considered as the backlog remaining to be purchased on the day the library is established, as opposed to items published and purchased during any "current" year. The estimated cost of this backlog is $4,000,000 of which some $500,000 is the minimum required for the first year's purchasing program. This minimum figure is necessitated by the absolute need for a library embarking upon this scale program to have a "most-favored" rating with the major international bookdealers. Without such a competitive rating, many required titles will remain unavailable. In addition to the $500,000 which will be the maximum annual backlog budget from the second year on, some $200,000 should be made available over a period of several years as a special fund to cover any unusual opportunities that might occur to buy very large blocks or libraries. This is of great importance during the first three years of the library's existence, when the contents of such blocks are not likely to have many duplicates in the library's holdings, but it remains a desirable feature over all eight years.

The other component of the acquisitions budget would concern current publications. About 2,000 periodical subscriptions, which will approach $30,000 per year (including laboratory clipping copies), will very much figure in the initial year's operation, and remain fairly stable throughout the later years; but current monographs, which will eventually reach an annual cost of some $40,000, will in the first year remain hidden in the monograph backlog, and only in the second year will it really appear as an added component. Two additional facts should be taken into account: (1) technical reports do not appear here because their costs really involve staffing and equipment only, and (2) once the Institute begins a publication program, the product should be made available to the library for purposes of exchange with other institutions. This last fact will not materially affect subscription costs, as many series available through exchange are not available through commercial subscriptions. In general, the basic build-up will require 8 years; but by proper selection policy the library should be in a position to start giving reasonably good service by its second year.

The above figures cannot be taken as very exact for any one year, since the international book market is always in a state of flux. However, over the first 8 years the total should average close to these annual levels. In addition, it should be remembered that these figures are based on the 1958 dollar. If these figures appear to be large, it should be remembered that scientific serial sets, unlike some other pieces of scientific equipment, increase in value with each passing year. A library of some 2,000 volumes of radiological journals from all corners of the world, each complete when purchased as lot in 1950 for $23,000, was bid for at $57,000 in 1957.

Functions and Staffing Required for Such a Library

The first step in planning the staff of such a library will be to select and obtain the Chief Librarian. The soundest basis for attracting the right person is to establish firm agreement and understanding on the working policy for the library between the Director of the Institute (to whom the Librarian must be directly responsible) and the Librarian. Continuance of the Chief Librarian in this position will then depend upon the results produced by the Librarian and upon the support the Director provides for the stated needs of the Librarian.

Creating this library will be an intensive and rigorous task, since it means setting up a truly great scientific library over a period of some eight years, as opposed to the usual build-up period of three to four generations. This means not only a speeded-up acquisition operation, but also preparation and cataloging in eight years what is normally cataloged over several generations of catalogers. It will tax to the utmost the library staff (the chief and his chief of services and chief of reference will, in effect, be on 24 hour duty during the first years) as well as the resourcefulness of a considerable number of very competent bookdealers. The Librarian must therefore be given free rein to assemble a really first-rate staff, first-rate not only in knowledge and skills, but also in enthusiasm (verging on dedicated fanaticism), in energy, and in ability to subordinate itself to the overall requirements of the Institute. He should also have the right to select, to reject and to reassign personnel to the various positions on the library staff.

The staff will consist of two functional groups (many groupings are possible, but the one chosen will work quite well in the circumstances under consideration): reference services and technical services. The two groups are naturally interdependent and there will be some amount of cross-training in order to make individuals aware of the effect of their operations on the other group and thus do a more intelligent job. Cross-training will also result from shifting individuals from one group to the other to meet shifting work loads. The work load will probably be heaviest on the technical services during the first two years, and after that it can be expected to lessen somewhat and the load on the reference staff increase. In addition to variations in work load, the type of Librarian selected will also affect the size and distribution of the staff.

Nevertheless, for purposes of planning, a general estimate of the staff and its distribution is presented. This size and distribution probably correspond most closely to conditions in the third year and after.

Reference service includes stack control, circulation control, current periodical service, inter-library loans, photocopy, answering reference requests, providing bibliographies, book and serial selection, etc. The workable staff would include the following:

1 - Chief of reference (professional)
1 - Reference librarian (professional)
1 - Assistant reference librarian (professional)
1 - Circulation librarian (sub-professional)
1 - Clerk-typist to the Chief
1 - General reference clerk
2 - Technical reports clerk-typists
1 - Current periodicals clerk
1 - Stack clerk
1 - Circulation clerk
1 - Interlibrary loan clerk

12 - TOTAL REFERENCE STAFF

Technical services include selection, searching and acquisition of books, serials, technical reports, maps, etc., carrying accountable and other fiscal records on the same, binding preparation and checking, work concerned with the preservation of poor-paper items, and all aspects of subject classification and cataloging. A normalized staff would include:

1 - Chief of technical services (professional)
1 - Cataloging librarian (professional)
3 - Monograph catalogers (professional)
3 - Technical reports catalogers (professional)
2 - Serials catalogers (professional)
1 - Acquisitions librarian (professional)
1 - Serials acquisition & exchange librarian (professional)
1 - Monograph acquisition librarian (professional)
1 - Technical reports acquisitions librarian (professional)
1 - Clerk-typist to Chief
10 - Catalog clerk-typists
5 - Acquisitions clerk-typists
2 - Warehousemen-clerks

32 - TOTAL SERVICES STAFF

No consideration has been taken of the possibility of staffing translation or subject-specialist services in the library. In any case the translation group would be small, and the subject-specialists are probably better attached to laboratories. However, should the Institute locate near a large university, then the possibility of using part-time and summer help should be considered very seriously.

SUPPLEMENT III

RADIATION PROBE FACILITY

Introduction

A requirement was expressed at the research planning conferences for a completely equipped facility for probing the atmosphere with the aid of electromagnetic radiation. The Institute was considered to be an ideal site for such an installation because of the possibility of achieving a close integration of this exploratory work with basic studies of the atmosphere. The types of probing systems recommended fell into four general classes: (1) microwave radar, (2) sferics, (3) optical radar (pulsed light), and (4) infrared. These will be discussed briefly in turn with estimates of the costs of equipment.

Microwave Radar

Microwave radar has a great many applications as a diagnostic tool in atmospheric research. Its potential in meteorological research has been only partially developed in spite of the vigor and enthusiasm of the presently small group of workers.

Radar Detection of Refractive Index Inhomogeneities. The early work of Friend indicated that sharp gradients in refractive index are detectable by radar techniques. The utilization of practical high powered radar systems has indicated the validity of Friend's theoretical deductions and preliminary experimental observations. Indeed, recent observations have indicated a potential for indirect probing far beyond the limits that Friend suggested. In addition to the detection of clear-air inversions, under proper conditions, all manner of small-scale circulations may be detected if they are associated with temperature-moisture inhomogeneities. These include the boundary of cumulus and other clouds (mantel echoes), subcumulus thermal echoes, turbulent layers, sea-breeze circulations, inversions, pre-frontal cloud-free banks, and dry fronts. Despite accumulating evidence of the broad capabilities of radar, it remains to demonstrate that sufficiently sharp gradients of refractive index exist to account for the magnitude of the echoes observed. This may be due either to a weakness in the theory or to the failure of existing instruments to measure the fine structure of atmospheric inhomogeneities.

Among the needs in this field are a fundamental study of the scattering mechanism (including the theory of scattering due to regular gradients and to turbulent inhomogeneities in the atmosphere), an aircraft measurement program to observe directly the fine structure of the inhomogeneities, while simultaneous quantitative radar observations are being made. While the fundamental studies are in progress, a more empirical approach is required to correlate radar observations with radiosonde measurements. This should include a number of vertically pointing radars operating over a broad range of wavelengths together with, hopefully, a balloon borne expendable refractometer. A high powered 10 cm short pulse-length heightfinder should be utilized for probing the 3-dimensional structure of small-scale circulations (convective processes, cumulus cloud boundaries, dry fronts). A higher resolution mobile system operating at 1 cm wavelength should be utilized to investigate sea-breeze radar echoes and micro-scale circulations.

Radar detection of atmospheric inhomogeneities offers one of the most hopeful means for making detailed indirect soundings of the atmosphere. Should such sounding techniques prove successful, a wide variety of heretofore invisible meteorological processes could be sensed. The nearly instantaneous mapping capacity of radar provides a possibility for a complete 3-dimensional visualization of a wide variety of atmospheric structures and their changes with time. Such processes are only poorly depicted by present techniques. These involve elaborate networks of meteorological instruments or aircraft soundings followed by tedious and expensive analysis.

To exploit the possibilities that seem attainable here would require the combined efforts of a group well versed in the theory of electromagnetic scattering (with access to a high-speed computer) together with a group capable of carrying on advanced experimental work with vertically-pointing radars operating at 400, 1,200, 3,000 and 35,000 mc/sec and RHI systems at 3,000 and 24,000 (or 35,000) mc/sec. In addition, development work on a high resolution airborne refractometer would be required for use on aircraft.

Particle Site Distributions of Atmospheric Hydrometeors. The scattering and attenuation observed in clouds and fields of precipitation depend upon the particle size distribution. The cloud and precipitation variables which are of general interest in atmospheric research are liquid water content, precipitation rate, and median particle size. The deduction of these quantities from radiation scattering and attenuation measurements is initially dependent on a knowledge of the particle size distribution.

Knowledge of size distribution in rain is fairly well advanced but in clouds and snowfall it is still primitive. In all cases it is necessary to determine the relationship of the size distribution of hydrometeors to the general physical characteristics of the clouds and to the nature of the synoptic weather situation. Were such relations known, a characterization of the particle size spectra could be anticipated within certain bounds.

Once the particle size spectrum has been determined for a wide range of conditions, a numerical computation program will be required to determine the exact scattering and attenuation coefficients to be expected over a broad range of wavelengths. This is particularly necessary at wavelengths less than 0.9 cm which have come into use only recently and for which scattering and attenuation information is sparse. It is at these short wavelengths that the Rayleigh scattering law is no longer valid for precipitation.

Development of refined instrumentation for automatic measurements of drop-size distribution is urgently needed.

Radar Detection of Motion and Turbulence in Regions of Hydrometeors. Doppler radar techniques provide means for measuring absolute target velocities. The spectrum of doppler frequencies provides a measure of the eddy motions superimposed on the mean velocity. The pulse-to-pulse echo intensity fluctuations detected with conventional radars can also provide information regarding the eddy motions. Thus measurements of doppler frequency shifts and echo intensity fluctuations promise extensive new information on the motions within detectable clouds and precipitation. Such data should enhance our knowledge of the dynamics of thunderstorms, tornadoes, and hurricanes in which comparable data can now be obtained only by direct sampling only at exceedingly great cost or hazard.

Continuous wave doppler radar is of limited usefulness in weather studies because of its present lack of range information. On the other hand, existing pulse doppler radars provide range data at the expense of placing limits on the maximum velocity that can be measured. With increasing range the lower the possible pulse repetition frequency and the smaller the doppler velocities that can be indicated unambiguously. It appears possible to overcome these limitations in a doppler system designed specifically for weather detection. Such a system should also be capable of displaying contours of doppler shift throughout the storm region scanned, or otherwise displaying the regions where different velocity regimes exist.

In addition to a development program, a combined theoretical and experimental investigation is required to determine the magnitudes of the doppler shifts to be expected from various configurations of precipitation, drop size distribution, winds, as a function of radar characteristics (i.e., wavelength, beam pattern, elevation angle, pulse length, etc.).

The use of a vertically-pointing doppler radar to measure vertical velocities in thunderstorms holds promise of revealing new knowledge of the dynamics of such storms. However, if the radar is fixed on the ground we must wait for the thunderstorms to pass overhead. Furthermore the changing structure of the storm cannot be followed. Therefore it is desirable to install such a doppler radar in an aircraft in order to follow the storm through its life cycle.

Radar Detection of Lightning. In recent years it has been found that radars operating at 10, 23 and 50 cm wavelengths can detect and display echoes from the ionized paths formed by lightning discharges. The potential usefulness of lightning detection radar both for fundamental studies of the lightning mechanism and as an operational tool for determining the electrical and associated hazards of thunderstorms in advance of their approach is very great. (Electrical activity is thought by some to be closely related to the occurrence of hail and to the atmospheric conditions associated with tornadoes.) In basic studies, the possibility of locating a lightning discharge exactly in space and time and of associating it with the structure and behavior of the storm as indicated by precipitation echoes holds promise of a major advance in our knowledge of the processes leading to the generation of electrical activity in the atmosphere.

As yet work in this area is in a pioneering stage. While lightning has been displayed on both the PPI and RHI scopes, knowledge of the reflection mechanism is still vague and quantitative data on echo intensity as a function of wavelength, target size and target structure is lacking. A suitable model of the ionized region cannot yet be made. As a result, it is not possible to specify the optimum characteristics (e.g., wavelength, polarization, pulse width, beam width, beam pattern, scan rates) of a radar suitable for lightning detection. While long wavelengths appear desirable to detect weakly ionized regions, short wavelengths are required to display lightning structure with adequate resolution. The shorter wavelengths favor a reasonable size antenna structure suitable for the high scanning speeds needed to increase detection probability. However, at shorter wavelengths, echoes from precipitation may obscure the lightning echoes unless the radar emission is circularly polarized. Since lightning echoes are transient, each one appearing on only one scan, special display techniques are required to differentiate them from persistent echoes.

In addition to these instrumental problems, theoretical studies are required to describe the reflection mechanism. The results of these investigations should be compared with laboratory experiments in which model discharges or ionized volumes are generated for the purpose of measuring their reflecting properties. Radar observations of lightning should be conducted simultaneously with sferics measurements in order to provide comprehensive knowledge of the discharge process and to determine which parts of the discharge sequence are responsible for the generation of sferic signals and ionized trails respectively.

Other Problems. The discussion given above is by no means exhaustive. The possibilities of determining the three-dimensional wind field from the movement of individual "generating elements" needs to be explored. Other problems include meso-analysis of thunderstorms and squall lines by the combined use of ground-based radar and instrumented aircraft, further development of radar chaff tracking techniques, improvement of a time-height radar for mapping cloud and precipitation echoes, and development of a multi-wavelength radar. The use of radar techniques to determine the electron density and thermal energy in those portions of the atmosphere above 100 km also offers attractive possibilities that may be opened by developing special equipment.

Equipment Requirements. To meet the requirements of a fully-instrumented weather radar research station, the equipment listed below has been recommended.

Basic Requirements	Cost
WSR-57 (Fixed) 10 cm PPI and RHI system or equivalent	$ 127,000
WSR-57 (Mobile) or equivalent	118,000
FPS-6 (Fixed) 10 cm RHI system with 0.9° vertical beam width and rapid scan or equivalent	212,000
0.86 cm High Resolution Scanning Radar (Mobile)	103,000
Fixed Vertically Pointing Radars for Continuous Sounding with 1° beam width at 0.86 cm, 10 cm, and 23 cm wavelengths	335,000
Pulse Doppler Radar at 5.6 cm with 8 ft. diameter scanning antenna (Mobile)	178,000
Mobile 5.6 cm Conventional Radar	67,000
Mobile Aircraft Surveillance Radar	168,000
Subtotal	$1,308,000

All purpose meteorological research radar

Basic Characteristics

Wavelength - 10 cm
Peak Power - 5 megawatts
Receiver Sensitivity - 10^{-14} watts
Antenna - 25 ft. diameter paraboloid
Beam - pencil beam for weather detection
- fan beam for lightning detection
Scan - 2, 4, 6, 8, or 10 rpm in both vertical and horizontal planes for weather detection
- 15 to 30 rpm for lightning detection

Basic Characteristics (Continued)

Antenna
Alternative - 25 ft. long parabolic cylinder with RHI scan accomplished by rapid electronic scanning. This would permit RHI's to be obtained while scanning simultaneously in azimuth.

Polarization - Circular, with facility to record cross polarized echo components on separate receivers and means to display both components simultaneously on same scope either in different colors or by contour mapping techniques.

Receiver - Logarithmic receiver with 80 db dynamic range. Second receiver detuned from transmitter for reception of sferic signals only.

Range Normalization - Out to maximum range on each range, 5, 10, 25, 50, 100, 150, 200 miles.

Pulse Repetition Frequency - Maximum consistent with ranges indicated above and duty cycle of magnetron.

Contour Mapping - Automatic mapping of three categories of reflectivity in three discrete colors. Contour spacing selectable at 3, 6, 10, or 20 db.

Calibration - Automatic receiver calibration by built-in RF test set.

Doppler - Doppler shift spectrum to be automatically measurable while scanning at any range and azimuth by adjustable gates. Three categories of Doppler shift to be automatically mapped in three discrete colors on either PPI or RHI scope. Spacing between adjacent Doppler shift classes to be selectable.

Indicators - Latest 16 inch diameter PPI and RHI indicators, both single and multi-color tubes. All variable radar parameters to be indicated automatically adjacent to CRT so that they may be photographed simultaneously with the weather pattern. Constant altitude pattern display shall be automatically obtained at six selectable levels.

Storage Techniques and Displays - Scan to Scan Moving Target Indication to be used so that lightning echoes may be separated from precipitation echoes and reinserted in a distinct color. A direct view storage tube shall be used on the output of the sferics receiver to display sferic counts and directions of maximum activity. Patterns at successive 10, 15, 20, or 30 minute intervals shall be stored and then simultaneously displayed in distinct colors to indicate development and motion.

Data Processing - Gated profile plotters shall permit analogue profiles of reflectivity, doppler shift, or polarization to be recorded at any preselected range while scanning. Values to be read out either in analogue voltages to direct writing recorders, or in digital form to punch cards. All scopes to be photographed automatically.

Estimated System Cost		$2,500,000
Fixed Vertically Pointing 75 cm Radar (150 ft. paraboloid)		500,000
	Subtotal	$3,000,000
Film Analysis Equipment		9,150
Oscilloscope Recording Cameras		22,850
Test Equipment		72,000
	Subtotal	$ 104,000

Sferics

The detection of sferics radiated by lightning discharges has permitted distant thunderstorms to be located by means of a network of radio direction finders. Until recently, observations have been made at very low frequencies. Knowledge of the energy spectrum of various types of sferics is extremely sparse, especially at VHF frequencies and above. The energy spectrum of a discharge provides information as to the shape of the associated current pulse. The use of VHF or higher frequencies also provides increased resolution and reduces ambiguity by limiting the range of detection to storms within line of sight. The change with time of each sferic signal amplitude provides further information as does the polarization of the emitted radiation. Detailed and comprehensive investigation of all these sferic characteristics is required.

In order to provide auxiliary information for the interpretation of the nature of the discharge, a proper study of sferics should also involve simultaneous measurements of electrostatic field. Since sferics data are pertinent to the lightning echo detection problem, the two studies should be closely coordinated.

Equipment Costs. Based on the assumption that three field stations would be operated, in addition to the principal station at the Institute, it is estimated that approximately one-half a million dollars would be required for a complete sferics installation. Major equipment items would include:

Parabolic antenna (for use in the electric component method)	$300,000
4 Adcock antennae	4,000
4 Azimuth display consoles	12,000
4 Photographic recorders	6,000
4 Magnetic type recorders	20,000
Supporting instrumentation	40,000
Field installation costs	78,000
Subtotal	$500,000

Optical Radar

There is a requirement for the development of pulsed searchlight equipment to determine the fine structure of the atmosphere, including the existence of refractive inhomogeneities, moisture ducts and haze layers which affect the propogation of electromagnetic radiation at visible and microwave frequencies. To be of greatest use, such equipment should be operated in conjunction with microwave probing techniques. The only equipment available at present for this work is an optical radar-type cloud height finder made in France. Unfortunately it suffers the disadvantage of being relatively insensitive. It is estimated that a year of engineering study and an outlay of the order of $100,000 would be required to complete the engineering study needed to improve such equipment. Then another year and another $100,000 would be required for construction.

Subtotal $100,000

Spectrometric Techniques

A high-resolution infrared spectrometer, perhaps of the interference type, is required to measure the line shapes of all atmospheric constituents and to compare measurements with theoretical studies of the line intensity growth, true line shape, position and broadening as well as with limb-broadening effects. The spectrograph can also supply needed information on the coefficients of monochromatic atmospheric attenuation in the infrared, and on the volume scattering functions needed to verify of the results of theoretical studies of the radiative transfer processes in continuous and layered media.

Infrared equipment operating in the 10 micron region should be valuable for studying of the thermal emissivity of the earth and sea surface as well as the temperature and extent of clouds. Basic procedures developed for ground stations and conventional airborne vehicles would find wide application in radiation-mapping techniques applicable to rockets and satellites.

Basic equipment required for this program, and for a spectrographic laboratory, includes the following:

Basic Equipment	Estimated Cost
Infrared variable pressure spectrometer	$ 300,000
Ultra-violet vacuum spectrometer	60,000
Visible range photographic and photomultiplier spectrometer	20,000
Far infrared interfrometric spectrometer	50,000
Microwave spectrometer	50,000
Twenty-inch coelostat and tower	50,000
Low pressure absorption tube	300,000
Accessories, pumps, lenses, optical flats and other equipment	170,000
Subtotal	$1,000,000

SUMMARY OF COSTS

Basic radar equipment	$1,308,000
Meteorological research radar	3,000,000
Radar test and analysis equipment	104,000
Sferics equipment	500,000
Optical radar	100,000
Spectrometric equipment	1,000,000
TOTAL	$6,012,000

SUPPLEMENT IV

ARCHITECTURAL STUDIES

Some preliminary studies of a building have been attempted in order to clarify the concept of an Institute for Atmospheric Research. These studies take into consideration the specific requests for space and facilities and the general requirements given by some of the hundred and more scientists who participated in the seventeen conferences held during the fall months of 1958 under the auspices of the University Committee for Atmospheric Research. Information from these conferences has, in turn, been translated into designs consistent with the advice of men experienced in the construction and management of several well-known university, government and industrial research laboratories. And to this has been added thoughtful concern for the human service that the Institute structure may perform, realizing that this is, after all, its most important function.

The function of the Institute building is to provide convenient space in which, with properly inspiring leadership, a "research atmosphere" can be developed and sustained. An architectural study cannot deal directly with the factors of intellectual stimulation; but to the extent that men react favorably to a pleasant and conveniently flexible environment, it is useful to give careful thought to the possible nature of an Institute and, for practical reasons, to its costs.

AN ARCHITECTURAL STUDY OF THE INSTITUTE

The ideas assembled on paper as a preliminary study of the Institute building, serve two purposes:

1. To provide a starting point for the development of a realistic concept of the Institute by visualizing at least one possible assemblage of working spaces that meets the expressed needs of the scientists consulted.

2. To serve as a basis for making defensible engineering estimates of costs to provide an Institute building fully equipped with utilities, finished interior surfaces and elementary furnishings; but without laboratory apparatus, library books, electronic and machine shop equipment, or an electronic computer.

This study has been limited by the uncertainties of site and actual personnel requirements. This restriction has forced consideration of an expansible structure capable of being erected on any reasonable site and in any climate, as a self-sufficient entity. Conditions existing at the chosen site may permit considerable relaxation of this high degree of self-sufficiency.

Characteristics of the Research Effort

In the recommendations of the research planning groups two quite different points of view were expressed. One requires the Institute to possess strong competence in instrumentation, data processing, field exploration and supporting services; the other, to develop major strength as a center where interdisciplinary work related to atmospheric processes may be pursued on theoretical and experimental grounds of the most basic kind. It seems desirable that both points of view be represented and that the balance between them may be expected to change repeatedly with time.

The contemplative aspects of the Institute effort require relatively little beyond quiet offices with access to the library and seminars, office-laboratory spaces for small scale experimentation on basic problems, and a rather major provision of space and funds for an advanced form of high speed electronic computer with accessory spaces for data reduction, programming, coding and data storage. To implement laboratory experimentation some spaces are needed for electronics and machine shops, with added space for stocks of laboratory apparatus. Utilities requirements are not heavy, but good over-all lighting and conditioned ventilation is necessary, especially in the space provided for the electronic computer.

In contrast with this is the recommendation that the Institute be prepared to deal with large scale field and experimental efforts beyond the capabilities of many universities. Such programs have been proposed as the development of high performance weather radar and optical probes with which to study the atmosphere above extended arrays of micro and mesometeorological ground stations together with aircraft and balloons to sample the atmosphere periodically; fundamental research into the data reduction and analysis problems, especially those resulting from the Institute's own field programs; the development of instruments for ground, aircraft, balloon, rocket and satellite reconnaissance and for these systems to produce reliable and intelligible data with a minimum of hand computation; study of the physics of precipitation and turbulence in thermally controlled wind tunnels; study of the fluxes of energy and mass between wind and water, and other critical matters which involve direct access to the atmosphere or large scale apparatus. These programs require considerable resources of space, power and equipment.

Clearly it would be a mistake to provide at the outset all the equipment needed for each of these endeavors. The apparatus is too specialized for one man's design to suit another's scientific interest and too costly to have standing idle. For these reasons the architectural study has concentrated on the provision of flexible spaces for the construction of experimental facilities, and the shop and office spaces needed to handle preparatory and maintenance problems with flexibility and simplicity. The latter characteristics are vitally necessary in order that the enthusiasm for an experimental effort may not be dampened by prolonged and obstructive preparation, and so too, that a wide variety of experiments may be considered as a matter of course.

General Approach

To provide flexibility of growth from small beginnings, the building has been conceived in terms of a game of dominos, in which symmetry is deliberately avoided to remove the necessity for matching any necessary expansion with an unnecessary member for architectural balance. Still the concept is far from amorphous.

Staff Center

The core of the building lies in the arrangement of the library, seminar and commons rooms which provide a focus of interest for the scientific staff. The commons room is designed to serve the dual purpose as a place for coffee-time discussion, and for casual reading of current periodicals. One can hope that this combination of attractions may draw staff members from their offices and laboratories at various times each day, encourage chance acquaintances and create opportunities for profitable conversation. (See floor plans at end this Supplement.)

The staff lounge and seminars adjacent to the commons room permit free passage from one to another and into the garden court. The dining room across the court may also serve to initiate conversations and to encourage the drift of groups to the staff lounge or commons room for further discussions or to the library, if controversy or new awareness so demands. The court with its surrounding spaces caters to the intellectual and metabolic hungers of the staff.

Synoptic Laboratory

The Institute staff is to be composed of scientists versed in widely different disciplines many of which do not concern the atmosphere at all directly. Still it is "unthinkable" that the Institute should not be concerned with current weather even though it strives to maintain a more cosmic point of view. Therefore, it has been suggested that a synoptic laboratory be given a conspicuous place in the staff center of the Institute. It has also been suggested that this laboratory might be part of the flight management office. To these ends suitable laboratory space has been provided near the commons room and library so that all who have occasion to pass may be aware of synoptic weather developments.

Administrative Spaces

Spaces for the Director and his staff, the accounting, purchasing, personnel and publishing functions, are located toward the front of the building so as to be accessible to the outside world with a minimum of disturbance to the scientific staff, and yet be close enough to the staff center to permit the Director to play an active role in the scientific life of the Institute and for the scientific staff to have convenient access to the administrative spaces whenever necessary.

Auditorium

The Institute may well be chosen as the site for scientific meetings -- perhaps often for international gatherings. To this end the design includes an auditorium seating some 550 persons, but of such a shape that it is as easy to talk across the assembly as from the platform. Entry to the auditorium is made through an acoustic trap so that those gathered for conversation in the foyer do not annoy those in more formal session. The auditorium is equipped with translators' booths so that during international sessions it is possible to permit open scientific discussion between persons quite ignorant of each other's language. The translators' booths are fitted with windows so that the translator may lip-read as well as hear the speaker. Connections between the auditorium and the publications room can also be arranged if it should prove helpful to transcribe discussions for immediate or later distribution. The identity of each speaker can be determined by the seat number at which the microphone is connected, or be monitored by the translators.

Dining Spaces

The auditorium is adjacent to the dining spaces and the court so that the adjournments of meetings permit the assembly to satisfy interim needs conveniently and within range of easy recall. The dining spaces are flexible and can be partitioned by means of track-mounted sound attenuating screens to suit the numerical demand or to subdivide groups when one or more formal discussions are in progress at mealtime. Smaller dining spaces are also provided on the court for seminar groups and administrative meetings.

The Library

It has been recommended that the Institute possess one of the best scientific research collections obtainable in order to provide the staff, and atmospheric research community, with ready access to the past in any discipline relating to the atmosphere and to cultivate scholarly research. Toward this end some 300,000 volumes may be assembled in the course of a decade. This rate of accession is so extraordinarily high that it is necessary to provide for a staff of about 45 librarians, cataloguers, clerks, and assistants; and a warehouse for receiving accessions, in addition to some 50,000 square feet of floor space for library stacks, carrels and studies. Allowance for this scale of library activity and collection has been provided on the north side of the court, on two floors. The first floor is devoted to library stacks, and the librarians' offices and work rooms. The second floor is arranged to accommodate carrels on the north, class rooms overlooking the court on the south, with stacks and a research librarian's office between. Spaces for the accession warehouse, bindery, and cataloguing rooms are provided on both library levels.

People and Facilities

In the concepts of the Institute that have been considered, the spaces for contemplative effort have been carefully arranged with respect to those for the more overt pursuits. For the latter, a wide bay is provided. This bay is adjacent to, but acoustically isolated from, the office spaces for quiet activities. This arrangement has been chosen to encourage collaboration between the theoretical and experimental researchers and at the same time to permit experimentalists to have equal access to the libraries. The noise of the bay is directed away from the spaces for quiet activities, which might have the best view. This arrangement permits a high degree of flexibility in the placement of future construction.

The Institute building has been conceived in expansible terms. The first stage provides for immediate construction with a capacity of some 550 people. This estimate results from the following considerations: Study of nearly a dozen existing laboratories has shown that in both mathematical and physical research a total of from 8 to 14 people, but most often 10, are required to provide proper support for each innovating scientist. These others include the administrative complement, scientific associates, laboratory assistants, programmers, machinists, electronics technicians, librarians, secretaries, kitchen staff, maintenance men, and so on. Thus a 550-man total means that some 50 innovating scientists may lead an Institute staff of some 100 research scientists, together with 200 technical and 200 supporting personnel. This lies within range of numbers recommended by the study groups, bearing in mind that each discipline must be represented by a "critical mass" of at least two, and sometimes as many as five, persons having related scientific persuasions. These critical numbers must be provided so that those in each of the several disciplines shall maintain their professional identities without which they may lose their usefulness to the Institute.

Some of the classifications of personnel considered in the designs are listed and analysed on pages 69 - 71.

Present and Future Space Requirements

Studies of existing laboratories have indicated that, for effective scientific effort, a minimum of 150 and an optimum area of 200 square feet of space be available for assignment to each person, and that some 300 square feet of active gross area per person be provided in all. In terms of the gross unit, the floor space required for research office-laboratories in the Institute might total 156,000 square feet for a scientific and technical staff numbering 520. This allows for an expansion of 33 percent above immediate needs.

In addition to research space it has been requested that the Institute be provided with 50,000 square feet for libraries, and that it posses an auditorium seating 550 persons, an adequate cafeteria, spaces for seminar and class rooms, space for an electronic computer, special laboratories for research in fluid mechanics, electromagnetic radiation and instrumentation, that adequate shops be provided together with the necessary administrative spaces. These features total some 215,000 square feet. These latter spaces being non-assignable and fairly flexible in their function and capacity it is probable that any future expansion of the research staff could be accommodated by construction on the basis of 300 square feet of gross space per person. Thus the initial 371,000 square feet could be made to accommodate twice the initial scientific staff by adding approximately 100,000 square feet of assignable research space in the future.

Research Spaces

The research laboratory-offices are arranged on either side of the main and branching corridors. For convenience in supplying utilities, man-high service alleys are fitted overhead along the lengths of the principal corridors. These contain the electric power busses, liquid and gas supply lines, air conditioning ducts, sprinkler and waste lines.

Research laboratory or office space is assignable in modules. These measure 9-feet along the corridor with a 16-foot depth to the window wall in the office modules on one side (144-ft^2), and 27-foot depth in the laboratory modules on the other (243-ft^2). The 9-foot module provides a number of comfortably proportioned shapes and window placements. Offices composed on the 9 x 16 foot module might measure 16 x 18, 16 x 27, and so on. Laboratory or office-laboratory spaces on the 9 x 27 foot module might measure 18 x 27, 27 x 27, 27 x 36 and so on as required, and be subdivided with alcoves if necessary.

Ceiling height between floors is 14 feet but a 2-1/2 ft plenum is formed between the structural ceiling and the illumination panel over each module. The plenum serves the several purposes of concealing the utilities lines brought in from the service alley, housing flourescent tubes and of distributing adequate volumes of conditioned air at low velocity. Services can be brought in between panels to supply island benches or office equipment arranged along the walls.

It is expected that a number of modules would be assigned to a scientifically coherent group and that subdivision of the space would be made at their own discretion. However, it is desirable that the coherent blocks of space be delineated by fire stops of semi-permanent masonry. Other partitioning can be of the kind best suited to the needs and desires of the scientific group concerned.

It seems desirable that the research spaces, in addition to having acoustic material overhead, should have vinyl tile floors to maintain cleanliness, quiet and have good resistance to wear. Similar flooring and acoustic treatment is desirable for the corridors so that it does not become necessary to close office or laboratory doors to maintain a contemplative atmosphere in the laboratory.

One side of each of the corridors contains structural verticals. To add interest to the corridors as places where chance discussions may occur it seemed desirable to vary the corridor width by placing the finish wall occasionally inside the verticals to provide a succession of shallow bays. These serve to clear the corridor of the ordinary obstructions, such as water coolers, hoses, and fire extinguishers, and to provide space for groups to withdraw a little from the main stream, or for the usual traffic of carts and dollies to find temporary parking places as needed. Similarly, an unassigned office space is reserved as a small seminar in the central part of each floor in each wing. These spaces, to serve as small areas for vigorous discussion in private, may possess a blackboard, a table, a few chairs, ash trays and a coffee pot, but generally not a telephone. The door should be spring loaded to close quietly but firmly.

The only specialized office-laboratory spaces brought to present notice are those required for chemistry. In these provision is made for "perchloric" and "AEC" hoods on the upper floor and ducts are accessible for venting less corrosive fumes as needed below. The chemical spaces are maintained at a slight positive pressure and the hood ducts at negative pressure to insure proper ventilation. The hood blowers and stacks, mounted on the roof, rise above walking level only the 8-feet required by AEC specifications.

This height permits a nearly clear horizon to be obtained from other parts of the Institute roof and a totally unobstructed sweep to be obtained from the 8-foot level. The coelostat, required to feed a 12-inch beam of sunlight into the spectrograph laboratory, must be mounted clear and generally upwind (to the westward if the Institute is situated in mid-latitudes) of the hood exhausts. The steerable 120-foot radar dish will necessarily tower above the coelostat level, but may be far enough removed from the main building to subtend an acceptably small angle and be north of the azimuth of the summer solstice on the eastern horizon. Similarly, the power house stack and standpipe can be far enough removed from the main laboratory to subtend small angles in the northern sky and perhaps be low enough for the center of main radar beam to pass above them. Terrain will be an important factor in determining the best disposition of these components.

Part of the laboratory roof is to be paved, provided with power outlets, ducts for temporary wires or pipes, and fitted with flush pad eyes at regular intervals so that a variety of equipment can be mounted upon it temporarily. To prevent water from collecting in the pad eyes and to keep these recesses from being obstacles to wheeled or foot traffic, it would be desirable to fill them with a waxy substance which is hard enough to sustain momentary loads, not too sticky, readily chipped out, and easily replaced by melting. The roof structure is designed to sustain distributed loadings of 100 lb/ft^2, but can be made to carry greater concentrated loads by tieing into the main structural verticals.

Shops and Special Laboratories

Study of the requirements for shops has revealed that it is usual for one experimentalist to consume the time of one machinist or one electronics technician, but only a small fraction of the time of each carpenter, mason, plumber, electrician and utility man. With these estimates and the recommended complement of experimentalists in mind it seems necessary to allow for a 20-man machine shop, an electronics shop of equal size and lesser auxiliary shop services.

A 20-man machine shop is not a trifling affair. It requires some 5,000 ft^2 of floor space with ceiling clearance between 12 and 14 feet, some 400,000 dollars worth of machines, and equal expenditure in small parts and attachments for these machines, approximately 200 total horsepower in separate motors, and stock and assembly rooms totaling some 2,000 ft^2 of floor space.

A comparable electronics shop requires equal primary and auxiliary space, preferably shielded on all sides, an investment in testing, analysis equipment and standards that approximates 500,000 dollars and depends on the emphasis of the work undertaken. The electronics shop should also have stocks of components and parts and either its own machine shop or convenient accessibility to the central shop.

To meet these needs, adequate spaces have been provided on the experimental court or bay for the machine and electronics shops together with smaller spaces for auxiliary shops, stock, and assembly rooms, which relate logically to each other and to both the instrumentation and experimental physics laboratories. The instrumentation laboratory is centrally located with respect to the machine and electronics shops and to the experimental physics and chemistry laboratories. The radar laboratory is situated next to the electronics shop and may share its testing and standards equipment with electronics, but is only diagonally removed from the machine shop, instrumentation laboratory and physical research spaces.

The open court on which the shops and major experimental laboratories face is strongly paved, but landscaped against the building to maintain a pleasant atmosphere and provide simple access to the underground piping and conduits carrying the fire and utilities lines from the power house to the Institute building. The open court provides space for the construction or repair of larger experimental devices, aircraft instrumentation in mock-up, parking and servicing of mobile radar equipments, and as a generalized area for logistic services.

While fork lift and motor crane vehicles will undoubtedly serve most of the lifting needs, and 2-ton monorails are provided in the shops, one 18-ton bridge crane has been provided for major lifting in the bay and in the fluid dynamics laboratory.

Large-Scale Experiments

The fluid dynamics laboratory is one architectural solution to the manifold problem presented by the straggling list of requests for major experimental space in which to house such apparatus as a vertical wind tunnel for precipitation research, a low speed horizontal wind tunnel with a very large test section for research in turbulence, rotating tank apparatus to study the properties of geostrophic flows, a large free surface of water over which to study energy exchanges with air, and so on. To this end a separate shelter measuring 60 x 100 ft by 40 ft high has been conceived to house experimental facilities of these sorts on a temporary basis simply because many of these experiments cannot be conceived in final form. This building is equipped with an 18-ton bridge crane leading to the experimental court where these large pieces of apparatus might be built and then installed for use under cover. Or if experimental work is concluded, the apparatus might be removed bodily from the laboratory to make room for successors, or improved versions. The roof, walls and floor of this building are removable with the help of the crane. In this way the test section of a wind tunnel can be arranged in any chosen direction and the closed circuit airflow brought around the outside of the building as temporary construction. Special pumps, refrigerating machinery and power sources are easily installed (with the help of the crane) under the removable floor panels, and as easily dismantled again as the experimental needs change.

This architectural treatment of the experimental problem may

1. Provide adaptable shelter for fairly sizeable experiments, and full-scale models (of precipitation mechanisms, for example).

2. Permit a wide variety of large scale experiments to be conducted conveniently, and without loss of enthusiasm owing to delays.

3. Encourage demolition of apparatus no longer in use and thus to avoid the tendency for apparatus to steer the direction of research.

4. Lessen the cost of major experiments by having the housing and power supply problems essentially solved in advance.

Where apparatus has continuing uses or has been developed to the point where finished permanent construction is warranted, it would be desirable to make a separate provision for it.

The Computer Laboratory

One of the facilities frequently mentioned, or even assumed, as a necessary part of the Institute is an advanced form of high speed electronic computer. Clearly this is a necessary adjunct to research along many possible lines and should receive appropriately prominent architectural notice. Provision has been made for a computer of the IBM 7090 class in a separate glass walled extension of the mathematical research wing. This jewel-like appendage to the main building permits separate air conditioning requirements to be met cleanly. In the basement space below the computer floor are the transformer vaults, heat exchangers, and storage spaces for programs and data collections. A plunger lift permits data on tapes and punched cards to be moved from active to stored status with a minimum of difficulty. Some 10,000 square feet of floor space have been provided in this cubicle. Actual space and power requirements can be met without major architectural modification when they become known.

Office space for the numerous programmers and coders needed to keep such high capacity computing equipment fully occupied has been arranged on the first floor of the mathematical research wing. Data collections may also be housed on this level or be stored as a part of the library collection in the warehouse or reserve library spaces.

Flow Patterns

One of the most important improvements in the design of the second version of the Institute building is the lessening of distances between offices, laboratories and the libraries, and in the provision of alternate routes between wings. The physical research wings are joined by an office-laboratory bridge at the second floor level, to provide easy communication between the two wings and yet not block off the garden court between them. In good weather the colonnade beneath this bridge should be a pleasant place in which to walk and talk. Similarly the computer laboratory forms part of an avenue for communication between the mathematical and physical research wings, and a second passage between the library and mathematical research wing is lined with studies. Thus it should be possible for a variety of routes to be traced between the finger-like wings other than the main corridor through the core of the building. Given this variety of passages and inviting prospects one can hope that the Institute building may prove to be a pleasant place which serves, in itself, to encourage scientific communication.

ARCHITECTURAL ENGINEERING AND BUDGET ESTIMATES

Acknowledgment

Much of the foregoing description of the Institute building and its functions has been worked out in collaboration with Mr. Herbert L. Beckwith of the architectural firm Anderson, Beckwith and Haible of Boston, Massachusetts. Additional information has been drawn from the advice of those scientists, administrators, engineers and others who have special competence in laboratory management and design. We must acknowledge with gratitude the help of Mr. M. S. Cheevers, General Plant Manager of the Bell Telephone Laboratories, Mr. C. L. Fenn, Chief Engineer of the Edo Corporation in problems of design, together with the consulting services of Mr. Carl M. F. Peterson, Director of Physical Plant, Massachusetts Institute of Technology, the George A. Fuller Construction Company of Boston, and the Delbrook Engineering Company of Cambridge, who have helped to make definitive estimates of the costs of construction and plant operations.

Some Criteria for the Present Designs

1. To provide flexibility for expansion of all major elements, laboratories, shops, library, and specialized research areas.

2. To provide an economical and flexible distribution system for laboratory services. In the present designs these consist of:

   Buss-duct and supply piping trunks run in furred plenum over first floor corridor.

Run-outs to second floor laboratories located on the first floor ceilings accessible through removable lighting panels.

Run-outs to first floor laboratories by means of vertical chases in corridor walls.

Horizontal distribution in laboratories by means of horizontal wall chases related to benches.

Drains for laboratory sinks located on first floor and basement ceilings.

Some circuits provided in laboratory areas connected to emergency power distribution to provide sustaining power for critical experiments.

3. To provide a north or south exposure for the majority of laboratory areas with sun control on the south exposure.

4. To provide space for equipment such as boilers, air-conditioning compressors, pumps and air compressors in a utilities building well removed from research areas.

   A. To allow for expansion in the course of time.

   B. To keep stack gases remote from (and to leeward of) research areas.

5. To provide laboratory roofs which will sustain 100#/sq ft live loads so that they may be used for experimental purposes. The roofs are to be provided with attachments for anchoring equipment in paved areas.

6. To provide a work bay convenient to the shops for the modification or assembly of large or heavy equipment. Provide this court with heavy duty (airport type) pavement and floodlighting.

7. To provide a fluid mechanics laboratory having removable (sliding) side wall and roof panel sections. Building to be equipped with an 18-ton bridge crane available to the work bay.

8. To provide framing in the shops designed to permit installations of 2-ton monorails.

The design for the Institute building has undergone progressive change during the course of this study. Engineering estimates were made by the George A. Fuller Company, the Delbrook Engineering Company and by the firm of Anderson, Beckwith and Haible on the design established by 12/22/58. Even before these were completed a new, and probably much more suitable design came to mind which it seemed worthwhile to develop in the short time remaining. This was done by 1/8/59. The estimates of costs for the 1/8/59 design have been developed by applying the unit costs obtained from the 12/22/58 study to the 1/8/59 concept. This is justified by the fact that the mode of construction and utilities supply is substantially the same in both concepts, only the ground plan having been altered.

The estimates for both designs are made in terms of New England prices. For the Denver area apply a factor 0.97 and for the Los Angeles area apply a factor 1.05. The estimates are given in accordance with the following assumptions, inclusions and exclusions.

Assumptions made in preparing the present budgets

1. Reasonably level site for the building complex.

2. Climate requiring both heating and air-conditioning.

3. Average soil bearing for foundations.

4. Overhead sprinklers required over half the building areas.

5. Laboratory floors designed to sustain 100#/sq ft live loads.

Items included in building budget

1. Site Work	Clearing brush and trees Rough grading Roadways and parking areas Work court (airport paving) Finish grading and seeding
2. Construction - Research buildings (completely finished)	Main complex Administration, laboratories, library shops, auditorium, and fluid dynamics laboratory.
3. Laboratory Services (connected to laboratories)	208-115V-3ϕ 4 wire 115V-1ϕ Direct current (conduit from utilities building to corridor distribution system only) High Pressure compressed air Low Pressure compressed air Gas Hot and cold water Distilled water Rough vacuum

4. Furnishings	Laboratory benches Office furniture Library stacks Auditorium seating Venetian blinds Chalkboards
5. Utilities and Services	Utilities building and power house Maintenance shops Tunnel from utilities building to main complex Water storage tank of 350,000 gals. Water service and fire protection piping (from tank throughout Institute). Water and fire pumps Sewerage disposal plant with a capacity for 1000 persons Storm drainage Electric duct lines Telephone and signal duct lines Site lighting Transformers Boilers Compressors and air cooling equipment Air compressors Stills Emergency generator
6. General	Contractor's profit Premium - performance bond 3% escalation allowance as established by Federal Reserve System.
7. Housing for Temporary Staff	Residence hall for 100 persons Year-'round family units for 10 families Summer family units for 10 families

Items excluded from building budget

1. Cost of land.

2. Cost of basic water supply (wells or conduit from project to source of supply).

3. Storm drainage beyond utilities building.

4. Roads beyond limits of developed area shown.

5. Laboratory apparatus and shop equipment.

Materials assumed in building budget

Structure	Reinforced concrete
Exterior Walls	Brick masonry or stone if economically available. Anodized aluminum window frames. Wash-out terrazzo spandrels. 1/4" plate glass
Roof	2" foamglass insulation 4 ply roofing Copper flashings Concrete working decks as shown
Partitions	Corridors - masonry blocks Intra-laboratory - plywood on wood framing Administration area - steel de-mountable
Ceilings	Mineral acoustic tile Lighting panels - diffusing plastic
Floors	Vinyl tile Laboratories Offices Corridors Cafeteria Wood block Shops Tile Toilets Kitchen
Doors	Exterior - hollow metal Interior fire doors - hollow metal Interior - solid-core wood

BUDGET SUMMARY

1.	SITE WORK	$	755,371	$	755,371
2.	CONSTRUCTION - Research Building		6,491,200		
	Plumbing		313,550		
	Heating		202,370		
	Electrical		924,950		
	Ventilating and Air Conditioning		1,473,900		
	Temperature Controls		384,550	$	9,790,520
3.	LABORATORY SERVICES				
	Electrical	$	602,450		
	Piping Services		334,900	$	937,350
4.	FURNISHINGS				
	Laboratory benches, sinks & cabinets (including shops)	$	508,565		
	Office Furniture		209,092	$	717,657
5.	UTILITIES			$	2,475,576
	SUB TOTAL			$	14,676,474
6.	HOUSING FOR VISITING STAFF	$	973,000		
	Furnishings		150,000	$	1,123,000
	TOTAL			$	15,799,474

SCHEDULE OF AREAS ON INSTITUTE PLANS

	Gross Area in Sq. Ft.	
Mathematical research	28,820	
Physical and instrumentation research	121,490	
Chemical research	5,750	156,060
Library stacks, workrooms and stroage	61,840	
Auditorium, lobby and cloak rooms	26,600	
Cafeteria and kitchen services	11,300	
Seminars and classrooms	10,570	
Shops and instrument laboratories	36,110	
Computer laboratory and data storage	21,200	
Fluid mechanics laboratory	11,410	
Administrative spaces	35,890	214,920
Sub Total		370,980
Maintenance shops and garages	10,250	
Boiler plant	9,230	19,480
Specially paved roof area	10,400	10,400
Residence hall	40,000	
Summer residence units	10,250	
Year-'round residence units	12,650	62,900
Total		463,760

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	Area in Sq. Ft.
Useful gross area of laboratory building	337,141
Basement utility area	33,900
Unassignable service and access spaces	55,100
Efficiency of use	73.6%

Unit Costs

To serve as a more general basis for comparisons the unit costs of the laboratory constructions estimated above are listed below:

UNIT COSTS OF CONSTRUCTION

	Unit Cost of 370,980 ft^2 of Enclosed Space	Unit Cost of 381,380 ft^2 of Useful Space*
Laboratory building with basic utilities (Cost $7,932,070)	$ 21.38/ft^2	$ 20.80/ft^2
Laboratory building with all designed services, site work and basic furnishings (Cost $14,676,474)	$ 39.56/ft^2	$ 38.48/ft^2
	Unit cost of 453,360 ft^2 of Enclosed Space	Unit cost of 463,760 ft^2 of Useful Space*
Total construction with basic utilities, site work and visitor's housing (Cost $12,136,017)	$ 26.77/ft^2	$ 26.17/ft^2
Total construction with all designed services, visitor's housing and basic furnishings, but without scientific apparatus (Cost $15,799,474)	$ 34.50/ft^2	$ 34.07/ft^2

These estimates are consistent with the unit cost of similar laboratory construction.

Considering that present planning has required intensive effort during four months and that during this time none of the detailed engineering required for actual construction has been attempted, it may well be necessary to allow a full and busy year for planning and engineering after a site has been selected for the Institute.

* Useful Space includes that portion of the roof specially paved for installation of experimental equipment.

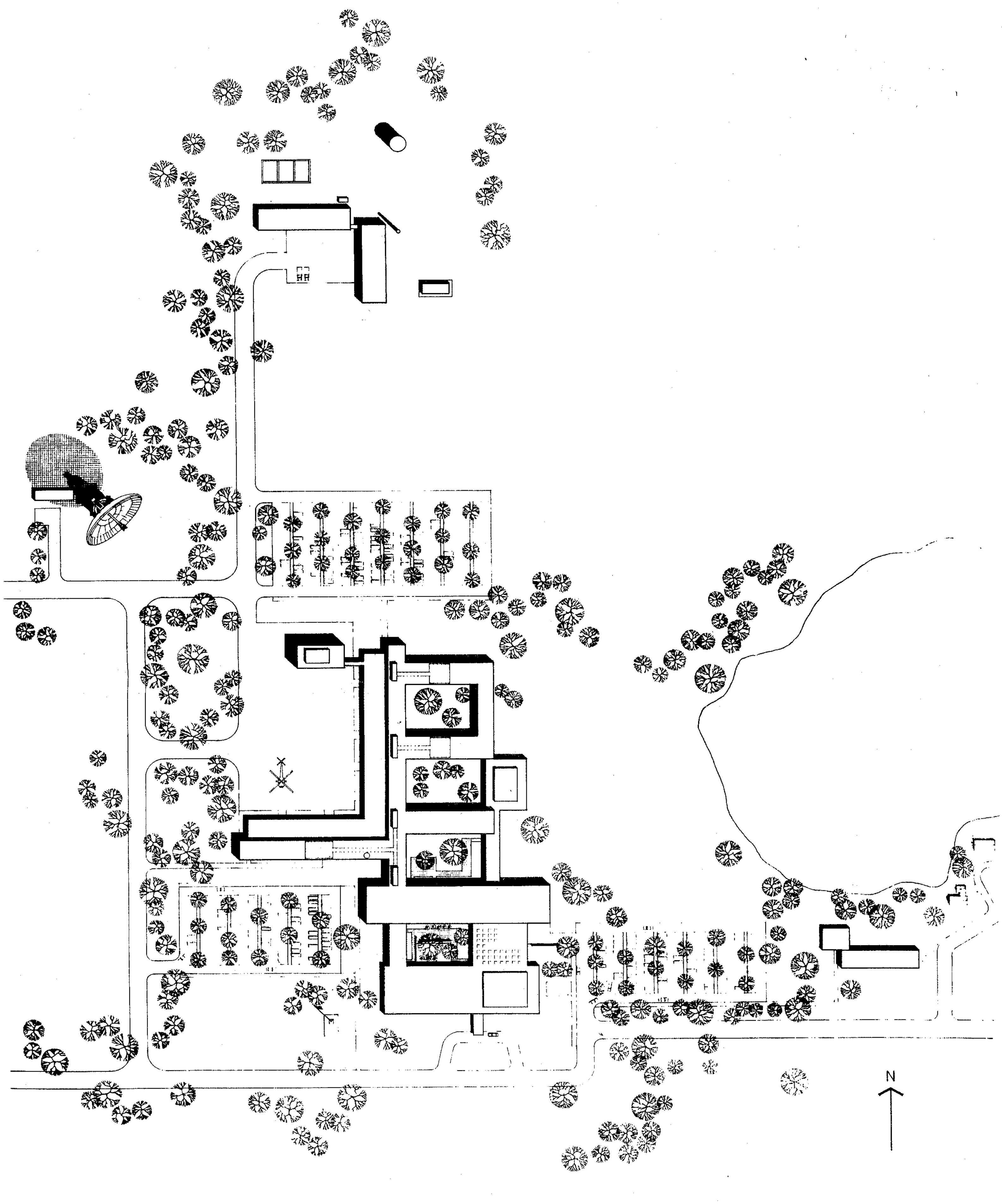
Phasing of Construction

An estimate of the feasible rate of progress in construction of the Institute building has been obtained from the George A. Fuller Company of Boston. Accurding to this estimate the construction can be accomplished in the course of 21 months, with limited occupancy being possible after the 17th month. This schedule allows one month for contingencies and an additional month for final adjustments of utilities systems and structural corrections. The schedule of monthly costs to construct the Institute, without visiting staff housing or allowances for utilities lines being run across the Institute property, is estimated as follows:

SUMMARY

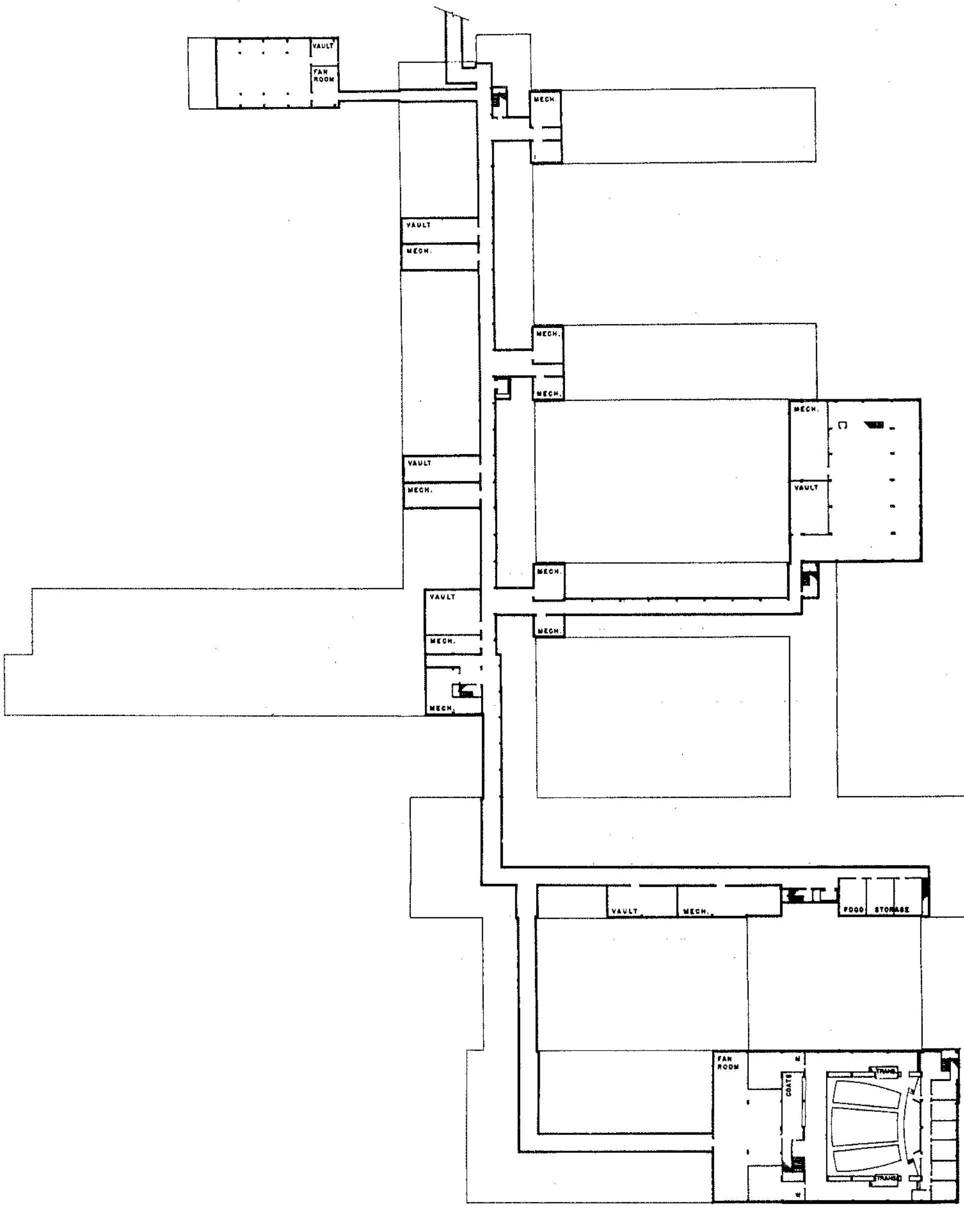
Month	Anticipated Monthly Payments
1	145,297.00
2	427,085.00
3	929,021.00
4	1,066,980.00
5	1,212,277.00
6	1,256,306.00
7	1,292,997.00
8	1,339,962.00
9	1,337,027.00
10	1,325,286.00
11	1,093,397.00
12	942,230.00
13	688,327.00
14	515,144.00
15	422,682.00
16	333,156.00
17	110,074.00
18	93,929.00
19	76,318.00
20	38,159.00
21	30,820.00
Anticipated total cost	$14,676,474.00

It should be remembered that prior to construction a period of at least 12 months will be required for the preparation of engineering and architectural drawings and for majing major decisions. During this year 25% of the architectural and engineering fees are due at the end of 4 months, an additional 50% at the completion of the year's design period. The remaining 25% is usually spread across the 21-month construction period as a direct function of the monthly costs of construction. An allowance of approximately 8% of total costs will be required to cover professional services in architecture; structural, service and special facilities engineering; and a model study of the site to assure proper clearances in the placement of outdoor research facilities.

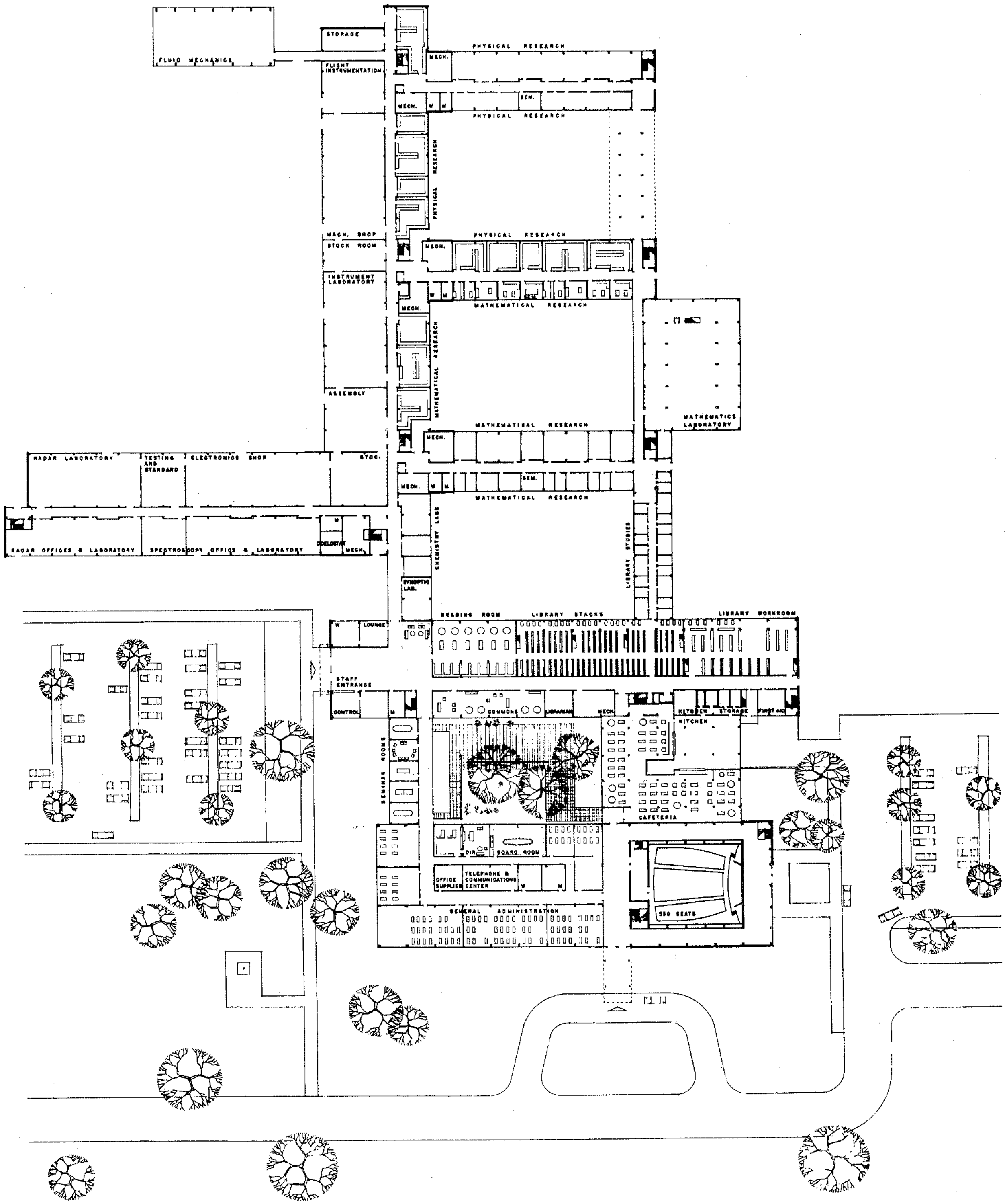


INSTITUTE FOR ATMOSPHERIC RESEARCH

PRELIMINARY STUDY
SITE PLAN SCALE 1" = 80' 6 JANUARY 1959
ANDERSON BECKWITH AND HAIBLE ARCHITECTS BOSTON MASSACHUSETTS

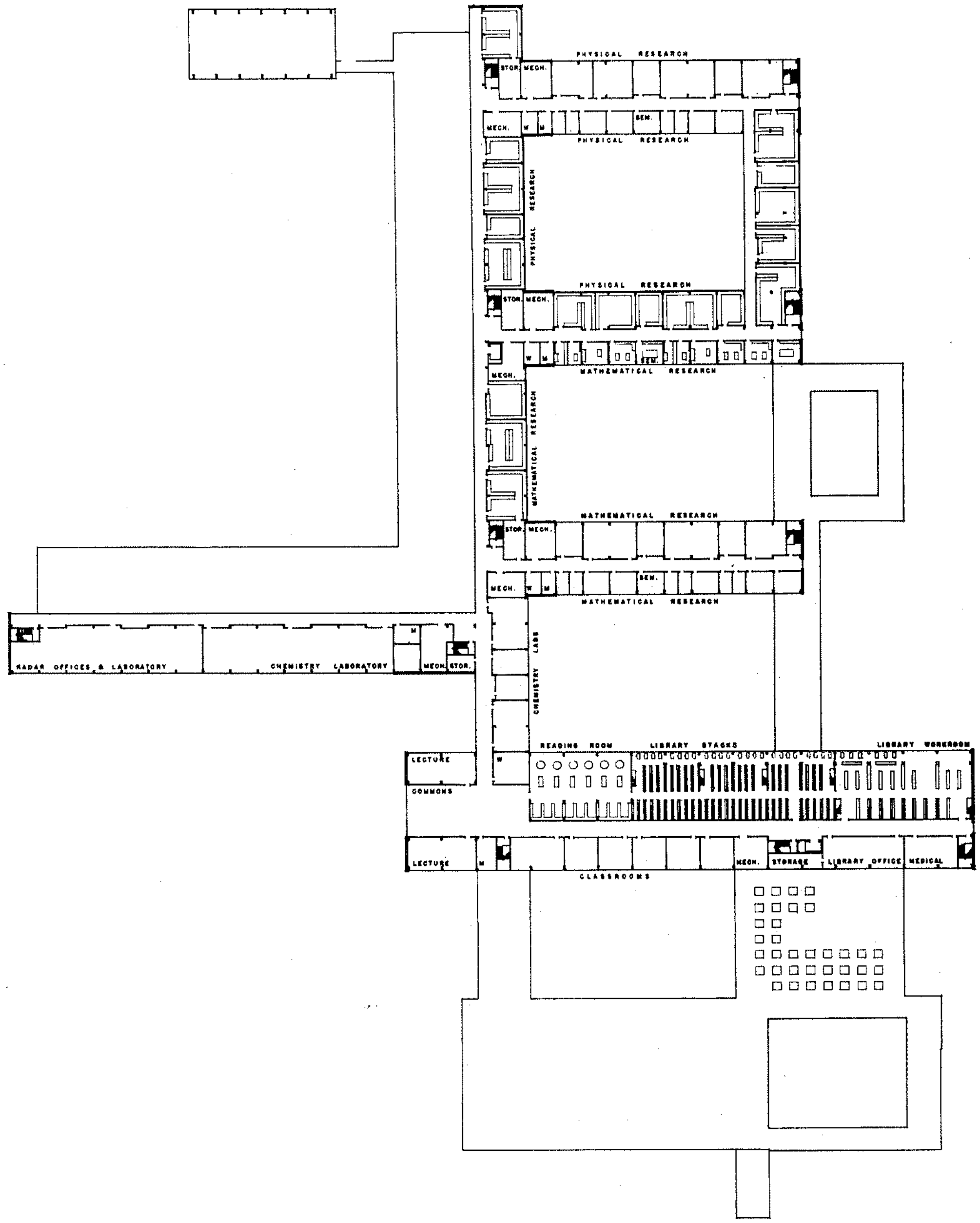


INSTITUTE FOR ATMOSPHERIC RESEARCH
PRELIMINARY STUDY
BASEMENT PLAN SCALE 1" = 40' 6 JANUARY 1959
ANDERSON BECKWITH AND HAIBLE ARCHITECTS BOSTON MASSACHUSETTS



INSTITUTE FOR ATMOSPHERIC RESEARCH

PRELIMINARY STUDY
FIRST FLOOR PLAN SCALE 1" = 40' 8 JANUARY 1959
ANDERSON BECKWITH AND HAIBLE ARCHITECTS BOSTON MASSACHUSETTS



INSTITUTE FOR ATMOSPHERIC RESEARCH

PRELIMINARY STUDY
SECOND FLOOR PLAN SCALE 1" = 40' 8 JANUARY 1959
ANDERSON BECKWITH AND HAIBLE ARCHITECTS BOSTON MASSACHUSETTS

APPENDIX A

RESEARCH AND EDUCATION IN METEOROLOGY

An Interim Report of the

COMMITTEE ON METEOROLOGY

to the

National Academy of Sciences

National Research Council

Washington, D. C.

January 25, 1958

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Committee on Meteorology

National Academy of Sciences

Lloyd V. Berkner, Chairman
Associated Universities, Inc.

Horace R. Byers, Vice Chairman
University of Chicago

Henry G. Booker
Cornell University

Jule G. Charney
Massachusetts Institute of Technology

Hugh L. Dryden
National Advisory Committee for Aeronautics

Carl Eckart
Scripps Institution of Oceanography

Paul E. Klopsteg
National Science Foundation

Thomas F. Malone
The Travelers Insurance Companies

Edward Teller
University of California

The Committee suffered a grievous loss during 1957 in the untimely death of two of its most distinguished members, Dr. John von Neuman and Dr. Carl G. Rossby. Both men had made monumental contributions to progress in meteorology. As co-chairman of this Committee, Dr. Rossby had participated in the deliberations of the group with the zest, the vigor, and the rare insight that had long since earned for him a pre-eminent position in meteorological research and education.

Preface

The Committee on Meteorology was organized by the National Academy of Sciences in April, 1956 for the purpose of bringing together scientists from meteorology and related physical and geophysical fields to view in broad perspective the present position and future requirements of meteorological research and to recommend the general outline of a program which would accelerate progress in this important field.

Very early in the deliberations of the Committee, it was recognized that the question of progress in meteorological research was inseparably linked to the problems of meteorological education and manpower. Ultimately two working groups were appointed to study in detail these two aspects of the central problem of progress in meteorology.

A series of six full Committee meetings was held during 1956 and 1957. The pattern of these meetings was soon established. It consisted of a judicious mixture of discussions within the Committee and conferences with active research workers in meteorology and related fields. Several sessions were devoted to an exchange of views with prominent educators in the general area of the earth sciences. The subjects covered in the technical conferences ranged all the way from current investigations on aurorae, ionospheric variations and tides in the upper atmosphere, through studies of the general circulation of the atmosphere and numerical weather prediction, the discussion of exchange processes at the air-ocean interface, and on to recent measurements of temperature and salinity at great depths in the Atlantic Ocean. By meeting at such widely separated points as the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution on the East Coast and Scripps Institution of Oceanography on the West Coast, and at research centers in between, the Committee attempted to take the pulse of atmospheric research activity in this country.

In addition, the working groups on research and on education or their representatives visited as many centers of research and education as possible and held conferences with many individuals and small groups.

From this intimate contact with meteorological activity in this country, the Committee has attempted to distill its impressions and summarize its findings and recommendations in the report which follows. The experience has been a stimulating one. The Committee is unanimous in its belief that entirely new horizons of knowledge are opening up in the study of our atmospheric environment. If the recommendations of our group will materially assist in the exploration of these dimly seen horizons and provide the impetus for a more vigorous assault on the important and fundamental problems in meteorology, the Committee will feel that its mission has been accomplished.

Acknowledgements

Without the encouragement and support of the Department of Commerce, and particularly of Under Secretary Louis S. Rothschild, the task to which this Committee addressed itself would not have been started. Of special importance in initiating the work of the Committee was the foresight of Dr. Francis W. Reichelderfer, Chief of the United States Weather Bureau, who pointed out the need for an appraisal of progress in meteorology in relation to advances in related fields and a consideration of the possibilities for hastening the orderly advance in this field by examining the nature and the scope of the research effort in relation to the nature and scope of the problems to be solved. The mature counsel of Dr. Reichelderfer and of Dr. Harry Wexler, Director, Office of Meteorological Research for the Weather Bureau, was of great assistance to the Committee during its deliberations.

Mr. John R. Sievers, Executive Secretary of the Committee, performed the task of gathering the material for the parts of this report dealing with manpower and education. This work included direct visits to most meteorological educational centers in the country.

Dr. William K. Widger, Chairman of the Committee on the Encouragement of Meteorological Research of the American Meteorological Society, graciously made available to the Committee preliminary results of a survey undertaken by his committee to determine what can and should be done to accelerate the research effort in meteorology. Mr. Kenneth C. Spengler, Executive Secretary of the American Meteorological Society, very kindly cooperated in providing information on manpower in meteorology being assembled by his office.

Finally, the warm thanks of the Committee go to the large number of meteorologists and other scientists who gave so generously of their time and knowledge in discussing their researches with the Committee.

In setting forth our analysis of the problems and our recommendations, we have attempted to take cognizance of the views of the individuals with whom we have consulted. Ultimate responsibility for our findings must, of course, rest with ourselves.

Introduction

In meteorology we are confronted with one of the most difficult, most important, most challenging -- and yet relatively one of the most neglected -- scientific problems of our times. It is a sad commentary on the intellectual maturity of our generation that it is necessary to emphasize the fact that the problems of meteorology are scientific problems. Somewhere along the way from the fundamental study of the atmosphere as a complex physical entity to the practice of weather forecasting, as brought to us by the modern media of communications, there has been a tendency on many sides to lose sight of the basic scientific nature of meteorology. In point of fact, the atmosphere was man's first scientific laboratory -- the milieu in which early scientists could and did observe practically all of the phenomena studied in the physical sciences today.

The first optical, acoustical, chemical and electrical phenomena were studied in their natural setting -- the atmosphere. Nucleation, condensation, precipitation, evaporation and ablation were observed and noted originally in connection with the phase changes of water in the atmosphere. Before the concepts of convective, conductive and radiative heat transfer had been formulated mathematically, they were studied in the air about us. The entire scale spectrum of hydrodynamic motion, ranging from minute turbulent eddies in the air at our feet to global patterns of vorticity miles above the ground, has long awaited a satisfactory explanation. Boundary problems, questions concerning the mechanism by which momentum, heat and moisture pass across the interface that separates the gaseous envelope of air from the underlying water and land, complicated thermodynamic processes characteristic of open systems, chemical, photochemical, and electrochemical processes -- all these and many more subjects encompassed by the physical sciences can be studied in their natural habitat if we but care to note them.

Adding zest to the search for new knowledge in the realm of classical physics through the study of the atmosphere is the fact that nature has artfully concealed the bits and pieces that make up the mosaic of a full and complete understanding of the atmosphere and why it behaves as it does. It is not possible to reduce the complex physical phenomena of the atmosphere-earth-ocean system in their entirety to laboratory size and subject them to detailed analysis. Moreover, our ability to observe all the elements that make up this complicated, many-variable system is so limited that we cannot describe it in all its ramifications at any given instant of time. The scientific search for knowledge must proceed by a process of successively examining the clues that a reluctant nature yields to the persistent scientist.

These clues may emerge from the discovery of a spectral line emitted by matter one hundred miles above the ground, or from the discovery of a jet stream coursing around the globe like a meandering river. The clues may arise from observations of temperature in clouds that yield showers in the tropics, or the discovery that if certain kinds of meteorologically irrelevant wave motions are mathematically filtered out of the equations that describe air movement, a better description of the future course of planetary wind patterns results. They may be in the fragment of geologic evidence that permits us to reconstruct the climate of a million years ago and thereby improve our knowledge of climatic forces today, or in the observation that ocean spray leaves "giant" sea-salt nuclei in the air about which condensation and cloud droplet growth proceed with relative ease. The list is virtually inexhaustible.

Nor are these clues gathered at random. Some are uncovered by chance, but more often than not, they are revealed by the systematic, painstaking application of the knowledge and tools contained in the storehouse of understanding of natural physical laws that represents the point of departure for scientific inquiry in all fields. As an example, we may mention that the systematic investigation of anisotropic turbulence in the atmosphere must be a necessary part of any attempt to understand large-scale atmospheric motions.

And yet the tilling of this fertile intellectual field has been left to a relatively few workers. This is surprising on two counts: the intellectual challenge entailed in the study of the atmosphere is undeniable, and the accomplishments of researchers in this field have really been remarkable. Why meteorology is relatively neglected is of interest, but of greater import are the steps that must be taken to bring more workers into the field. The rewards of personal satisfaction in adding to our fund of knowledge are great. Moreover, the stakes are high as the intellectual aspects of the cold war assume increasing importance in winning and holding the respect and confidence of the peoples of the world. By comparison with fields of technology, currently receiving great attention, in which the basic research has given way to engineering refinement and development, meteorology holds great promise as an area in which the opportunities for fruitful basic research are almost unlimited.

Nor is the atmosphere the setting for physical processes only. It is also the milieu for every biological process on the face of the earth. It is, indeed, the environment into which we are born; it is the environment in which we live and carry on our multifarious human activities; and it is the environment which each year claims some of our kind before their normal life expectancy has been reached. From such a point of view, a proper understanding of this milieu takes on enormous economic importance. Do we wish to fly an airplane? Do we wish to grow a crop? Do we wish to ship perishable goods in an unheated or unrefrigerated conveyance? Do we wish to sail a ship? Do we wish to live securely by the ocean's edge or on the rich flood plain? Do we wish to regulate our supply of natural gas at the source so that homes will be heated and complicated gas transmission system will be efficient? Do we wish to enjoy outdoor recreation? Do we need to fight a battle? Do we -- but the list is endless. The value of applying our still admittedly incomplete knowledge of the atmosphere to climatic analysis and weather forecasting has been placed at more than a billion dollars a year.

While weather forecasting is but one aspect of meteorology, it is the crucible in which our understanding of the atmosphere and its mode of operation is tested. To the extent that we cannot observe and cannot understand and cannot explain atmospheric processes, our forecasts of the future consequences of these processes will be imperfect -- and the poorer our understanding the less perfect the forecasts. By the same token, however, increments of knowledge will mean increments of accuracy and, superimposed on the by-no-means negligible level of current accuracy, each increment of improvement in weather prediction will have increasingly greater economic significance. Ultimately, it may be expected that business, industry and agriculture will adjust their activities to utilize dependence on weather rather than seek to avoid dependence on weather. Agricultural planning is only one example of such an activity. One is led to the inescapable conclusion that our nation's best economic interests require a more active attention to the meteorological problem. Indeed, the question might well be raised, "Can we afford not to?" The petroleum industry estimates that a modest improvement in long-range temperature forecasts would be worth one hundred million dollars a year through more economical operations. Considerations such as these could be multiplied many times in support of the argument that there are potentially great economic returns from an investment in meteorological research.

A more somber note can be struck that gives even further urgency to plans for extending our scientific studies of the atmosphere. This has to do with recent, very limited, success in achieving a measure of control over the weather under certain specified conditions. Because there are almost certain to be misconceptions in the public mind on this score, the Committee wishes to be unmistakably clear on the matter. It would be an inexcusable distortion of presently available knowledge and a grievous violation of trust for this Committee to seize upon the single issue of weather control to argue for an expansion in the meteorological research effort in this country. To start a crash program aimed at achieving a significant measure of control over large-scale weather patterns during the next few years is unrealistic in the light of currently available information.

This does not mean, however, that the question of weather control should be excluded from the evidence pertaining to a re-examination of our national effort in meteorological research. Quite the contrary.

There have been several achievements in weather control during the last decade which, coupled with a remarkable increase in the magnitude of energy which man can control, have raised the probability of weather control by several orders of magnitude. Among the most important of these are: (1) the demonstration that under very special conditions, it is possible to produce a perceptible local increase in the precipitation from clouds; (2) the demonstration that under very special conditions, it is possible to dissipate the cloud cover over an appreciable area; and (3) the demonstration that the rate of evaporation from a free-water surface of modest extent can be significantly reduced by spreading a monomolecular layer of an evaporation-inhibiting fluid over the water surface.

Now the road that leads from the type of local weather control represented by these results to control of large-scale weather patterns is long and winding and there very well may be insurmountable road blocks that would halt the would-be-traveler. Of one thing we may be sure: the kind of research required to find out whether or not such road blocks exist is precisely the kind of fundamental research that is required to satisfy the intellectual and economic arguments advanced earlier. Specifically, before it will be possible to ascertain the extent to which alteration of natural weather processes is possible in any given instance, it will be necessary to be able to state in quantitative terms what would have happened if man had refrained from interference in that instance. This clearly implies precision in weather forecasting greater than has been achieved up to the present time.

It even appears likely that the feasibility of large-scale weather control will depend in no small part on the ultimate limitations on the predictability of weather. If the tendency of small causes to grow to large effects in the atmosphere is sufficiently marked to impose rather severe limitations on predictability, it is conceivable that weather control could be achieved rather readily by influencing these small causes. Naturally, the consequences of such attempts at influence in the incipient stage would have to be known before control could be achieved in the true sense of the word.

Actually, then it is not necessary either to raise the specter of the use of weather control as a weapon or to hold out high hopes of great peacetime benefits that might be reaped from such activities to justify more attention to meteorological research, since it can be amply justified on other grounds. Certainly, research on some aspects of weather control is an appropriate part of an expanded research program in meteorology, but to justify the program solely on that ground or to let weather control studies as such, dominate the program would be unwise. There are substantial fields of scientific investigation in cloud physics, atmospheric radiation, and atmospheric circulation which can be expected, in time, to establish the nature of the physical processes in the atmosphere that will, in turn, shed light on the scientific basis for weather control.

It is well to bear in mind, as supporting rather than primary evidence, that even though the probability of achieving large scale weather control in the foreseeable future is small, the implications should it be achieved are very great. Beyond the foreseeable future it is likely that man will one day exert significant control over his environment. It may be noted that hastening that day will be a by-product rather than an end in itself to the recommendations of this Committee.

It is apparent from the discussion above that there are a battery of good and sufficient reasons for a vigorous assault on problems concerned with an improved understanding of our atmospheric environment. Before proceeding to recommend just how this might be accomplished, it is in order to examine the present position in meteorological education and research. To view this position with the proper perspective, a very brief account of some of the highlights in the historical development of meteorology will be presented.

Some Highlights in the Historical Development of Meteorology

It has already been remarked that the atmosphere was man's first scientific laboratory. It is not surprising that the first scientific treatise on the subject was prepared by Aristotle about 350 B.C. What is significant is that the emphasis on intellectual pursuits in Greece at the time of Aristotle gave rise to a work which was to stand as the authoritative treatment of the subject for nearly two thousand years. In fact, it was not until a local government under Ferdinand II of Tuscany again gave encouragement to scientific work in the seventeenth century that further significant progress was made. The breakthrough here was the invention of the thermometer by Galileo and of the barometer by Torricelli. Thus began the quantitative era in meteorology.

During the next two hundred and fifty years, the study of weather was closely allied with basic scientific work -- in fact, much of the scientific work of the times was concerned with the science of the atmosphere. Although weather prediction was attempted as early as 1820, it was not until the invention of the telegraph in about the middle of the nineteenth century that it became a practical endeavor. With the development of organizations primarily responsible for collection of weather data and preparation of weather forecasts in the latter part of the nineteenth century, a gradual schism developed between science and meteorology. This schism was by no means complete, nor was it as pronounced in Europe as it was in the United States. It had the effect in this country during the early part of the twentieth century of reducing the work of the meteorologist almost to the status of a trade. Meteorology came to be thought of more and more as the practice of weather forecasting and less and less as the branch of science dealing with the atmosphere.

Meanwhile, a fresh approach to the meteorological problem was being developed in Norway under the vigorous leadership of V. Bjerknes. Some of this thinking began to infiltrate into this country and a notable step was taken in 1928 with the establishment of a meteorology course at the Massachusetts Institute of Technology, leading to the foundation of an American school of scientific meteorology. By 1940, this healthy influence had begun to spread into the national weather service, and departments of meteorology had been established in sufficient number to handle, albeit with some difficulty, the strenuous demands for training of weather officers for the armed services that developed during World War II. It may be remarked in passing that had the planting of scientific seeds in meteorology at M.I.T. in 1928 been delayed only a few years, the meteorological effort during World War II would have been irreparably damaged.

The war years were characterized by a preoccupation with the training of large numbers of young men and women as weather forecasters for the armed services. As a result of some remarkable foresight in setting high standards for admission to these training programs, a large number of young people with excellent backgrounds in mathematics and the physical sciences was brought into the field. For the most part, however, their contact with meteorology was restricted to weather forecasting and about eighty per cent of them turned to other pursuits when the war ended.

Enough able people remained in meteorology, however, to provide the human resources for an expanded program of scientific investigation in the post-war era. The number of colleges and universities offering professional and scientific education in meteorology was expanded to twenty-two with seven of these schools providing graduate education leading to the doctorate in meteorology. Two important factors in the expansion of the academic effort in meteorology have been the continuing manpower requirements of the armed services, in particular those of the Air Force, and the sponsorship of research at the universities by the Office of Naval Research and The Geophysics Research Directorate of the Air Force Cambridge Research Center. The modest support for research and education arising out of these military requirements has, surprisingly enough, sustained a level of activity that is quite high compared to the pre-World War II era.

The significance of this postwar effort is twofold. In the first place, some of the scientific aspects of meteorology other than weather forecasting have been receiving badly needed attention. As an example, the rapid expansion in the study of the physics of clouds and the precipitation mechanism may be cited. Much has been accomplished toward a better understanding of the processes by which atmospheric water vapor is converted into rainfall. As might be expected, every bit of new knowledge that is acquired raises a whole series of new questions. But the important thing is that these questions are being asked. In the second place, there has been encouraging progress in attempts to close the gap between theory and practice in weather forecasting. This is best illustrated by the modest success that has been achieved in the use of high-speed computers in solving the equations that relate the motion of the air to its thermodynamic properties of state.

These two illustrations might be supplemented by many more, but they will serve to make the point that in the opinion of the Committee, and, incidentally, of many other thoughtful individuals who have considered the matter, meteorology now stands on the threshold of a truly exciting and productive era -- one in which man's understanding of his environment is about to increase at a rapidly accelerating rate. It is only logical to expect this new knowledge to have many important applications. Moreover, there are new scientific tools, such as radioactive tracer techniques, high-level rockets, radar and earth satellites, which promise to provide entirely new diagnostic aids in probing some of the hitherto unexplored aspects of the atmosphere.

This, then, in barest outline, brings the historical development of meteorology up to the present time. We shall now turn our attention to a more detailed analysis of some of the characteristics of modern-day meteorological research in relation to the nature of the scientific problems that must be solved.

RESEARCH IN METEOROLOGY

The Present Position

The influx of new men into the field during and after World War II, the post-war expansion in meteorological education and the consequent availability of new academic appointments, and the well-managed and far-sighted, although modest, programs in support of meteorological research by the Office of Naval Research and the Geophysics Research Directorate have all combined to provide a strong stimulus to meteorological research since 1945. That these efforts have been fruitful is attested to by advances that have been made in cloud physics and weather modification, the application of radar and aircraft observations to the large-scale investigation of weather systems, and the application of high-speed computers to numerical weather prediction -- to cite three specific examples of developments of scientific leadership in this country.

This resurgence of activity in meteorological research has not been without concomitant problems. Furthermore, there is a strong conviction in the meteorological community that present meteorological research falls considerably short of the effort that not only is possible but is well-justified from scientific, economic, and national security considerations. For example, a little over a year ago the Council of the American Meteorological Society took the following action, as recorded in the minutes of their meeting on October 22-24, 1956:

> "Voted, that the Council believes that meteorological research is not progressing at the rate actually made possible by recent technological developments and advances in related fields; accordingly the Council directs the Committee for the Encouragement of Meteorological Research (operating, if necessary, within a broadened statement of its function) to study the problem of increasing the total research effort, to diagnose the present limitations of the rate of research progress (e.g., inadequate support, lack of variety of sources of support, lack of incentive or attractive positions, lack of trained personnel, inadequate facilities, poor working relations with fellow physical scientists), and finally, to recommend to the Council any key actions that it might take to encourage an increase in the research effort or to remove impediments to progress."

Studies by the Society's committee have been going on during the past year and, although they have not yet reported back, the Academy's Committee on Meteorology has maintained liaison with them.

At the present time, the major source of support for meteorological research in the United States comes from the Defense Department and is provided by contract arrangements with the universities. A certain amount of research is carried on within the Defense Department primarily in the Geophysics Research Directorate of the Air Force Cambridge Research Center, in the Army Signal Corps, in some Navy groups, and within the Department of Commerce in the United States Weather Bureau. For the most part, the research of the universities is in the form of relatively small project-type efforts and the total sum of money involved is <u>less than three million dollars a year</u>. Currently, there is one major project under way, the National Hurricane Research Project, a cooperative undertaking of the United States Weather Bureau and the Department of Defense. Continuation of this project was in serious jeopardy for several months following the end of the 1957 hurricane season in the North Atlantic and at the moment, only one more year of active life is foreseen.

Some Meteorological Problems of Current and Potential Importance

In seeking ways in which the meteorological research effort might be strengthened and the rate of progress accelerated, it is necessary to consider some of the meteorological research problems and the implications of a concerted effort to solve them. Among the problems which are of basic importance to meteorological science as a whole, and in which an increased effort can be expected to yield important new discoveries, one may list the following:

1. The application of large-scale, high-speed electronic computers to the study of atmospheric dynamics. The knowledge gained from such a study can be expected to lead, as a by-product, to improve methods of short and long range weather prediction.

2. The investigation of energy transfer processes in the atmosphere, such as:

   a. the phase changes of water substance (cloud physics).

   b. turbulent transfer of heat and momentum (especially turbulent exchange at the air-earth and air-ocean interface.

   c. heat transfer by long and short wave radiation.

3. The study of physical climatology. Once reasonably satisfactory solutions of the problems of large-scale atmospheric dynamics and of atmospheric energy transfer have been obtained, it should be possible, with the aid of electronic computers, to formulate a purely physical theory of our present climate. This would open the way to a rational study of weather modification and of paleoclimatology.

4. The general circulation of the oceans. An understanding of the ocean circulations is a prerequisite to a physical explanation of climate since the atmosphere and the oceans form a linked dynamical system; changes in the surface temperatures of the oceans produce atmospheric changes, and these, in turn, produce changes in the ocean circulations.

5. Upper air studies, especially those involving the interrelationships of the energetics of the upper atmosphere, its motion and motion of the lower atmosphere. This is at present a poorly explored field and one in which collaboration between meteorologists and upper atmosphere physicists may be expected to have fruitful consequences.

6. The development of instrumentation for the precise measurement of physical phenomena in the atmosphere. The utilization of such

devices as radar, aircraft, rockets, and satellites will undoubtedly yield much new and valuable information about the behavior of physical processes in the atmosphere. The present effort in this direction is small in comparison with what might be done. Although these devices have been, or will be, used extensively in other applications, so far there has been relatively little work on their meteorological utilization and little research on the purely meteorological design problems.

7. The study of such meso-scale phenomena as tornadoes, squall-lines, and hurricanes. These studies can be greatly facilitated by a more extensive and more systematic use of the powerful meteorological instruments mentioned above. Here the requirement is for a full-scale observational study of the detailed characteristics of the three-dimensional structures of these systems. Enough experience has been gained with the National Hurricane Research Project to evaluate the magnitude of the task and to provide guidance for a greatly expanded effort.

8. The use of radioactive and isotopic tracer techniques for the study of air trajectories and diffusion phenomena in the atmosphere and the water cycle in the earth-ocean-atmosphere system. This field of investigation is in its infancy and can be greatly expanded. The study of the water cycle is made imperative by the need for better understanding and utilization of our water resources.

It should be emphasized that the above list is not intended to be complete. An element of personal choice is inevitable in any such selection. However, this list is sufficiently representative to indicate the scope of the research effort that will be required to solve the most urgent problems of meteorology.

Requirements for a Successful Scientific Attack on the Major Research Problems

Because meteorology encompasses so much of the field of classical physics, it is apparent that considerable interdisciplinary cooperation will be required to solve these problems, especially in view of the high degree of specialization which already prevails in the scientific world. In this respect, meteorological research suffers at the present time, probably because, even in the scientific community, meteorology has come to be associated with the practice of weather forecasting. In point of fact, the tendency in meteorological research has been away from interdisciplinary effort rather than towards it, as evidenced by the separation of studies in the upper atmosphere from studies in the troposphere.

Another requirement for substantial progress toward a solution of the scientific problem of meteorology is that the scale on which research is conducted must be commensurate with the scale of the problem. The atmosphere is a huge system and the facilities to study that system must be on a large scale. For example, in research to understand the inherent nature of a hurricane, a line squall or a tornado, the diagnostic tools include elaborate radar systems, aircraft functioning as meteorological probes, and networks of observing stations. Indeed, so important is the task of describing what is going on in the atmosphere that one of the basic research needs is a very general investigation of methods for probing the atmosphere. There is a serious danger that our desire for observational material and our ability to use such data may soon outstrip our technical capabilities, and quite likely, our economic capacity to provide them. Now as perhaps not since the time of Galileo and Torricelli, we need some bold and imaginative thinking in the field of meteorological instrumentation.

Similarly, in research aimed at theoretical analysis of global wind systems in order to understand the nature of large-scale weather patterns, and in phenomenological studies of the atmosphere by modern statistical methods, it is clear that a large-capacity, high-speed electronic computer is becoming almost indispensable. The demand for time on such computers is rising very rapidly and the requirements for speed and storage capacity are already beginning to tax the available commercial facilities.

The global nature of the weather problem and the imminent availability of earth satellites as research tools highly adaptable for studying the atmosphere on a global scale are going to affect the complexity of meteorological research by at least ten-fold.

Three notable characteristics of meteorological research as it is presently being conducted are almost completely incompatible with those characteristics which will be mandatory in the foreseeable future if satisfactory progress is to be made. The first of these is the lack of stability. This deficiency was brought home in painful fashion in the fall of 1957 when government expenditure ceilings resulted in the termination of a substantial number of research contracts at the universities. Besides disrupting the research effort, this unfortunate situation had the more serious consequence of discouraging promising students from entering or continuing in a field in which the continuation of a program, once started, is subject to such uncertainty.

A second characteristic is a tendency towards the fragmentation into excessively small projects of research activities which, by their very nature, require a large effort -- either in degree of instrumentation, in scale of observation, or amount of data gathered -- for obtaining definitive results. This has caused much wasted effort. Of course, much work is and must remain of an individual character requiring small facilities, or perhaps only pencil and paper. But because of the large-scale or global aspects of the atmosphere there must, in addition, be large-scale activities adequately staffed and instrumented. Until such facilities are provided, their lack imposes a serious obstacle to the advance of scientific meteorology.

The third characteristic of the present support of research is a tendency to look upon research projects as a means of fulfilling certain military requirements rather than as an aid in determining military requirements. This aspect of the problem involves the distinction between fundamental research and applied research or development. It should be clearly understood that there is a very specific place, and an important place, for applied research or development. Moreover, the point at which one begins and the other ends is not always clear. Most of the fundamental research carried on during the past decade has been justified as having ultimate application to military problems. If this broad-gauged point of view had not prevailed, there would indeed have been little basic research of any kind in meteorology. With the Department of Defense and particularly the Air Force having, by sheer necessity, to devote its major attention to taking care of military requirements in meteorology associated with existing weapons and tactics, there is likely to develop a weakness in the support of fundamental research just at the time when it is most needed.

Summary of Findings with Respect to Research

The discussion of the preceding section may be summarized as follows:

1. Although substantial advances have been made in recent years in meteorological research and many promising new avenues of exploration have been opened up, the magnitude of the present effort is inadequate to exploit fully the potential which exists at the universities.

2. The lack of stability in the support of meteorological research at the universities has had a deleterious effect not only on the total meteorological research program but also on the attraction of capable students and scientists to work in this field.

3. It is not always clearly recognized whether government support at the universities is for basic or applied research. This situation leads to confusion and frequently results in a bias of the objectives of the research, which is inimical to the conduct of basic research.

4. The nature of the scientific problems that are to be solved requires a broad interdisciplinary effort.

5. The scale of the systems which come under the purview of the meteorologist is so large that the diagnostic tools of the researcher must by necessity involve large, elaborate and complicated equipment.

Moreover, much research needs to be done in devising suitable probes for investigating the structure of the atmosphere and the processes which take place in the atmosphere.

6. While there is great merit in small investigations aimed at exploring specific areas of knowledge, fragmentation of research in meteorology has been carried to such a degree that it is difficult, under present circumstances, to mount the effort required for a fruitful exploitation of knowledge and techniques that have become available during the last fifteen years.

The findings of the Committee lead to the inescapable conclusion that a vastly augmented research effort is required if our national capability for research in meteorology is to be fully exploited and the scientific, economic and military needs met. Recognizing that the bulk of basic research is conducted at the universities, we have directed our first thoughts to find means for effectively increasing the present university research effort. Our assessment of the nature and importance of the problems being investigated, the means for pursuing these investigations, and the conditions under which the investigations are made lead to the first recommendation:

Recommendation 1

Present support for meteorology at the universities and kindred institutions should be increased immediately by fifty to one-hundred percent, to be directed toward support of basic research. The Committee recommends that the increase be sought primarily from federal agencies which support basic research, with assurance of stability of such support.

The above recommendation is deemed to be fundamental; yet the Committee does not feel that essential research objectives in meteorology can be met if this recommendation is carried out in its entirety. More is required than the simple strengthening of existing institutions. Indeed, the Committee believes that such a strengthening will take on its true significance only if additional means are found at the same time to tap the far larger reservoir of scientific manpower that exists in the parent fields of the basic sciences -- physics, chemistry and mathematics -- and to provide the research facilities of a size and scale commensurate with the global character of the problem. The Committee, therefore, makes the following additional recommendation:

Recommendation 2

A National Institute of Atmospheric Research should be established.

This Institute should have the following characteristics:

a. It should constitute a center of intellectual activity that would bring together scientists from meteorology and the related physical sciences. To assure maximum benefit and effects in the education and training of graduate students, the Institute should be located in closest possible proximity to a university or universities having established graduate schools with strong departments in mathematics and the physical sciences.

b. It should provide research facilities on a scale required to cope with the global nature of the meteorological problem. These facilities would include modern scientific and technological tools such as a large-scale, high-speed electronic computer, a meteorological flight squadron, a laboratory for fundamental research on techniques for probing the atmosphere by electromagnetic radiation, and a laboratory for fundamental research on the use of satellites and rockets as probes of the atmosphere.

c. To assure the free movement of scientists between the Institute, the universities, and government agencies, it should be independently operated by a corporation sponsored by a group of universities under a prime contract with the National Science Foundation. The support of government agencies having interest in meteorology is highly desirable but should be arranged through a single contract and coordinated by the National Science Foundation.

d. Support should be provided at a level which would permit a capital investment of fifty million dollars spread over a five year interval and an annual budget of approximately fifteen million dollars at the end of five years.

With able and imaginative leadership and strong support from the scientific community, particularly from the existing meteorological research establishments, such an Institute would appear to be capable of fulfilling many of the needs for augmented research which the existing establishments cannot satisfy. It could at once offer career positions in atmospheric research to non-meteorologists and thus immediately establish effective contact with the parent sciences; it could engage in research activities which are not now encompassed by existing departments; it could maintain large research facilities which are not now available to individual departments and which would, in any case, overbalance their research and educational programs; it could provide a stimulating and effectual milieu and meeting place for research workers in allied or interrelated fields. In short, it could serve as the magnet to draw in the outside manpower that will be needed to make the order of magnitude increase in our present research effort, which we believe to be necessary.

EDUCATION AND MANPOWER IN METEOROLOGY

General Statement

If support for meteorological research on the scale recommended by this Committee is achieved, there remains the question of the adequacy of manpower resources in meteorology to meet the growing needs. It soon became apparent in the Committee's studies that the answer to this question must be in the negative. Manpower shortages are characteristic of all the sciences, so the answer was not surprising, but it was found that in many respects the problem is more acute in meteorology than in any of the other sciences. Except for the training of military students, whose excursion into the field is for the most part temporary, the output of meteorologists from the universities is inadequate to meet even the static needs of the science.

Summary of Findings with Respect to Manpower

The results of the Committee's review of the status of manpower and education in meteorology, based on data from current surveys and its own investigations, are given in the report of its working group on this subject reproduced in the Appendix. Some of the characteristics of the manpower situation in meteorology, most of which are peculiar to this science, may be summarized as follows:

1. Approximately 90 percent of the working meteorologists are government employees, civilian or military. This concentration of meteorologists in the Federal Government is not the most effective way to advance the science.

It is well known that careers in the military and civil government services are unattractive to a majority of young scientists. This factor is believed to be one of several which cause students to shun meteorology. Industry is just beginning to realize the advantages that accrue through the employment of meteorologists. The funneling of meteorologists into business and industry would not reduce the numbers available for government service; it would be expected to so increase the attractiveness of the field of meteorology as to make a larger body of young scientists available for all types of duty. A student's initial distaste for government work often is overcome by the time he has been graduated and has become familiar with the caliber of scientific services and research in the government agencies.

2. A disproportionately large number (about 33 percent) of meteorologists is in the 5-year bracket representing World War II veterans who are being followed by a wholly inadequate number of younger men.

None of the other sciences has so unbalanced an age distribution as meteorology. Unless something is done to fill the channel at the source, a sharp-crested wave of manpower will go through the field followed by a disastrous ebb. At the present time, the situation results in an absence of enough young men to fill initial career positions.

3. Salaries paid for meteorologists are comparable with those paid other scientists, and are at the top, on a par with salaries of physicists, for those with doctor's degrees.

This latter fact may be a result of a supply-and-demand situation, as suggested by the next finding.

4. The percentage of meteorologists with doctor's degrees is the lowest of any scientific group.

5. The percentage of persons with no degree at all, who are designated by their employers, by themselves or by their scientific society as meteorologists, is the highest of any scientific group.

This type of finding seems to result mainly from the near-monopoly in the field by the Government, and a lack of qualified career beginners. The U.S. Civil Service practice of: (a) permitting untrained persons to be promoted into essentially professional jobs on the basis of experience in lieu of education, and (b) eliminating the formerly useful distinction between subprofessionals and professionals is largely responsible for this situation. In the far-flung system of field stations of the U.S. Weather Bureau, many of the duties are of a routine nature which can be performed by persons of limited higher education. Lacking a nucleus of young college graduates of reasonable experience and competence, the Bureau puts older men somewhat deficient in educational background into positions of considerable professional standing. Similarly, the Air Force has airmen and the Navy has mates and chiefs making weather forecasts.

From the facts and interpretations given here, it is obvious that not enough students are going into meteorology. The existing educational facilities appear to be adequate to meet the requirements of equalizing the imbalance of manpower. The problem is to get the students; the difficulty is in communicating with the potential students.

Since meteorology is a derived science (derived from physics, mathematics, chemistry, etc.), it is difficult for the student to be in touch with it before he has completed fairly extensive work in the background fields. By that time he may have already decided to become a physicist or a mathematician. The fact that classical physics and applied mathematics no longer are "in style" may aggravate the situation. Furthermore, meteorology is taught only at a few schools and the high school and college curricula hardly make mention of it. The student obtains his impression of the field from the television and newspapers in which the "meteorologist" is pictured as a weather man making pseudo-scientific attempts to forecast the weather.

On a scale in keeping with its limited resources, the American Meteorological Society is currently carrying on a program to stimulate interest in meteorology. The experience and facilities of that organization can be used to improve the manpower situation.

Recommendation 3

It is recommended that the American Meteorological Society take the initiative and responsibility for increasing its activities in stimulating interest in meteorology ten-fold or more, and that, as necessary, it seek federal funds for this purpose, preferably from the National Science Foundation.

The details for carrying it out and costs proposals should be furnished by the Society based on its experience. The objective of this undertaking should not be an attempt to attract all students into the field of meteorology, but to provide them with the opportunity to choose this field if it interests them. Included in the program should be the following activities:

a. Reach students through contacts with schools, through published material and publicity, through television, etc., to stimulate their interest in meteorology.

b. Develop industrial and other non-government career opportunities which would make the field more attractive.

c. Assist high schools and colleges in establishing general courses designed to acquaint students with the field of geophysics, in general, and of meteorology, in particular.

d. Prepare a comprehensive career bulletin on meteorology.

e. Promote the preparation of text material in a unified series on meteorological subjects for high schools and elementary schools. Film material should be included. (See also Paragraph 6 of the following section.)

f. Provide assistance to high schools and colleges, by way of printed material and films, for example, to enable teachers and others to be more effective in their guidance and counseling responsibilities.

Summary of Findings with Respect to Education

The situation with regard to meteorological education, covered fully in the Appendix, may be summarized as follows:

1. There appears to be a need for revision of the university meteorological curricula to embrace the new aspects introduced or envisaged by leading scientists in the field.

Actions taken and trends being followed at M.I.T. and Chicago are examples of the re-orientation needed. At M.I.T. the graduate program has been combined with a special curriculum in the Earth Sciences. As background for specialization in any of the Earth Sciences, including meteorology, the students follow a program in classical physics. A laboratory of the Earth Sciences is the center around which the program is developing. At Chicago, new developments in atmospheric physics and chemistry, including coordination with other sciences, have been incorporated into a specialization in meteorology, with a reduction of the attention paid to standard weather forecasting routines.

2. High schools and colleges need assistance in establishing general courses designed to acquaint students with meteorology as a fundamental and exciting part of geophysics.

3. A general need is expressed for new university meteorological textbooks, but there is no indication of willingness on the part of qualified persons to give up important research and teaching to prepare the required texts unless better support for this type of work is made available.

4. Scholarships and fellowships at all levels are either inadequate or are not playing the part they should in bringing young scientists into meteorology. More predoctoral fellowships might help to increase the number of Ph.D.'s to a proper proportion. On the other hand, of about 900 predoctoral, postdoctoral and faculty fellowships granted by the National Science Foundation in the last six years, only six have gone to meteorologists. This might indicate a general lack of knowledge among meteorological students regarding the extent of the fellowships available in the physical sciences through the National Science Foundation.

5. The Committee finds that meteorology can benefit and has benefited by the attraction of scientists in related fields to turn attention to meteorological research problems that might interest them. Such scientists could be attracted through postdoctoral fellowships.

6. There is much to be done at the levels of the secondary and elementary schools to improve the manpower and meteorological or science education programs. Many of the problems are common to science

as a whole. Text material, career counseling material and direct approaches to students and teachers are necessary. (See recommendation under manpower findings on preceding pages.)

7. The Weather Bureau has an active education program, but to meet new scientific challenges and to improve the general educational level of its employees, these activities could well be expanded.

8. It has been found that there is a desire for the universities with meteorological departments to band together in order to put into effect programs necessary for keeping up with or actually promoting the new surge in the growth of the science which appears to be imminent. Relationships to other sciences are to be considered.

Recommendation 4

Representatives of departments of meteorology at the universities should form an inter-university committee to consider curricula, student recruitment, fellowships and textbooks.

This Committee might:

a. Explore with the National Science Foundation, private foundations and industry the question of adequate scholarship and fellowship support and the full use of available support.

b. Improve and modernize curricula in keeping with the new trends in meteorology.

c. Explore the possibility of alleviating the textbook shortage by obtaining special grants to qualified writers of textbooks so that they may take time off from their teaching duties to do their writing and have income to supplement the small royalties they will receive.

d. Cooperate with the American Meteorological Society in improving contacts with schools and colleges where a source of potential manpower may be reached.

e. Review needs and problems in meteorological research.

f. Offer assistance to the Weather Bureau and other agencies in the improvement of combined educational and personnel situations in these agencies.

Recommendation 5

The Chief of the Weather Bureau should be offered the help of a committee of university meteorologists in the educational and personnel development programs of the Bureau.

A committee consisting of three university meteorologists, one university general educator and a Weather Bureau representative could periodically review the programs and make recommendations for improvements. The committee members should make frequent visits to field stations to encourage and counsel personnel concerning individual and group education programs and to make sure that highly promising young scientists are not left undiscovered. The committee should concern itself also with the personnel actions of the Bureau as they relate to the educational problems, with a view toward the accomplishment, within the Bureau, of a general elevation of the education and professional competence of personnel. Discussions with the Civil Service Commission and others aimed at raising the professional stature in the Government service might be included in the activities of the committee.

Recommendation 6

The university meteorological committee and other interested meteorologists should acquaint themselves fully with the availability of fellowships and scholarships in the sciences, and take the responsibility for providing guidance and direction for well-qualified students to obtain such assistance toward their education in meteorology.

APPENDIX

EDUCATION AND MANPOWER IN METEOROLOGY

Introduction

Since the emergence of commercial aviation in the 1920's, the demand for qualified meteorologists has consistently exceeded the supply. Although some thousands of meteorologists were trained in World War II, only about 20 percent of them remained in meteorology, and within a year after V-J Day, the shortage again appeared. As we approach the close of the decade of the 1950's we find the output of meteorologists from the universities inadequate to meet even the static needs of the science. If the field continues to grow as it has in the past, sharp action must be taken to stop a dilution and a lowering of standards in the science.

Since this Committee holds that meteorology not only must be allowed to grow but must be pushed into a major expansion in research, the problem of manpower and education is of great concern to it. For research, this means quality of personnel as well as numbers.

The first question which faces those who are seriously concerned with the low numbers of students choosing meteorology as their career in science is: "Does this situation reflect existing shortcomings in the science of meteorology, and if so, what should be done to correct them?" In an effort to determine an answer to this question, the Working Group on Education of the Committee on Meteorology conducted a brief study of manpower and education in meteorology.

Information for this study was largely obtained from available surveys, from data supplied through answers to questionnaires sent to universities and colleges and meteorological organizations, from answers to letters of inquiry to individuals and through personal contacts with those persons in the educational, operational and research agencies in meteorology.

Manpower Resources in Meteorology

The National Science Foundation is currently conducting its second survey of the Scientific and Technical Personnel in the United States, based upon the returned questionnaires from persons contacted through the cooperating scientific societies. Results of this second survey should give accurate and more conclusive data on the manpower resources in the various scientific fields than was obtained from their first survey, conducted during 1953-54.

The data presented in this section had to be based primarily upon the results of this first National Science Foundation survey. These findings are modified and brought up to date, in part, where more recent manpower information was available(1).

The distribution of employed meteorologists is given according to the type of employer in Table 1. The total number of meteorologists can only be considered approximate. First, some meteorologists employed by government and private agencies are not included, and secondly, the numbers have been gathered over a period of time, such that the personnel count listed under the agencies does not represent an accurate count at any specific time.

The total number of meteorologists in this survey was approximately 5300, comprised of government employees, military personnel, employees in private meteorology and industrial organizations and universities and colleges. More recent, incomplete data indicate that the figure should be closer to 7000. If the student populations are also considered, there is a potential of perhaps 8000 or more in meteorology. Another 1000 or more technical personnel are employed by meteorological agencies.

Table 1. Distribution of Meteorologists by type of employer and field

Government (Civil Service)	Military	Industry	Colleges & Universities
2464	2327	347	135

Students			Military Reserve	
Civilian	Air Force	Navy	Air Force	Navy
405	214	92	1325[1]	650

1 - About 12 percent of the Air Force reserve personnel are employed in meteorology, science or science teaching and engineering fields.

(1) The American Meteorological Society, Air Force Cambridge Research Center, Air Weather Service, Naval Weather Service and the U.S. Weather Bureau have cooperated in making newer data available for this study.

In Table 2 the age distribution in meteorology and other sciences is given.

Table 2. Percentage age distribution of Scientists

Field	Under 25	25-29	30-34	35-39	40-44	45-49
Astronomers	-	12.1	18.2	12.4	12.1	13.6
Chemists & Chem. Engrs.	0.1	8.4	20.3	23.8	17.4	11.0
Geologists	0.5	12.2	24.1	18.7	14.1	11.0
Mathematicians	2.8	17.0	24.0	17.2	13.1	9.9
Meteorologists	0.4	7.4	19.7	32.7	17.6	12.9
Physicists	0.9	13.5	28.0	18.8	13.3	9.2

Field	50-54	55-59	60-64	65 & over
Astronomers	11.3	5.2	6.7	8.4
Chemists & Chem. Engrs.	7.4	5.0	2.9	1.8
Geologists	7.8	5.5	3.1	3.0
Mathematicians	6.9	3.9	2.6	2.6
Meteorologists	5.4	2.3	0.9	0.7
Physicists	7.3	5.0	2.9	1.8

The number of meteorologists in the age group 35-44 is 50 percent, and 33 percent between 35-39 years...this some four years ago. The key points in this table are reflected in three ways: the percentage of meteorologists in the age group 55-65 years is only about 3 percent compared to an average of about 8 percent for all scientists; approximately 8 percent of the meteorologists are less than 30 years of age compared to an average of about 12 percent for all scientists; the mode for meteorologists stands out very sharply at 35-39 years of age. The influence of World War II training is seen here, and shows the extent to which it has left its mark in the field of meteorology as compared to the other sciences.

Salary information obtained by the National Science Foundation survey (Table 3) revealed that the median annual salary for all meteorologists was $6050, for geologists $7250, and for biologists $6275. Those physicists and meteorologists having a doctorate degree had a high median annual salary of $7850, which is $1450 higher than the lowest median reported, that of $6400 for the astronomers. All other meteorologists were indicated to have a median annual salary of $5975, or $1875 less than those meteorologists with a doctorate.

Many factors are involved in differences in the median annual salaries other than educational attainment, such as age, type of employer by whom the majority of meteorologists are employed, and the functions to which scientists devote a majority of their time.

The level of education of scientific personnel in Table 4 gives the percentage distribution of bachelors, masters and Ph.D. degrees among the scientific fields.

The percentage of meteorologists with a bachelor's degree only is 46 percent, with geologists highest at 56 percent. The lowest percentage of scientists with only a bachelor's degree was among the astronomers and psychologists with 10 and 3 percent respectively.

The variation of the percentage is not so great among those scientists with a master's degree, ranging from 19 percent in the chemists to 42 percent in the psychologists. For the scientists with doctorate degrees, extreme ranges were again encountered. Meteorology is lowest with 8 percent; and astronomers highest with 65 percent. Other scientists showed 47 percent for biologists, 48 percent for chemists, 51 percent for physicists and psychologists with 55 percent.

Compared with an average of 32 percent of scientists employed by educational institutions, only about 16 percent listed their major function as teaching. The highest percentage of teachers was among the mathematicians, 39 percent, and astronomers, 31 percent. Lowest of the percentages of scientists engaged in teaching were the meteorologists, with about 9 percent, and the geologists with about 8 percent.

The percentage of scientists who have as their main function teaching is given in Table 5.

Significance of the Data

The tables show the following characteristics of meteorology which are of interest in relation to the other sciences:

1. Approximately 90 percent of the working meteorologists are government employees, civilian or military.

Table 3. Median Annual Professional Salaries

Field	All employed scientists	Scientists with Ph.D. Degree	All other scientists with less than a Ph.D. Degree
Astronomers	$5950	$6400	$5450
Biologists	6275	6750	5850
Geologists	7250	7675	7150
Mathematicians	6300	6725	5925
Meteorologists	6050	7850	5975
Physicists	7275	7850	6600
Psychologists	5850	6600	4975

Table 4. Level of Education of Scientists (Percent)

Field	Ph.D. Degree	Master's Degree	Bachelor's Degree	Less than Bachelor's Degree
Astronomers	65.2	21.8	10.3	2.7
Biologists	46.6	21.1	32.2	0.1
Chemists	47.8	19.0	31.7	1.5
Geologists	16.6	24.5	55.9	3.0
Mathematicians	42.4	35.3	21.7	0.6
Meteorologists	8.0	22.0	45.9	24.1
Physicists	51.1	25.6	21.6	1.7
Psychologists	55.0	41.8	3.1	0.1

Table 5. Distribution of Scientists who listed teaching as their main function

Field	Percentage of Scientists as teachers
Astronomers	30.8
Biologists	24.9
Chemists	11.4
Geologists	7.7
Mathematicians	38.8
Meteorologists	8.6
Physicists	19.6

2. A disproportionately large number (about 33 percent) is in the 5-year bracket representing World War II veterans who are being followed by a wholly inadequate number of young men.

3. Salaries paid for meteorologists are comparable with those paid other scientists, and are at the top, on a par with salaries of physicists, for those with doctor's degrees.

4. The percentage of meteorologists with doctor's degrees is the lowest and the percentage with no degree at all is highest of any scientific group. The latter statistic results partly from the fact that many persons of limited education are classified by their employers, by themselves, or by their professional society as meteorologists.

5. Teaching is a minor occupation of meteorologists.

In view of the high salaries paid to meteorologists having doctor's degrees, it is surprising that there are not more of them. Perhaps the law of supply and demand is operating. The small number of graduate students obtaining the Ph.D. degree may result from an inadequacy of scholarship and fellowship support. In this connection it is worthy of note that, of about 900 predoctoral, postdoctoral and faculty fellowships granted by the National Science Foundation in the last six years, only six fellowships have gone to meteorologists. This may be a lack of realization on the part of meteorologists of existing opportunities for support.

Evidence that the state of employment opportunities in meteorology is being altered, may be found in the increasing numbers of private weather organizations which have been formed during the past ten years; from 6 in 1948 to 26 in 1957. Also the increasing number of individuals entering industrial firms is noted, and an effort to create a greater interest of industries and business firms in the services of meteorologists is being made.

The tables might suggest that more meteorologists should enter the teaching field, but the present meteorology teacher-student ratio of approximately 1:10 does not indicate a great need for increasing the teacher population in meteorology at this time.

From the facts and interpretations given here, it is obvious that not enough students are going into meteorology. As will be pointed out in the next section, the existing educational facilities appear to be adequate to meet the requirements of equalizing the imbalance of manpower. The problem is to get the students; the difficulty is in communicating with the potential students.

Universities and Colleges

There are at present seven universities which offer graduate training in meteorology leading to the doctorate degree. There are, in addition, four universities which offer the doctorage degree in other scientific fields with an option in meteorology. Another eleven universities offer either undergraduate training, graduate training not at the Ph.D. level, science training with option in meteorology or science training with a special field of meteorology a part of the course of study.

Those universities offering a doctorate degree in meteorology are:

University of California at Los Angeles
University of Chicago
Florida State University
Massachusetts Institute of Technology
New York University
Pennsylvania State University
University of Washington

Those universities offering a doctorate degree with an option in meteorology are:

A. & M. College of Texas
Johns Hopkins University
Oregon State College
St. Louis University

Those universities offering undergraduate or graduate training not leading to the doctorate degree in meteorology are:

University of Arizona
Iowa State University
University of Miami
University of Michigan
University of Minnesota
University of New Mexico
Oklahoma A. & M. University
Rutgers University
University of Texas
University of Utah
University of Wisconsin

An examination of the training program of some additional 100 universities revealed that sketchy elementary meteorology and/or climatology courses are generally available whenever a full curriculum in geography is carried. However, meteorology courses may be given in a variety of departments, ranging from agriculture through geography to marine sciences.

Of the total student population, about seventy-five percent are in attendance at the eleven leading universities having graduate meteorology programs. Of these, approximately fifty-two percent are undergraduate students, thirty-three percent are graduate students working toward their master's degree, and fifteen percent are graduate students working toward their Ph.D. degree. These percentage values can be applied in only very general terms to the student populations. In some universities the total student population is at the graduate level with some 40 to 50 percent of the students working toward a doctorate degree. At other universities, the Ph.D. candidates may be only 5 percent or less of the total students receiving meteorology training.

While the percentage figures of the student level of training at the leading universities is encouraging, in that it suggests a greater number of meteorology students are now continuing into graduate study than might be interpreted from Table 4 in the previous section, a complete evaluation of the status of the meteorology student population cannot be made without some comparative data in the other sciences. Sufficient data have not been obtained for such a comparison at this time.

Departments of meteorology at most universities are in physical plants that are inconvenient or temporary but they appear to be adequate with respect to classrooms, office space, libraries, workshops and instrument laboratories. Their capacity for students is not being taxed and in many cases they could manage an increase in student numbers from fifty to one hundred percent.

With respect to the questions on curricula, all university meteorological staff members who were interviewed indicated their belief that the science of meteorology would best be served if the scope of the teaching programs were broadened. Proposed methods to realize this were: (1) a greater depth in the prerequisite courses of mathematics, physics and chemistry; (2) a greater emphasis of training in physical meteorology, micrometeorology, hydrology, theoretical and dynamic meteorology; (3) a reduced scope in meteorological analysis and forecasting; and (4) a greater effort to emphasize the engineering applications of meteorology.

In regard to textbooks, the entire group was unanimous in stating that deficiencies in textbooks existed in all major fields of meteorology. Physical meteorology was the one field receiving the greatest demand for a better and more up-to-date textbook. Following closely was the need for a new textbook in general meteorology. In approximate order from here were a 'survey' meteorology text; theoretical and dynamic meteorology; a climatology text written for meteorologists; and undergraduate texts on forecasting.

Those who have written textbooks find that the market is too small to provide royalties commensurate with the amount of work involved.

Other comments made with respect to the general field of meteorology education dealt with the philosophical aspects. It was generally felt that better communication between the disciplines of the earth sciences would be an excellent program. But many did not feel that the groups should necessarily be united as a new and distinct organization or department. It was felt that the science of meteorology would not be helped in any way by detracting them from its identity.

A feeling was expressed that elementary teaching of meteorology should be separated completely from the field of geography, for geography has little to contribute to the science of meteorology.

Improved Graduate Programs

The Committee on Meteorology has followed with interest the reorientation of the graduate program in meteorology at the Massachusetts Institute of Technology. The undergraduate major in meteorology has been abolished and only the graduate degrees are awarded. Most significantly, however, the program has been combined with a special curriculum in the earth sciences. As background for specialization in any of the earth sciences, including meteorology, the students follow a program in classical physics, including hydrodynamics, elasticity, plasticity, geomagnetism as well as courses in their special field. A laboratory of earth sciences is the center around which the program is developing. Professor Henry G. Houghton has become Director of the Laboratory of Earth Sciences. A strengthening of the staff in theoretical meteorology and theoretical mechanics has accompanied the change.

At the University of Chicago greater emphasis on specialization in physical meteorology -- high-atmosphere and radiation physics, cloud physics and atmospheric chemistry (including isotopes) -- has been included in the graduate program. It is now possible for a Ph.D. candidate to specialize in one of three branches: (1) theoretical meteorology and hydrodynamics; (2) practical or general meteorology; (3) physical meteorology. A new graduate course in geophysics given in the Department of Geology has attracted some meteorology students and the work in atmospheric chemistry and cloud physics is tied in with courses in chemistry and physics and with research in the Enrico Fermi Institute.

Correspondence Courses

There are ten universities in the United States which are currently offering one or more correspondence courses in meteorology at the college level, but six of these offer only one elementary course in meteorology, some of rather shallow content. One school offers two courses, one each in elementary meteorology and climatology. Three universities offer a correspondence study program consisting of five courses or more. These universities are the University of Oregon (Oregon State System of Higher Education) offering two elementary courses and three advanced courses; the University of Utah which is offering five advanced courses in meteorology; and Pennsylvania State University which offers a total of eleven courses ranging from elementary meteorology through synoptic meteorology, meteorological statistics, to dynamics and physical meteorology. In addition, they offer two courses at the high school level.

Most schools will allow only a maximum of fifteen semester credits earned through correspondence training to be applied toward their bachelor's degree. No university will allow graduate credit to be earned through the completion of a correspondence course.

The problem of allowable credits seems to lie principally in the region of variation in course content to that in a regular university course. Also, there is some question as to the value of a correspondence course in certain fields, particularly in regard to synoptic meteorology. This is a very basic problem which might be taken under consideration by an inter-university committee that was formed with the intent of dealing with problems of this nature.

The question of correspondence courses is of importance in considering the problem of the Weather Bureau in raising the educational achievement level of its employees, as will be indicated on subsequent pages.

Service Schools

The U. S. Naval Postgraduate School, located in Monterey, California, is the only service-operated school in which commissioned personnel may obtain undergraduate and graduate training in meteorology. The Naval Postgraduate School was officially established in Monterey in December, 1951, completing the transfer, which was initiated in 1948, from Annapolis, Maryland.

In 1955, the Postgraduate School was accredited by the Western College Association, and in addition, the Committee on Engineering Schools of the Engineering Council for Professional Development has accredited the curricula in aeronautical, electrical (electronic), mechanical and ordnance engineering.

The curriculum in the department of aerology (Navy term for meteorology) is separated into three divisions. These are the basic, the undergraduate and graduate training programs. The successful completion of the undergraduate program generally leads to the student qualifying for the bachelor's degree. A certificate of completion is awarded those persons satisfactorily completing the basic program. The curricula in the graduate program affords the student an opportunity to qualify for the degree of Master of Science in Aerology.

The number of students attending the aerology training program is about ninety.

The Air Force Training Program in meteorology has, since about 1953, been handled through the various universities. About eleven universities have Air Force students in attendance, totalling about 200 students. Air Force personnel are also sent to special short-term courses offered by Massachusetts Institute of Technology, University of Chicago and the U.S. Weather Bureau. There is still one course in Modern Weather Techniques lasting six weeks, which is being given at Chanute A. F. B., Rantoul, Illinois.

U. S. Weather Bureau Training Program

A brief outline of the Weather Bureau training program is given here to indicate the extent to which this organization is aware of the need for a concerted effort to continuously bring to the employees the opportunities to learn of the new developments in meteorology. This training leads to the improvement in the professional and technical competence, and develops employees which can be of better service to both the Weather Bureau and the communities in which they are located.

In the internal training program there is a four-month refresher course, given twice a year in Washington, D. C., to which key personnel are brought and informed of recent activities and advances in the various branches of meteorology. Special speakers and tours are arranged as part of this training program. This is not a college-type course.

There are also some correspondence courses handled by the training section in Washington.

A Student Trainee Program was initiated in 1951 with the purpose of giving promising undergraduates in meteorology training in Weather Bureau operations. In the summer of 1956 some 23 students participated in this program including two who were graduate students.

Another program consists of sending career Civil Service people with a background in mathematics and physics to the various meteorology schools for one year each for additional training. These persons generally return to their original stations. This program also sends selected individuals to universities for advanced study or research. A variation on this is to assign men to do Weather Bureau research at a university or to supply men to work on some university research project. Weather Bureau personnel are also sent to special classes at universities, such as the two-week summer course in tropical meteorology, and radar meteorology at MIT; to the advanced forecasting course at the University of Chicago, a three month course; and to the one semester course at the University of Miami in radar meteorology.

A new program just beginning is the Federal Service Entrance Examination in which persons with any college degree take a general examination and are placed on the Civil Service list. Based on criteria submitted by the Weather Bureau, the Civil Service Commission selects persons for appointment as GS-5's who are sent immediately to school for one year. Upon completion they return to the field as GS-7's.

Approximately seventy men have participated this past year in the total training programs of the Weather Bureau. This number is expected to expand to 150-200 in the calendar year 1958.

Education and Manpower Activities of the American Meteorological Society

The American Meteorological Society is presently devoting a great deal of time to the problem of interesting students and teachers in the field of meteorology. The materials which they are sending out to persons requesting information fairly well covers the field of meteorology. Such materials include brochures from industries and private meteorologists, special issues of the amateur magazine, "Weatherwise," reprints of articles on topics of interest, maps and other general information on meteorology and the society and its publications.

The results of such a program as this can be evaluated only after a lapse of some time. But from the increased number of inquiries the American Meteorological Society and other meteorology agencies have received, the interest shown by civic groups, children's activity groups both within and without the school area, and business and commercial concerns, it has become apparent that the public is becoming more and more aware of the importance of the atmosphere and its caprices upon their own activities. There is good reason to believe that this interest lies latent in even greater numbers, and such a program that has been undertaken by the A. M. S. should bear increasing response with the passing of time.

The Society also has active committees working on problems in special fields such as radio and TV and industrial meteorology, and problems in secondary and higher education. The common goal of such committees is not only to create an interest in meteorology, but also to maintain the technical integrity of those already in the field. This effort is also concerned in building a good working relationship between the professional meteorologist and the public.

In an attempt to determine the extent to which the various local branches of the A. M. S. are participating in the activities within their own communities and schools, questionnaires were sent to the thirty-five branches throughout the United States and possessions. At the time of this writing, nineteen responses have been received. From the answers given on the questionnaires, five branches have indicated that they have provided speakers to other scientific or civic groups; three have sponsored or participated in science fairs or exhibits; and four have presented one or more radio or TV programs on some facet of meteorology.

In addition, approximately seventy percent of the responding branches invited speakers from other fields to their meetings.

Speakers from the fields of earth science, astronomy, oil and canning industries, statistics, electronics and the press were indicated.

The membership of those branches which supplied information totaled about one thousand, the majority of which were meteorologists, of course. However, some twenty different fields were represented within the membership. Aeronautics, agriculture and astronomy, the natural and physical sciences, education, radio and press, and insurance and engineering were noted. This is a healthy indication of the scope of interest in the field of meteorology, and the extent to which 'outside' contacts can be realized through the many local branches of the A. M. S.

EDUCATION IN ELEMENTARY AND SECONDARY SCHOOLS

Curricula

The science curricula in primary and secondary schools was examined with a view toward determining not only the nature of the science courses taught, but to what extent such courses influence additional interest in the sciences.

In the elementary schools the science program is primarily that of stimulating the child's interest and awareness of his environment, at school, at home, in the park, city and in the country. Most such 'units of learning' are given from the kindergarten through the eighth grade, and range generally from fifty to seventy such units. In most every case, such units were heavily weighted toward the biological sciences (approximately 45 percent). Another twenty percent were devoted to safety and science appreciation. The remaining number of units were fairly evenly distributed over such subjects that might be listed as physics, geology, chemistry, astronomy and meteorology.

The amount of science is, of course, governed in large part by the qualifications of the teachers assigned to a given school during the school year.

Of the some 27,000 high schools in the United States, it has been found that in 1956 approximately 47 percent did not offer a course in physics, and that about 23 percent offered neither chemistry or physics. After an examination of many high school bulletins in which the junior and senior high school curricula were given, it must be concluded that most of the limited science curricula occurred in the small high schools or rural school districts. In every case of high schools located in populated areas, courses in biology, physics and chemistry were given. And in most cases a freshman general science course was required of all high school students.

Science Teacher Training

Money being spent in America to develop scientists would return greater dividends through an equalization of emphasis on the various sciences in the grade school science program and in the science training of future teachers.

In the spring of 1956 only about 250 persons graduated from colleges with training to teach high school physics. Only about one-half of these will find their way into high school classes due to the diversion of the rest into other occupations, military service, or for other reasons. This is clearly a lamentable few to replace teachers who have retired or are lost through death or resignation. This situation is further aggravated by the large increases in enrollment this fall, with the total enrollment nearing 7 million, and expected to reach about 11 million in another eight years. In Chicago alone, the increase of total students in the public schools over last fall is well over 13,000, and the total enrollment nearly one-half million.

With the percentage of new high school teachers in the graduating classes of colleges dropping at a larger rate than the number of graduates themselves, during the first five years of this decade, the schools have had to either use teachers who were inadequately prepared for teaching science, or drop courses that the high school students want and should have. This shortage cannot help but be reflected in the number of students who will be entering scientific careers.

It is only necessary in this report to draw attention to the problem of shortage of science teachers and to endorse the existing programs aimed at relieving the situation. There are more than fifty major private and governmental organizations now active in supporting science teaching and the recruitment of science teachers. The National Science Foundation supports a large-scale system of summer science teacher institutes, numbering 96 such institutes in the summer of 1957. Through these efforts it is hoped that the present trend will be reversed.

High School Counseling

The increase of student populations has created shortages not only in the physical facilities of the schools, in qualified teachers, but seems to have outstripped the counseling programs also. Although considerable progress is being made to correct the inadequacies of the counseling programs, the main work of the persons employed in counseling capacities still consists of dealing with the academic, social and emotional characteristics of the student.

The full-time employment in most of the Chicago high schools of an Adjustment Teacher (academic), Placement Counselor (work and scholarships), Attendance Counselor (social and emotional) and Career Teacher (student testing), indicates the scope of and need for a considerable effort, as recognized by the Chicago School Administration.

However, it was learned that career or college counseling of the individual student was the rare exception. This is most likely due to the shortage of qualified persons, and to the lack of awareness of the high school student that such counseling is available. Also the lack of knowing just how to inquire and what to inquire about may be an important factor. In meteorology, not only do the students indicate a minimum of knowledge of career opportunities, but also, they are not aware of the extent of the science of meteorology beyond the operational or weather forecasting aspects. In view of the history of the science of meteorology, perhaps this should not be too surprising. The type and subject matter of newspaper and magazine articles, radio and TV programs on weather are other important factors here.

The solution to this state of affairs can, of course, encompass many aspects of the structure of the educational program. But what can be done to better assist the high school student in choosing his career in science, with the existing educational program, should be the prime concern at this time.

Another aspect of the problem comes to mind when one contemplates that something like 50% of all high school graduates come from the smaller high schools where the only counseling to be expected would come from the teachers who, in most instances, are probably not qualified to give advice and guidance.

Summary of Broad Educational Problems

Considering the immense scope of the problems which today exist in the field of education from kindergarten through college, it is almost necessary to approach them through the avenues which at this time give promise of returning the greatest good within the shortest period of time. With the continually increasing student numbers, the generally inadequate physical plants of the schools, the shortage of teachers in all grade levels, the shortcoming in the present curricula in schools and in teacher training, and the many other factors which contribute to the over all situation occurring today, certainly any one group cannot hope to correct the basic evils which have lead to these circumstances.

The basic problem of education in meteorology does not consist entirely of the weaknesses in the public schools. It extends also to the need for more and continued education in the roll and influence of the science of meteorology in the personal and professional activities of parents, of the general public, of leaders in business and industry and also of key personnel in governmental offices.

APPENDIX B

RESOLUTION PASSED BY REPRESENTATIVES OF UNIVERSITIES AND KINDRED INSTITUTIONS AT A MEETING IN NEW YORK CITY, JANUARY 31, 1958

To: Dr. Detlev W. Bronk, President
National Academy of Sciences

RESOLVED: It is the sense of the assembled representatives of universities and kindred institutions engaged in meteorological, and oceanographic and related research and teaching that the Interim Report of the Committee on Meteorology of the National Academy of Sciences be endorsed, that present support for basic research in meteorology at academic and related institutions should be substantially increased, and that a National Institute of Atmospheric Research operated by an association of universities should be established to bring together scientists from meteorology and the related physical sciences and to provide research facilities on a scale required to cope with the global nature of the meteorological problem. It is further requested that appropriate organizational steps for establishing such an institute be taken immediately by the National Academy of Sciences acting in concert with the universities and kindred institutions.

Werner A. Baum, Florida State University
Reid A. Bryson, University of Wisconsin
Horace R. Byers, University of Chicago
Phil E. Church, University of Washington
Bernhard Haurwitz, New York University
Solomon Hollister, Cornell University
Henry G. Houghton, Massachusetts Institute of Technology
A. Richard Kassander, University of Arizona
Morris Neiburger, University of California (L.A.)
Hans Neuberger, Pennsylvania State University
Sverre Petterssen, President, American Meteorological Society
Roger Revelle, Scripps Institution of Oceanography

APPENDIX C

STATEMENT BY DR. DETLEV W. BRONK, PRESIDENT NATIONAL ACADEMY OF SCIENCES

Two years ago, with the enthusiastic support of Louis Rothschild, Undersecretary of Commerce, and Francis W. Reichelderfer, Chief of the United States Weather Bureau, I appointed a committee of the National Academy of Sciences to consider and recommend means by which to increase our understanding and control of the atmosphere which profoundly affects our lives and property, our transportation and communications, and all living things. Because of the widespread importance of this committee's studies and recommendations, we are today releasing its report for general publication. In doing so I wish to commend the committee for its tireless efforts to give new consideration to a science which can greatly increase human welfare. During the course of its work the committee suffered great loss through the untimely deaths of two distinguished members, Carl Rossby of Stockholm and John von Neumann.

The report is timely. New developments in physics, chemistry, geophysics, mathematics, astronomy, and space technology provide new tools and new horizons for the science of meteorology. New awareness of the importance of space around us should insure the sympathetic hearing and adequate support for the proposals.

The report makes sweeping recommendations on a large scale. This is as it should be, for the atmosphere is a vast system and the facilities to study that system must be created on a large scale. Accordingly, one of the most important recommendations of the committee is the creation of a National Institute of Atmospheric Research. It is proposed that this Institute, created and supported by Federal funds, shall be under the general direction of a group of most interested universities. This will insure that it can satisfy the needs of our various governmental agencies and defense establishments and also facilitate the work of our university departments of meteorology. It is significant that representatives of the universities which are most active in the field of meteorology have enthusiastically supported this recommendation that such a National Institute be created.

A second important recommendation is that present support for meteorology in the universities of this country be greatly increased through Federal support. It is remarkable that a science which deals with atmospheric conditions which have such a profound economic importance has been so inadequately financed in the past.

A third group of recommendations provides for improved educational facilities in meteorology and greater opportunities for employment of young meteorologists subsequent to the completion of their education. Up to now most of the opportunities have been on a short-term basis because Federal support for meteorology has been provided for year by year. This has made it impossible to carry forward long-term studies so necessary in a science such as this and has discouraged young people from going into this field of science.

The report makes clear that an exciting opportunity for the major progress in meteorological science exists at the present time. On the one hand, there are important new clues to natural processes that can lead to a very substantial improvement in understanding the ever-changing environment that the atmosphere provides. On the other hand, powerful new tools have become available that are capable of pursuing these clues on the planetary scale on which the weather is formed.

Earth satellites on regular patrol will play a major role in meteorological progress. Preparation and instrumentation of patrol satellites and reception and analysis of their data involve special measures, however. High-speed computers hold real promise in the development of more reliable short-range forecasts and possibly longer-range climatic predictions. Carefully instrumented aircraft are continuously necessary to understand the physics of hurricanes, typhoons, tornadoes, and other violent manifestations of atmospheric motion. Substantial devices are needed for the study of cloud physics so that the origin of rainfall and its dependence on many other factors can be understood. These are problems, facilities, and opportunities which the proposed National Institute of Atmospheric Research could provide.

In releasing this report on behalf of the Academy, I am convinced that we are potentially on the threshold of a new era in understanding our environment. Therefore, I have urged our Government to give most earnest consideration to its recommendations.

DETLEV W. BRONK

APPENDIX D

STATEMENT OF DR. F. W. REICHELDERFER, CHIEF
UNITED STATES WEATHER BUREAU

If weather even in the early days had not been so important to man, meteorology might now encompass what the word originally implied -- the science of "the things above," including all phenomena of outer space, the heavenly bodies and the very high layers of the atmosphere as well as the weather and climate of the "atmosphere" itself. Thus astronomy, astrophysics, aeronautics and so on might have been branches of meteorology, the general science of the atmosphere. But weather and climate have always had a special place in man's mind and it was natural that meteorology came to have the more limited meaning. Recent discoveries together with the future role of artificial earth satellites for meteorological observations will certainly broaden the scope of meteorology.

The scientific literature and especially many of the papers published through the American Meteorological Society and the American Geophysical Union show that meteorologists have from time to time emphasized the relationships among the several branches of geophysics and have suspected that research would eventually bring out unknown inter-relationships which would tend to remove the academic boundaries set up between various earth sciences. In the future, more attention will doubtless be given to the science of the atmosphere as a whole.

It is timely that the first Interim Report of the Committee on Meteorology of the National Academy of Sciences should strongly recommend expansion of research in this field and propose establishment of a National Institute for Atmospheric Research. This institute could provide those larger and more costly facilities for atmospheric research in the broadest sense that would normally go beyond the capacity of individual research groups as presently organized. The Report of the Committee recommends first an expansion of research support for the universities and institutes now active in this field and capable of conducting larger research programs. As the first requisite for greatly expanded research, the Report emphasizes a plan for attracting research scientists in much larger numbers to work in the fields of meteorology and the atmosphere as a whole. These broad programs will contribute to the future growth and usefulness of the science and of the private and public institutions and organizations engaged in the study and applications of meteorology. Although modifications in some of the details may be made as the general plan progresses, this Report offers a sound concept for development of research scientists and research facilities for study of the atmosphere, and it merits cooperation and support of all who are interested in advancement of meteorology and geophysics. The Committee has made an excellent beginning.

F. W. REICHELDERFER

APPENDIX E

FIRST PROGRESS REPORT

OF THE

UNIVERSITY COMMITTEE ON ATMOSPHERIC RESEARCH

First Progress Report

of the

University Committee on Atmospheric Research

Membership

George S. Benton	Johns Hopkins University
Reid A. Bryson	University of Wisconsin
Horace R. Byers	University of Chicago
Phil E. Church	University of Washington
Bernhard Haurwitz	New York University
Seymour L. Hess	Florida State University
E. Wendell Hewson	University of Michigan
A. Richard Kassander	University of Arizona
Dale F. Leipper	A and M College of Texas
Morris Neiburger	University of California (L.A.)
Hans Neuberger	Pennsylvania State University
Benjamin Nichols	Cornell University
J. Robert Stinson	St. Louis University
Henry G. Houghton	Chairman, M.I.T.

First Progress Report

of the

University Committee on Atmospheric Research

Introduction

On January 25, 1958, the Committee on Meteorology of the National Academy of Sciences issued an interim report entitled "Research and Education in Meteorology." The thesis of that report is that it is essential to the safety, defense and economy of the United States that the national effort in atmospheric research be substantially expanded and its continuity assured. To this end the Committee made several broad recommendations, supported by an analysis of the present situation and of the magnitude of the research effort required. The Academy Committee made it clear that the first requisite to progress along the lines recommended was the enthusiastic support by the universities most active in atmospheric research. In broad outline this was accomplished at a meeting held in New York on January 31, 1958, at which the representatives of eleven institutions unanimously approved a resolution endorsing the recommendations of the Academy Committee.

It was clear to the representatives of the universities most concerned with atmospheric research that it was their responsibility to carry forward the effort so imaginatively and forcefully initiated by the Academy Committee, with the aim of bringing the recommendations into effect. Accordingly the chairmen, or their representatives, of eleven university departments of meteorology met informally at U.C.L.A. on February 26-28, 1958, and constituted themselves as the University Committee on Atmospheric Research, hereafter abbreviated, UCAR. It was agreed that the membership of UCAR should consist of the Chairmen, or their designees, of university departments that offer the doctorate in meteorology plus at least one representative from a university department active in the physics of the high atmosphere. It was also considered desirable that there be additional representation from the field of oceanography. UCAR decided to seek a grant from the National Science Foundation to defray its expenses. In the interim, travel and subsistence expenses have been furnished through the courtesy of the Committee on Meteorology of the National Academy of Sciences. The UCAR met at the University of Wisconsin on March 28-29, 1958, and at the National Academy of Sciences in Washington on May 22-23, 1958. The Committee on Meteorology of the National Academy of Sciences has been represented at all meetings of UCAR.

The UCAR found it necessary to review the entire question of atmospheric research in considerable detail. As will appear later much of the detailed planning remains to be accomplished. It is striking that UCAR has reached almost exactly the same conclusions as the Academy Committee although there is only one member common to the two committees.

It early became apparent that there were three separable but closely related aspects of the problem -- university research, the national institute and scientific manpower. To facilitate our deliberations, working groups were established in each of these areas and this report is divided in the same fashion. An executive committee was also appointed consisting of the chairman and two other members.

UCAR is aware of a sense of urgency both because of the immediate needs for an expansion of atmospheric research and because of the current reformulation and refocussing of the entire national scientific research effort. On the other hand we realize that the magnitude and importance of the tasks we have undertaken make it imperative that our decisions be based on a full and careful analysis of the problem. As a reasonable compromise it has been decided to issue a series of progress reports, of which this is the first. In this report an effort is made to outline our broad recommendations and to attempt preliminary cost estimates for immediate budgetary planning. We can be much more specific now about university research, because of our intimate knowledge of this area, than we can about the proposed National Institute of Atmospheric Research.

The Need for an Expanded Research Effort

UCAR strongly concurs with the cogent arguments for the necessity of an expanded effort in atmospheric research as presented in the Interim Report of the Committee on Meteorology. In the light of man's mastery of matter and energy his ignorance of his large-scale physical environment is striking and incongruous. This ignorance costs us dearly in human privation and death as well as in economic losses. Burgeoning populations and the increasing complexities of civilization will surely magnify such losses unless we learn how to mitigate the effects of nature's blows.

We must reckon with the possibility that some degree of control of the weather ultimately can be achieved. Our national security as well as our economy and comfort demand that we acquire the basic knowledge requisite to a realistic decision on the feasibility of weather control. Whether or not weather control proves possible, more adequate basic knowledge of the atmosphere is requisite to the solution of a wide variety of pressing problems. These include weather forecasting for both short and long periods, forecasting the behavior of the ionosphere for radio transmission, the control of atmospheric pollution, the escape and re-entry of space vehicles and a wide variety of environmental problems of both the military services and private enterprise.

Although our national security must be uppermost in these parlous times we hold that the strongest case for atmospheric research lies in its humanitarian aspects. The atmosphere and its phenomena know no national boundaries but affect the lives and well-being of all of mankind. The food and fresh-water supplies of the world are closely related to climate and the weather. The atmosphere is a natural resource of limited capability and the explosive growth of the world population demands that this resource be used in the most effective way possible. We believe that a bold and imaginative research program with such humanitarian objectives could contribute to our current national effort to win the hearts and minds of the peoples of the world.

None of these objectives can be achieved until we acquire a much more complete basic understanding of the atmosphere in all its phases. In view of the magnitude and complexity of the problem the current effort is pitifully small. Nevertheless, enough progress has been made in the past decade that there is now a clear opportunity for tremendous strides if only the necessary facilities, manpower and money can be made available. Without a major increase in the current effort it may require decades to make significant progress towards the important goals outlined above.

It cannot be too strongly emphasized that progress towards future mastery of the atmosphere is dependent on the establishment <u>now</u> of a stable, long-term program of basic atmospheric research. There will be a continuing need for applied research for the solution of important military and civilian problems but the immediacy of these needs must not be permitted to warp or dilute the basic research program. The success of applied research is directly dependent on our store of fundamental knowledge and any subversion of basic research to immediate needs will have serious consequences in the future. This report and the work of UCAR is addressed specifically to basic research as was the report of the Academy Committee.

Requirements

As clearly stated in the report of the Academy Committee, an expanded effort in atmospheric research requires the strengthening of the university research programs. It was further recommended that a National Institute of Atmospheric Research be established. To make this expansion of research possible, ways must be found to substantially increase the number of research scientists. It is logical and convenient to consider these three aspects separately although it must be kept in mind that they are intimately interrelated. As indicated earlier UCAR has established working groups in these three areas to facilitate our consideration of the problems.

University Research

The bulk of the basic atmospheric research is conducted at about 17 universities. The same universities train research scientists (as well as practitioners) and the research programs are an essential part of graduate education. Since it will devolve on these universities to train the atmospheric research scientists needed to establish and maintain an expanded research effort, it is clear, for this reason alone, that the research program of the universities must be strengthened and expanded. It is our firm conviction that the universities must continue to play the leading role in atmospheric research even when a National Institute of Atmospheric Research is established. This conviction stems not from a proprietary interest in the university departments but from the belief that education and research are inseparable partners and that complete dominance in research by a single center would be inimical to progress.

The current university atmospheric research program is supported almost entirely by agencies of the Federal government. About 90 percent of the Federal funds come from the Defense Departments, the small remainder coming principally from the National Science Foundation and the Weather Bureau. A preliminary survey conducted by UCAR reveals that the 17 principal universities engaged in atmospheric research currently receive about $3,500,000 per year from research contracts and grants in this field. These same universities estimate that they need immediately an additional $1,400,000 annually for the strengthening of their present programs without significant increases in major staff and facilities. Within the next 3 to 5 years the universities estimate a need for an additional $2,500,000. Thus in 3 to 5 years the 17 universities feel that they will require, for an effective research program, a total annual research budget of about $7,400,000 which is about double the present rate. The immediate increases are required to continue research in important areas no longer receiving significant military support (e.g., cloud physics and boundary layer phenomena) to compensate for the increased cost of living not provided by the level budgets of recent years and to cover the increased expense of research resulting from the use of modern facilities such as high-speed computers and instrumented aircraft. The longer-term increases are to provide for a research effort expanded to a level that will require more research scientists. The figures presented here do not include funds for the purchase of needed new research facilities at the universities nor do they include funds for atmospheric research at universities not included in the survey. It is thus realistic to plan on a somewhat larger budget.

There is general agreement that the present procedures through which research support is now provided to the universities include a number of undesirable features. Most of these were also noted in the report of the Academy Committee.

1. The lack of stability of support resulting from one year (or sometimes shorter) contracts. It is unrealistic to undertake a program of basic research for a period of one year. This procedure makes it difficult to plan ahead and is not conducive to the attraction and retention of capable staff and graduate students. Most universities must make commitments to staff and graduate students in early spring for the following academic year and this necessary lead time is incompatible with one-year contracts. A minimum contract period of three years is recommended, preferably with provision for an annual review to maintain the contract in force at least two years ahead.

2. The impact of military requirements often adversely affects a continuing basic research program. Specific end-product objectives are usually incompatible with basic research. The military have a continuing and important need for applied research and, under certain circumstances, it may be appropriate for universities to undertake such research. On the other hand, it is imperative that the universities maintain freedom to conduct basic research unhindered by immediate military or civilian needs.

3. The fractionation of research into several small but closely-related projects at a single university imposes undesirable restrictions and leads to an unnecessary and wasteful multiplication of paper work and reports. (This comment is not aimed at the small contracts used for the support of individual research.)

4. Present support does not provide the flexibility to follow new leads and to take advantage of new developments while they are "hot." University departments should have grants which can be used in broad areas of research as the needs and interests of the moment dictate.

The deficiencies noted above could have led to the effective stifling of basic atmospheric research. That they have not redounds to the credit of those individuals in the governmental agencies who have actually administered the contract research programs. In many respects the restrictions have lain more heavily on them than on the universities. The removal of these restrictive practices will permit more effective use of the research dollar and the development of a sounder research program.

First recommendation: It is recommended that the annual budget for atmospheric research at the universities be increased immediately by $1,500,000 to $2,000,000, these funds to be used to stabilize and strengthen the present university research programs.

Second recommendation: It is recommended that the governmental agencies supporting atmospheric research make budgetary plans to increase the support of fundamental atmospheric research at the universities such that it will reach about double the current level in 3 to 5 years.

Third recommendation: It is recommended that the contractual arrangements through which governmental agencies support basic atmospheric research at the universities be modified so as to provide long-term stability, to reduce fractionation, to eliminate the direct impact of practical military and civilian requirements on basic research and to provide greater flexibility in the use of the funds.

Manpower

The national effort in basic atmospheric research can be strengthened and expanded only as a comparable increase in the number of research scientists working in the field can be achieved. The inherent difficulty of the problems demands scientists of the highest competence and the interdisciplinary nature of the field requires scientists with varied backgrounds. The large problems of the atmosphere are inherently different from the problems of the laboratory sciences and a substantial fraction of the research group must consist of those with extensive training and experience in the geophysical sciences.

It is difficult to obtain a satisfactory estimate of the number of scientists now engaged in atmospheric research. From the information available to it UCAR estimates that there are about 300 scientists with the doctorate who classify themselves as meteorologists or atmospheric physicists. This may be taken as a preliminary estimate of the present number of atmospheric research workers since there are some competent researchers without the doctorate and not all holders of the doctorate are in research. On the order of one half of these research scientists are on the staffs of the universities.

To double the present research effort some 300 additional scientists must be brought into the field. It is expected that the establishment of a National Institute of Atmospheric Research will serve to attract mature scientists from contiguous fields and will also serve to dramatize atmospheric research to prospective graduate students. It is clear that the universities must train the major part of the new manpower required. This must be in addition to the present rate of training, which is not even adequate to provide replacements in a static situation. It is estimated that the universities should produce Ph.D.'s at the rate of at least 50 to 60 per year. The average rate during the 5-year period 1953-57 has been 10 per year. The universities can at least double their present graduate output without significant additions to their staffs and facilities. Past experience strongly suggests that the universities can expand their student populations with the demand and that the limitation is the number of capable students that can be attracted.

Meteorology is a derived science which must draw upon students with a solid training in the basic sciences (physics, mathematics, chemistry). One of the obstacles to an expansion in the educational program is that potential graduate students are usually quite ignorant of meteorology as a research field. They think of meteorology as a profession devoted primarily to routine weather forecasting. We feel that an essential element in a campaign to increase the number of students is a program to bring the importance and the challenge of atmospheric research to the attention of undergraduate majors in science and mathematics. To this end, with the support and guidance of UCAR, the American Meteorological Society plans to submit a proposal to the National Science Foundation for the support of a program of visiting lectureships at colleges and universities. Under this program a number of research meteorologists will go on tour in the fall of 1958 to (1) demonstrate the vitality of atmospheric science, (2) present one or more of the challenging problems of the atmosphere and (3) make known the opportunities available to graduate students and research scientists.

Although the educational campaign outlined above is necessary it is not a complete solution. Today the great majority of graduate students must be granted financial aid. Much of the current aid to meteorology students is in the form of graduate assistantships associated with the sponsored research programs. More such assistantships will become available as the university research program expands. We also plan to encourage more graduate students in meteorology to apply for National Science Foundation fellowships. To attract students not yet decided on atmospheric studies UCAR proposes to solicit funds from private sources (foundation and industry) for the establishment of a small number of financially-attractive fellowships. This will aid in recruiting the very best talent and should attract applications from a large number of well-qualified students most of whom can be offered graduate assistantships. Preliminary contacts with foundations suggest that this proposal can be implemented if it is aggressively promoted.

A good source of potential graduate students is the group of Air Force Weather Officers who leave the service each year. These men have had one year of university training and at least two years of field experience in meteorology. A fair proportion have adequate undergraduate preparation and they all have a much better appreciation of the field of meteorology than the typical undergraduate. UCAR plans to explore with the Air Weather Service means for informing these officers of the opportunities for graduate training and research careers several months before they are discharged.

UCAR is aware that the manpower question is the most critical and difficult problem facing it and will continue to devote much effort to methods for its solution. A serious deterrent is the present lack of a sufficient number of attractive career opportunities. The National Institute and the expanded research effort at the universities should provide many such opportunities. On the other hand, such expansion is dependent on manpower and it takes 3 to 5 years beyond the bachelor's degree to train a competent research scientist.

National Institute of Atmospheric Research

A consideration of the scale of the large problems of the atmosphere and of the facilities and personnel required for an effective attack on them demonstrates the need for a National Institute. An attempt to mount an attack on one of the major problems at a single university would inevitably results in an imbalance that would seriously affect the educational program. Some examples of the type of problems that demand solution will serve to demonstrate the need for a National Institute.

It is of major importance that we acquire an understanding of the large-scale dynamics of the upper atmosphere and of its coupling with the lower atmosphere. One of the most difficult aspects of this problem is the collection of adequate data from the upper atmosphere. This will have to come from a variety of sources including rockets, high-altitude balloons, ionospheric measurements, observations on meteors, the airglow, aurorae, the magnetic field and others. The collection and interpretation of such data require scientists from a number of disciplines and they must be provided with complex facilities. The theoretical analysis of the results must be undertaken by hydrodynamicists and mathematicians in concert with their colleagues who have collected and interpreted the data. Mathematical models must then be developed and tested on a high-speed electronic computer.

Cloud physics is, broadly, the study of water substance in the atmosphere. The parts of this problem range in scale from the microphysics of the nucleation and growth of cloud elements to the large-scale effects of the release of the latent heats accompanying phase changes. A study of cloud physics demands a fleet of aircraft with extensive specialized instrumentation, ground-based and airborne radar and special laboratory facilities. Much of the present instrumentation, including radar, is cumbersome, unreliable and poorly-adapted to the job; thus a large program on instrument development is the first step. Personnel required include various types of instrumentation specialists, chemists, physicists and meteorologists. The handling and analysis of the large amount of data involved will also require special facilities.

One of the central problems of meteorology is the development of an adequate theory of the large-scale circulation of the atmosphere. One of the major deterrents to progress has been the lack of adequate data particularly over oceanic areas and in the Southern Hemisphere. As a result of the IGY and future satellite observations, vast new data resources will soon be available. Mechanized analysis particularly of the satellite data will be mandatory. For the proper utilization of the data it will be necessary to have a computer of greater speed and storage capacity than any currently available.

Many more such problems could be listed. Their common features are the magnitude of the effort involved, the variety of scientific disciplines required and the need for complex and specialized facilities. It would clearly be unwise for a single university to undertake problems of this magnitude, yet they are essential to progress in atmospheric research. The data and results of such National Institute projects would be certain to stimulate research at the universities on a scale proper to the university environment.

In summary, the compelling reasons for a National Institute of Atmospheric Research are:

1. the need to mount an attack on the fundamental atmospheric problems on a scale commensurate with their global nature and importance;

2. the fact that the extent of such an attack requires facilities and technological assistance beyond those that can properly be made available at individual universities;

3. the fact that the difficulties of the problems are such that they require the best talents from various disciplines to be applied to them in a coordinated fashion, on a scale not feasible in a university department; and

4. the fact that such an institute offers the possibility of preserving the natural alliance of research and education without unbalancing the university programs.

As a result of our deliberations we have arrived at the following principles which should govern the operation of the Institute:

1. The National Institute should be controlled and operated by a corporation set up by a group of interested universities, but must be open on an equal basis to qualified scientists from all universities and other organizations. Foreign scientists should be included because of the global nature of the problems, to emphasize the humane motivation of the research and to provide an additional source of trained personnel.

2. The emphasis should be on basic research and particularly on those basic problems that are of such magnitude as to be beyond the capabilities of individual university departments in scope of effort or in facilities.

3. Because of the scope of the problems the major portion of the financial support must come from the Federal government, although support from other sources should also be sought. Because of the basic nature of the research the Federal support should come through the National Science Foundation rather than through operational agencies of the government.

4. The activities of the Institute should be organized in such a way that they support and strengthen the programs of the universities. The participating universities are prepared to make initial sacrifices to establish the Institute, but an important part of the over-all program is the expansion of atmospheric research at the universities.

5. An effective attack on atmospheric problems demands the concerted application of a variety of scientific disciplines and skills and the National Institute must be made as attractive to other scientists as to meteorologists and atmospheric physicists.

6. The major portion of the scientific staff should be transient or only quasi-permanent. The opportunity to work for a year or two on a challenging problem under favorable conditions while on leave from another institution is one of the best means of attracting competent men from all disciplines to contribute to progress in atmospheric research.

7. A major effort of the Institute must be in the advancement of our capabilities for the measurement of atmospheric variables.

The attraction of men from other disciplines of highest competence in the development of measurement techniques is essential to the progress of our understanding of atmospheric processes.

The core of the National Institute must be the scholarly investigation of the large, fundamental problems of the atmosphere, hence, the core must be competent research scientists. But these scientists must be supported with the most powerful research tools that can be devised, be they instruments, computers, field facilities or models. They must also have adequate technical and logistic support at their disposal. Thus the two major attractions of the Institute should be the intellectual stimulus and the availability of the most modern facilities. The working conditions and attitudes should be much like those of a university and this should be fostered by adequate provisions for graduate students to conduct thesis investigations there.

Although the emphasis must be on scholarly research it is inevitable that the research facilities will require more space and money than the men who use them. This means that the size and cost of the Institute cannot be determined, except in broad outline, until final decisions are reached on the nature and scope of the facilities to be provided.

Because of the lead time required for the planning and construction of buildings and facilities, UCAR recommends that initial appropriations for the National Institute be sought as early as possible, namely in the supplementary budget for fiscal 1960 and in the regular 1961 budget. This will require the preparation of fully-documented proposals to the National Science Foundation in time to permit budget requests to be submitted to the Congress in January, 1959. The preparation of such proposals will require the services of a full-time staff who should begin their work at the earliest possible time. The UCAR has neither the resources nor the legal status necessary to the preparation and submission of such proposals. Accordingly the UCAR has recommended to the universities they represent the establishment, at an early date, of a university corporation which would have the following functions:

1. Employ a full-time staff to prepare the specific proposals for submission to the National Science Foundation.

2. Serve as the contractor with the National Science Foundation.

3. Serve as the governing body of the proposed National Institute of Atmospheric Research.

4. Undertake the steps necessary to recruit scientific manpower and, in general, to publicise the program of atmospheric research.

As now visualized, the timetable for future steps is as follows:

July 1958	Establishment of university corporation
Summer 1958	Appointment of full-time staff for the preparation of proposals for FY 1960-1961
December 1958	Submission of proposals for FY 1960 and 1961 to National Science Foundation
July 1959 - July 1960	Expanded full-time staff undertakes detailed planning of facilities and buildings. Selection of site
July 1960 - July 1961	Construction begins. Scientific staff begins research in temporary quarters
July 1961 - July 1964	Construction of buildings completed and major facilities installed. Steady expansion of staff
1965	Institute attains full operational status at level now planned.

Preliminary Cost Estimates

Although firm cost estimates must await further study it is possible to make preliminary estimates now that will almost certainly be correct within a factor or two. Our considerations of the manpower problem suggest that it is reasonable to anticipate that the Institute will house 100 atmospheric research scientists by 1965. It is further estimated that facilities of the type contemplated will require 100 professional people for their development and operation. In addition, the normal proportion of non-professionals will be required. On the basis of these personnel estimates and the timetable presented above the budget has been estimated for each year from fiscal 1960 through fiscal 1965.

In fiscal year 1960 the item under planning covers the salaries of the planning staff, travel, rental of quarters and substantial amounts for fees to consultants of various kinds including architects. The item under design and construction contemplates the possible need for purchase of the site and down payments on certain special facilities such as the high-speed computer. Since manpower is a critical factor it is felt that funds should be available for hiring scientific staff from the outset. The major construction costs are placed in fiscal 1961 and 1962. The items for scientific staff increase sharply in fiscal 1962 when occupation of the permanent buildings becomes possible. The figures presented in the table compare favorably with those of similar organizations such as MURA, when adjusted for an Institute of the size we envisage.

Preliminary Budget Estimates for the

National Institute of Atmospheric Research

Fiscal Year	Institute Planning	Design and Construction	Scientific Staff	Research Operations	Total
60	$250,000	$ 1,000,000	$ 100,000	$ 100,000	$ 1,450,000
61	250,000	12,000,000	200,000	400,000	12,850,000
62	100,000	7,000,000	1,600,000	2,300,000	11,000,000
63	-	4,000,000	3,000,000	4,000,000	11,000,000
64	-	1,000,000	4,000,000	5,500,000	10,500,000
65	-	500,000	4,100,000	5,600,000	10,200,000
Total	$600,000	$25,500,000	-	-	$57,000,000

APPENDIX F

EXCHANGE OF CORRESPONDENCE BETWEEN UCAR AND DEFENSE AND COMMERCE DEPARTMENTS

THE UNIVERSITY COMMITTEE ON ATMOSPHERIC RESEARCH

July 21st, 1958

The Honorable Sinclair Weeks
Secretary of Commerce
Washington, D. C.

and

The Honorable Dr. Paul D. Foote
Under Secretary of Defense for Research and Development
Department of Defense
Washington 25, D. C.

Dear Mr. Secretary:

The fourteen universities in the United States which are engaged in graduate education and research in the sciences of the atmosphere met at the Pennsylvania State University on July 18-19 to take the decisive steps to carry out the recommendations of the National Academy of Sciences relative to the national need for expansion of atmospheric research. You were present or were represented at the meeting last February in the White House at which Dr. Detlev Bronk, President of the Academy, and Dr. Lloyd V. Berkner, then Chairman of its Committee on Meteorology presented the recommendations. We are pleased to be informed of the friendly interest of your organizations in the proposals.

One of the principal recommendations of the Academy was that a National Institute of Atmospheric Research be established by an association of the universities engaged in meteorological research. It was indicated that the main support for such an institute might properly come from agencies of the Federal Government. Subsequent discussion has evolved a tentative plan for financing through the National Science Foundation.

The universities are taking the steps toward the establishment of the management group for a National Institute of Atmospheric Research. In doing so, we are keenly aware of certain risks, the most critical of which is the possibility that the enthusiastic support of the institute may lead to a relaxation or reduction of financial backing of programs now going on or needing expansion in the universities themselves. If there is a real basis for fears that retrenchment of this type would occur, we would hesitate to place our institutions in a position of sponsoring a national center.

We wish to urge that in your consideration of research financing in your agency, the real intent of the Academy interim report be kept in mind. That intent is that in the public interest, atmospheric research efforts should be augmented on all fronts. It should be noted that the first recommendation of the Academy is, in fact, that support of atmospheric research in the universities should be substantially increased.

Furthermore, it is believed to be especially detrimental to the development of this science and against the public interest to shift entirely the responsibility for Federal financial support to the National Science Foundation simply because that agency is expected to administer the principal support funds for the proposed National Institute and other new programs in this area.

For your information, there is attached a list of the fourteen institutions represented at this meeting and initiating this letter. Each university is represented by a scientist and a responsible administrative officer.

Sincerely yours,

Henry G. Houghton
Acting Chairman

cc: Dr. J. R. Killian
Dr. A. Waterman
Dr. F. W. Reichelderfer
Dr. D. W. Bronk
Dr. M. Greenberg
Director of Naval Research
Chief Signal Officer

ASSISTANT SECRETARY OF DEFENSE
WASHINGTON 25, D. C.

Research and Engineering
5 August 1958

Dear Mr. Houghton:

Thank you for your letter of July 21, 1958 concerning the establishment of a National Institute of Atmospheric Research. I certainly understand the concern of your member universities with regard to a possible reduction of financial backing in the event of the establishment of the proposed national institute. I should like to assure you that insofar as I am concerned, the strongest possible defense posture must be maintained, and this can only be accomplished through the optimum utilization of the Nation's scientific, technical, and industrial resources. It is our policy to support a very broad and continuing basic research program, and through that broad support to maintain contact between the Military Departments and the Nation's scientists. This certainly implies an intent to continue financial support to scientists in industry, in government-operated laboratories and institutes, and in universities, as well as in other non-profit institutions.

It is, of course, our policy to coordinate our basic research program with the National Science Foundation and to encourage the support of sound basic research by other government and private agencies, but we fully intend to support with Department of Defense funds those areas of research which contribute to the accomplishment of the over-all administration of the Department of Defense.

Sincerely,

(signed) Paul D. Foote

Dr. Henry G. Houghton
Acting Chairman
The University Committee on Atmospheric Research
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

cc: Dr. J. R. Killian
Dr. D. W. Bronk
Dr. A. T. Waterman

THE SECRETARY OF COMMERCE
WASHINGTON 25, D. C.

5 August 1958

Professor Henry G. Houghton, Acting Chairman
The University Committee on Atmospheric Research
Department of Meteorology
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Professor Houghton:

Your letter of July 21 with reference to expansion of research in meteorology and related atmospheric sciences is timely and of much interest to us. It is gratifying to know that fourteen of the interested universities are going ahead with the plans recommended in the Interim Report of the Committee on Meteorology of the National Academy of Sciences.

I can assure you of our continuing interest in the advancement of knowledge in these important sciences of the atmosphere. I agree with you that the basic research at the universities must be continued, and although the details have not yet been worked out, I am sure that the whole-hearted cooperation among government agencies directly concerned and the universities and other research institutes prepared to carry on scientific studies will open the way to great progress in this field. Representative of this Department including the Weather Bureau will be in touch with you as the plans of the University Committee continue to be developed.

Sincerely yours,

(Signed) Sinclair Weeks
Secretary of Commerce

APPENDIX G

RESOLUTION PREPARED BY UNIVERSITIES IN JULY, 1958

RESOLVED, that the scientific and administrative representatives of the fourteen universities here assembled endorse the establishment of a non-profit corporation for the purpose of the promotion of research in atmospheric problems by:

1. Fostering support of such research at individual universities;

2. Developing manpower for attack on these problems;

3. Organizing and operating a National Institute for Atmospheric Research;

4. Assisting universities, other institutions, and individuals in their development and progress in atmospheric research and related activities, such as applications of chemistry, mathematics, physics and engineering in the study of the atmosphere; and

5. Fostering and encouraging advancement of knowledge concerning the atmosphere in all of its aspects together with the education and training of personnel in this field of study; and

BE IT FURTHER RESOLVED, that it is the sense of this group that the Board of Directors for Trustees of this corporation consist of two representatives, one scientific and one administrative, from each of the member institutions, to be appointed by the member institution, and that there be an executive committee of the Board of Directors for Trustees with such powers as may be delegated to it by the Board of Directors for Trustees through the By-Laws of the corporation; and

BE IT FURTHER RESOLVED, that the attached draft of the Agreement be recommended for adoption to the fourteen organizing institutions as early as possible; and

BE IT FURTHER RESOLVED, that copies of this Resolution and the attached draft of the Agreement for Cooperation in Atmospheric Research be sent by the temporary chairman to the chief executive officer of each of the fourteen universities here represented, the Director of the National Science Foundation, the President of the National Academy of Sciences, and responsible officials of other appropriate organizations.

July 18, 1958
(The names of the fourteen universities are listed on the next page.)

APPENDIX G (Continued)

University of Arizona
University of California
University of Chicago
Cornell University
Florida State University
Johns Hopkins University
Massachusetts Institute of Technology
University of Michigan
New York University
Pennsylvania State University
St. Louis University
Texas Agricultural and Mechanical College
University of Washington
University of Wisconsin

APPENDIX H

AGREEMENT FOR COOPERATION IN ATMOSPHERIC RESEARCH

This Agreement by and between The Board of Regents of the University and State Colleges of Arizona acting for and in behalf of the University of Arizona, a public educational corporation of Arizona, with its principal office in the City of Tucson, State of Arizona; The Regents of the University of California, a public corporation of the State of California, with its principal office in the city of Berkeley, State of California; The University of Chicago, an Illinois corporation, with its principal office in the City of Chicago, State of Illinois; Cornell University, a New York corporation, with its principal office in the City of Ithaca, State of New York; The Johns Hopkins University, a Maryland corporation, with its principal office in the City of Baltimore, State of Maryland; Massachusetts Institute of Technology, a Massachusetts corporation with its principal office in the City of Cambridge, State of Massachusetts; The Regents of The University of Michigan, a constitutional corporation of the State of Michigan, with its principal office in the City of Ann Arbor, State of Michigan; New York University, a New York corporation, with its principal office in New York City, State of New York; The Pennsylvania State University, a public educational corporation of the State of Pennsylvania, with its principal office at the City of University Park, State of Pennsylvania; Saint Louis University, a Missouri corporation, with its principal office in the City of Saint Louis, State of Missouri; Texas Agricultural and Mechanical College system, a public educational corporation of Texas, with its principal office at the City of College Station, State of Texas; The Board of Regents, University of Washington, an agency of the State of Washington, with its principal office in the City of Seattle, State of Washington; The Regents of the University of Wisconsin, corporate body of the State of Wisconsin, with its principal office in the City of Madison, State of Wisconsin;

W I T N E S S E T H:

WHEREAS, each of the above-named parties to this Agreement desires to participate in the promotion of research in atmospheric problems, and

WHEREAS, the Committee on Meteorology of the National Academy of Sciences has strongly urged the development of a nationwide program for this purpose, and

WHEREAS, the National Science Foundation has made a grant to the Massachusetts Institute of Technology in the amount of fifty-two Thousand Four Hundred ($52,400.00) Dollars on behalf of the University

Committee on Atmospheric Research and has indicated a strong interest in the furtherance of this program, and

WHEREAS, The National Science Foundation has encouraged the member institutions of the University Committee on Atmospheric Research to incorporate for the purpose of carrying out the program.

NOW, THEREFORE, the parties hereto agree as follows:

1. To organize a non-profit organization for the purpose of promotion of research in atmospheric problems by:

   a. Fostering support of such research at individual universities;

   b. Developing manpower for attack on these problems;

   c. Organizing and operating a National Institute for Atmospheric Research;

   d. Assisting universities, other institutions, and individuals in their development and progress in atmospheric research and related activities, such as applications of chemistry, mathematics, and physics in the study of the atmosphere; and

   e. Fostering and encouraging advancement of knowledge concerining the atmosphere in all of its aspects together with the education and training of personnel in this field of study.

2. For the purpose of working out the details of the establishment of the corporation, each party hereto upon signing this Agreement agrees to designate two of its staff members, one from its staff of scientists and one from its administrative staff, as members of an Organization Committee.

3. That Henry G. Houghton of the Massachusetts Institute of Technology is hereby named temporary chairman of the Organization Committee with authority to advise the National Science Foundation and other appropriate organizations as to the progress currently made toward the establishment of the corporation. Said temporary chairman shall call a first meeting of the Organization Committee after execution of this Agreement by seven (7) of the parties hereto and shall act until such time as a permanent chairman is selected.

4. Each party hereto agrees to pay a membership fee in the sum of Two Thousand Five Hundred ($2,500.00) Dollars within thirty (30) days after the execution of this Agreement, which payment shall be made to the Massachusetts Institute of Technology and deposited in a trust fund account for the purposes hereinafter set forth.

No additional financial obligation is incurred by the parties hereto by execution of this Agreement. However, it is contemplated that, upon establishment of the corporation, additional obligations may be incurred by the parties hereto not to exceed the sum of Two Thousand ($2,000.00) Dollars per year for a five-year period.

Any party to this agreement may withdraw prior to incorporation upon written notice to the temporary chairman or his successor. Upon such withdrawal the party withdrawing shall be entitled to a refund of any payment made pursuant to this Article, less its pro rata share of expenses incurred to the date of withdrawal.

5. Disbursements may be made from said trust fund account only for payment of expenses necessary for or incidental to the organization, incorporation, or chartering of the corporation contemplated to be organized under the terms of this Agreement, upon authorization of the Organization Committee or its duly authorized representative.

6. The corporation shall be organized under the laws of such state as the Organization Committee may determine.

7. The Articles of Incorporation and original By-Laws of the corporation shall contain such provisions as meet with the approval of the Organization Committee and are not inconsistent with the terms of this Agreement.

8. It is expressly understood and agreed by the parties hereto that the sole financial responsibility or liability being assumed by the parties hereto is to pay funds in accordance with the terms of Article 4 hereof.

9. Within thirty (30) days after the corporation is established, the Organization Committee or the Massachusetts Institute of Technology shall turn over to said corporation all monies remaining in the trust fund account; or if for any reason the Organization Committee determines that the corporation should not be organized as herein contemplated, then within thirty (30) days after such determination, the Organization Committee or the Massachusetts Institute of Technology shall refund pro rata to the contributing parties hereto all monies remaining in the trust fund account.

10. This Agreement shall not be binding until signed by at least seven (7) of the parties hereto.

11. Copies of this Agreement may be signed separately and, when so signed by seven (7) of the parties hereto and delivered to the temporary chairman herein named, shall constitute one and the same instrument.

12. Upon receipt of copies of this Agreement signed by seven (7) of the parties hereto, the temporary chairman shall notify the parties of the effective date of the contract, request payment as provided in Article 4 above, and call the first meeting of the Organization Committee.

IN WITNESS WHEREOF, the parties hereto have caused this Agreement to be executed in their respective names and behalf by their duly authorized officers and their respective seals hereunto affixed.

The Board of Regents of the University and State Colleges of Arizona acting for and behalf of the University of Arizona

Date Signed:____________________ By____________________

The Regents of the University of California

Date Signed:____________________ By____________________

The University of Chicago

Date Signed:____________________ By____________________

Cornell University

Date Signed:____________________ By____________________

The Johns Hopkins University

Date Signed:____________________ By____________________

Massachusetts Institute of Technology

Date Signed:____________________ By____________________

	The Regents of The University of Michigan
Date Signed:________________	By______________________
	New York University
Date Signed:________________	By______________________
	The Pennsylvania State University
Date Signed:________________	By______________________
	Saint Louis University
Date Signed:________________	By______________________
	Texas Agricultural and Mechanical College
Date Signed:________________	By______________________
	The Board of Regents, University of Washington
Date Signed:________________	By______________________
	The Regents of the University of Wisconsin
Date Signed:________________	By______________________

APPENDIX I

STATEMENTS BY UNIVERSITY HEADS

UNIVERSITY OF ARIZONA, Dr. Richard A. Harvill, President:

"It is a matter of genuine gratification to me and to all concerned that the University of Arizona can go forward in further association with other institutions in important endeavors to develop vital research projects in atmospheric physics."

UNIVERSITY OF CALIFORNIA, Raymond B. Allen, Chancellor:

"The importance of the proposed Institute to our national welfare and defense needs no special emphasis in the light of Russia's well-known activities in atmospheric processes which relate directly to California's serious water problem. The University of California looks forward to a long and fruitful partnership with other distinguished universities in exploring one of mankind's most challenging frontiers."

THE UNIVERSITY OF CHICAGO, Lawrence A. Kimpton, Chancellor:

"The University of Chicago, for nearly two decades, has sponsored a strong program in basic research in meteorology. It is essential that universities continue basic research in this field. Universities must also continue to train scientists qualified for atmospheric research.

"We welcome the opportunity to join with other universities in an effort to increase man's knowledge of the atmosphere through the formation of a proposed Institute for Atmospheric Research. In pledging our cooperation, we wish to emphasize that we believe the goal of the Institute should be to augment rather than to supplant the important work in meteorological research now being carried forward successfully in university laboratories. We have every confidence that the proposed National Institute of Atmospheric Research will measure up to this responsibility."

CORNELL UNIVERSITY, Deane W. Malott, President:

"We anticipate that the association of universities will make important contributions to the ever-increasingly important field of meteorology and atmospheric physics."

THE JOHNS HOPKINS UNIVERSITY, Milton S. Eisenhower, President:

"The proposed National Institute promises a concentration of scientific talents and facilities which should assure rapid and significant advances in atmospheric research. The importance of such research to business, industry and agriculture, as well as to the national defense, can scarcely be overestimated.

"At Johns Hopkins interest in the expansion of fundamental studies of the atmosphere is not confined to meteorologists, but extends also to some of our physicists and to those in the related fields of geography, oceanography and water resources. We welcome the opportunity to join with other academic institutions in the development of a new center for such studies."

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, J. A. Stratton, Acting President:

"The Massachusetts Institute of Technology welcomes the opportunity of joining with other leading educational institutions for the promotion of basic research on the problems of the atmosphere. Our national security, as well as our economy and comfort, demand that we acquire the basic knowledge relative to the possibility of weather control. The atmosphere and its phenomena affect the lives and well-being of all of mankind. To meet these challenges there is a need for a bold and a greatly expanded effort in basic research of the atmosphere in all its phases."

UNIVERSITY OF MICHIGAN, Harlan Hatcher, President:

"New fundamental knowledge about the atmosphere in its many aspects promises great benefits to the nation and to the world. The University of Michigan is pleased to be a founding member of the new University Corporation to foster greatly accelerated advance in atmospheric science. More vigorous and comprehensive programs of university instruction and research are an urgent necessity. The National Institute of Atmospheric Research, which is being planned under the guidance of the new University Corporation, holds great promise for the future. Perhaps our children will see a world where weather may be modified, and even controlled, for the benefit of all."

NEW YORK UNIVERSITY, Dr. Caroll V. Newsom, President:

"New York University welcomes this opportunity to cooperate with its sister institutions for the purpose of founding the National Institute of Atmospheric Research. The Institute can encourage and catalyze research opportunities beyond the capacities of any single institution. The combined research experience and allied interests of the Institute's member institutions should insure a bright future for this important new national facility.

"We believe this cooperative effort will heighten interest in and give needed impetus to the advancement of the sciences of the atmosphere. It can generate a whole spectrum of fundamental and developmental programs and through them give us new information about our environment that is vital to the continuing progress of civilization."

THE PENNSYLVANIA STATE UNIVERSITY, Dr. Eric A. Walker, President:

"This nation-wide endeavor to supplant individual effort with cooperative effort is proof complete that the science of meteorology is rapidly achieving the recognition to which it is entitled. I am confident that by such cooperation, atmospheric research on all levels will be considerably strengthened and the advance of meteorology generally greatly accelerated."

SAINT LOUIS UNIVERSITY, Very Rev. Paul C. Reinert, S. J., President:

"The new corporation for the promotion of atmospheric research is the result of free cooperation among outstanding public and private institutions of learning. As such it is a significantly American answer to the critical need for organized and intensive research in these fields. Saint Louis University is proud to be part of this national research effort."

TEXAS AGRICULTURAL & MECHANICAL COLLEGE SYSTEM, Dr. M. T. Harrington, President:

"The Texas A & M College System and its relatively new department of Oceanography and Meteorology are pleased to have the opportunity of joining with eleven other interested universities in furthering the national effort in atmospheric research. Through our growing participation in meteorology work, it has become obvious that a unified approach to many meteorological problems which are complex and world-wide in significance holds great potential for the contribution to the safety and well-being of Mankind."

UNIVERSITY OF WISCONSIN, C. A. Elvehjem, President:

"The incorporation of the University Committee on Atmospheric Research marks a significant step forward in putting the national effort in meteorological research in proper perspective to its importance to the people of the nation and the state. The University of Wisconsin is proud to join the other great universities who form the corporation, and to take part in this important development."

APPENDIX J

EXCERPTS FROM THE ANNOUNCEMENT OF A WORKSHOP IN METEOROLOGY THE UNIVERSITY OF CHICAGO

June 23, 1958 through July 18, 1958

Meteorology, like many fields of science, is currently faced with a severe shortage of competent scientists, particularly at the highest levels of capability and achievement. From all indications this shortage will become much worse before it becomes better, because the flow of students through the few schools offering graduate training in meteorology has not kept pace with the increasing demands for scientists in the field.

The seriousness of this problem transcends the field of meteorology itself. Meteorology is one of the key fields of the earth sciences and it is generally agreed that the shortage of earth scientists in the face of expanding areas of need represents a problem of first magnitude.

. . .

The reason for a shortage of meteorologists seems to be two-fold: (a) meteorology is primarily a derived science and as a result previous training in mathematics, physics and chemistry is essential; and (b) there is a serious lack of suitable lines of communication between meteorology and potential meteorologists. Some of the difficulty may also result from the fact that society tends to mistakenly identify meteorology as concerned only with tomorrow's weather, whereas in fact less than half of the meteorologists are engaged in weather analysis and forecasting for the general public.

In order to meet the increasing demands for high-calibre meteorologists of advanced training, the Department of Meteorology at The University of Chicago will conduct a special workshop for four weeks during the summer of 1958 in which a limited number of qualified applicants will receive an expense-paid introductory course into all phases of meteorology -- meteorology as a science, as a profession, and as a career.

. . .

During the period of June 23, 1958 through July 18, 1958, a selected group of 30 students will pursue a special course of meteorology at The University of Chicago. The students will be given a program of lectures, laboratory demonstrations and exercises and field trips which will be aimed at giving them a comprehensive view of geophysics as a whole and of meteorology in particular. There will be approximately 100 contact hours during the four-week period (exclusively of field trips) for which the University will grant two units of credit (6 2/3 semester hours). The program of study will be conducted on a high academic plane. Interest will be added by relating meteorology to the other aspects of geophysics. The students will be given a view of the opportunities for graduate work in <u>all</u> universities offering such training in the hope that some of them will subsequently be encouraged to continue their academic training in meteorology.

. . .

Through a grant from the National Science Foundation all expenses for tuition and fees, room and board in University dormitories and books will be paid by the University of Chicago. In addition each student selected will be reimbursed for round trip transportation from his home or school. The students will be required to provide for their own incidentals such as laundry and personal expenses while in Chicago. Sunday evening meals and meals while on one-day field trips cannot be provided at University expense.

. . .

To be eligible for this special program, a student must have completed three or four years of undergraduate training in a normal four-year program leading to a B.S. in mathematics, physics, or chemistry, or in one of the other physical sciences or engineering. Exceptionally well-qualified students with two years of college may be selected if necessary to fill out the quota, providing that they have met the minimum requirements in mathematics and physics. The program is open to both men and women, but since the purpose is to develop U. S. potentialities in meteorology, foreign nationals will not be considered.

. . .

Course Content - The chemical, thermal and electrical structure of the atmosphere; propagation of heat, light, sound through the atmosphere; surface layers of the atmosphere; fronts and air masses; oceans; clouds and hydrometeors; water of earth and atmosphere; organized circulations of the atmosphere and oceans; weather forecasting; general circulation and heat balance of the atmosphere; geophysical aspects of meteorology.

APPENDIX K

RESOLUTION ADOPTED BY THE GOVERNORS' CONFERENCE

Fiftieth Annual Meeting

Americana Hotel
Bal Harbour, Florida

May 21, 1958

X. METEOROLOGICAL RESEARCH

WHEREAS, the National Academy of Sciences and the National Research Council have completed a re-examination of our national effort in meteorological research; and,

WHEREAS, this re-examination has revealed areas of national meteorological research needs, well-justified from scientific, economic and national security consideration attested to by advances in cloud physics and weather modification, the application of radar and aircraft observations to large-scale investigation of weather systems, and the application of high-speed computers to numerical weather prediction; and,

WHEREAS, the strengthening and acceleration of meteorological research can be expected to yield important new discoveries including the application of electronic computers to the study of atmospheric dynamics, the investigation of energy transfer processes, the study of physical climatology, upper air studies, understanding of the general circulation of the oceans, development of instrumentation for precise measurement of atmospheric phenomena, and the use of radioactive tracer techniques for studying the atmosphere; and,

WHEREAS, the re-examination of meteorological research problems has led to the development of proposals to the Congress of the United States by the National Science Foundation to augment and fully exploit our national capability for research in meteorology to meet our scientific, economic and military needs, including the establishment of a National Institute of Atmospheric Research; and,

WHEREAS, such strengthening of our national effort in meteorological research has great significance to the several states and their economies;

NOW, THEREFORE, BE IT RESOLVED, that the Governors' Conference commend the proposals of the National Science Foundation to strengthen and accelerate our national effort in meteorological research and urge to the Congress of the United States its support of these proposals to meet our national scientific, economic and military needs in the study of atmosphere and weather phenomena.

(Passed unanimously and published in the quarterly State Government, Summer 1958, pp. 164-165, Council of State Governments, Chicago.)

APPENDIX L

EXCERPT FROM INTRODUCTORY REMARKS BY THE HONORABLE RICHARD M. NIXON, VICE-PRESIDENT OF THE UNITED STATES, AT A CONFIDENTIAL BRIEFING SESSION HELD AT THE FIFTIETH ANNIVERSARY MEETING OF THE COMMITTEE FOR ECONOMIC DEVELOPMENT ON NOVEMBER 21, 1957 IN WASHINGTON, D. C. (SUBSEQUENTLY PUBLISHED IN SOVIET PROGRESS VS. AMERICAN ENTERPRISE BY DOUBLEDAY & COMPANY, INC., GARDEN CITY, NEW YORK, 1958)

..."I was talking just the other day with Dr. Teller of the University of California, one of our great scientists, and a man who perhaps has as keen an understanding of the whole world struggle as any man to whom I have talked in many years. He emphasized the fact that while we needed the development of scientists and technicians who would see to it that the United States developed an adequate military capability, we must not make the mistake of concentrating our scientific endeavors in the military field to the exclusion of non-military fields that might be just as effective, and in the end might prove more decisive in the world struggle.

"He gave one example which I thought was extremely interesting. He said that at the present time we have developed the capability to estimate what will happen to the weather, with some degree of accuracy, at least five days in advance. At the present time studies are taking place in the research field, in the United States, the Allied countries of Europe, and in the Soviet Union, of a long-range, very theoretical nature concerning the possibility of not only estimating the weather but of being able to control the weather, bringing rain, for example, at a time when and to a place where we want to bring it.

"And Dr. Teller said, 'I would not suggest to you that if we made a massive effort in this field it would succeed, but I also tell you that no one who is aware of the possibilities in the field of science could with assurance say that it was not possible to develop the ability to control the weather.' And he came to this conclusion. He said, 'Under the circumstances, then, we cannot afford to make the mistake of failing to concentrate the necessary effort in this particular field to make a break-through, if a break-through is to be made, because if this does become possible, and if the Soviet Union should make the break-through first, the ability to control the weather would have infinitely greater effect psychologically and also, in the long range, economically, than any development or anything we might have thought of militarily.' This, I agree, is, to a group of practical businessmen, educators, and government people, thinking which is perhaps pretty much in the theoretical field. It does, however bring home the lesson we must have in mind as we put emphasis on our military and scientific potentials in order to meet the threat with which we are confronted.

"My first suggestion to this group, which thinks not simply in traditional terms but also imaginatively about the future, is that we not make the mistake of concentrating our scientific potential too much in the military and lose sight of the great possibilities in other fields."...

APPENDIX M

EXCERPT FROM ADDRESS BY DR. JAMES R. KILLIAN, JR.,

BEFORE THE CONFERENCE ON RESEARCH AND DEVELOPMENT

AND ITS IMPACT ON THE ECONOMY

IN WASHINGTON, D. C., MAY 20, 1958

. . . "But we must also recognize that our research needs are going to require special kinds of institutions separate from the universities. This comes about largely because of the magnitude of equipment and facilities required for much of modern research. The great particle accelerators required by nuclear physics are reaching such size and cost that they no longer can be financed by a university or limited in their use to a single institution. This is becoming true in other fields. In a recent report by the National Academy of Sciences Committee on Meteorology on needs for research and education in meteorology, it urged the establishment of a National Institute of Atmospheric Research which could provide the research facilities on a scale required to cope with the global nature of the meteorological problem as described in this report. These facilities would include: 'modern scientific and technological tools such as a large-scale, high-speed electronic computer, a meteorological flight squadron, a laboratory for fundamental research on techniques for probing the atmosphere by electromagnetic radiation, and a laboratory for fundamental research on the use of satellites and rockets as probes of the atmosphere.' As envisioned, such an institute might be sponsored by a group of universities and would offer opportunities to university scientists and graduate students, but it would be an autonomous institution standing separate from any single educational institution and planned to serve all institutions responsible for research and education in meteorology. Other examples could be cited where we need to find new institutional patterns and relationships to provide research facilities adequate to deal with modern research techniques but too expensive to be confined to a single institution. We must develop the counterparts of the research institutes in Germany and the USSR, but we must do it by properly relating them to our universities, and thus avoid a serious weakness in the foreign institutes." . . .

APPENDIX N

EXCERPT FROM THE REPORT STRENGTHENING AMERICAN SCIENCE
BY THE PRESIDENT'S SCIENCE ADVISORY COMMITTEE
DECEMBER, 1958

..."In other areas of science, notably meteorology, progress has been handicapped by lack of tools and facilities adequate for the job at hand and of adequate numbers of trained research personnel. The U. S. now spends less than $5 million a year for basic research in meteorology, yet a single tornado can destroy scores of lives and ruin millions of dollars worth of property. And hurricane "Diane", of 1955, produced record floods in five states and a billion dollars worth of destruction. Compared to the immense forces at work in these great storms, man's efforts at understanding have been puny and ineffectual. Commendably, private and Government action is now being initiated on a proposal made early this year by a special committee of the National Academy of Sciences, which recommended a substantially greater effort in atmospheric research."...

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Membership of the President's Science Advisory Committee

Dr. Robert F. Bacher, Professor Physics, California Institute of Technology
Dr. William O. Baker, Vice-President (Research), Bell Telephone Laboratories
Dr. Lloyd V. Berkner, President, Associated Universities, Inc.
Dr. Hans A. Bethe, Professor of Physics, Cornell University
Dr. Detlev W. Bronk, President, Rockefeller Institute for Medical Research and President, National Academy of Sciences
Dr. James H. Doolittle, Vice President, Shell Oil Company
Dr. James B. Fisk, Executive Vice President, Bell Telephone Laboratories
Dr. Caryl P. Haskins, President, Carnegie Institute of Washington
Dr. George B. Kistiakowsky, Professor Chemistry, Harvard University
Dr. Edwin H. Land, President, Polaroid Corporation
Dr. Edward M. Purcell, Professor of Physics and Nobel Laureate, Harvard University
Dr. Isidor I. Rabi, Professor of Physics and Nobel Laureate, Columbia University
Dr. H. P. Robertson, Professor of Mathematical Physics, California Institute of Technology
Dr. Paul A. Weiss, Rockefeller Institute for Medical Research
Dr. Jerome B. Wiesner, Director, Research Laboratory of Electronics, Massachusetts Institute of Technology
Dr. Herbert York, Chief Scientist, Advanced Research Projects Agency, Department of Defense
Dr. Jerold R. Zacharias, Professor of Physics, Massachusetts Institute of Technology
Dr. James R. Killian, Jr., Chairman, Special Assistant to the President for Science and Technology, The White House

APPENDIX O

LETTER FROM THE COUNCIL OF THE AMERICAN METEOROLOGICAL SOCIETY

Dr. Detlev W. Bronk, President
National Academy of Sciences
2101 Constitution Avenue
Washington 25, D. C.

Dr. James R. Killian, Jr.
Special Assistant to the President for Science and Technology
The White House
Washington, D. C.

Dr. Alan T. Waterman, Director
National Science Foundation
Washington, D. C.

The Council of the American Meteorological Society has studied and discussed with great interest the report on "Research and Education in Meteorology" prepared by the Committee on Meteorology of the National Academy of Sciences. Formal action has been taken by the Council endorsing and supporting Recommendations Number One and Two of this report that:

> "Present support for meteorology of the universities and kindred institutions should be increased immediately by fifty to one hundred per cent, to be directed toward support of basic research. The Committee recommends that the increase be sought primarily from federal agencies which support basic research, with assurance of stability of such report."

and

> "A National Institute of Atmospheric Research should be established."

By vote of the Council, the Secretary was directed to inform you of its action in endorsing these two recommendations.

The Council has also voted authorization for the Executive Committee of the Council to prepare proposals and seek funds for implementing Recommendation Number Three addressed to the American Meteorological Society, suggesting that it substantially increase its activities in stimulating interest in meteorology. This program has already been initiated and specific plans for a comprehensive program have been prepared.

Very truly yours,

Thomas F. Malone,
Secretary

Membership of the Council of the American Meteorological Society

Sverre Petterssen (President), The University of Chicago
Henry T. Harrison (Vice-President), United Air Lines
Thomas F. Malone (Secretary), The Travelers Insurance Companies
Henry DeC. Ward (Treasurer), Eaton and Howard, Inc.
James N. Austin, Massachusetts Institute of Technology
Werner A. Baum, Florida State University
Robert G. Beebe, Midwest Weather Service
John C. Bellamy, Cook Research Laboratories
Gordon D. Cartwright, U. S. Weather Bureau
Richard A. Craig, Florida State University
George P. Cressman, U. S. Weather Bureau
Robert G. Fleagle, University of Washington
Robert D. Fletcher, USAF Air Weather Service
Joe R. Fulks, U. S. Weather Bureau
Joseph J. George, Eastern Air Lines
Helmut E. Landsberg, U. S. Weather Bureau
Arthur E. Merewether, American Airlines, Inc.
Albert K. Showalter, U. S. Weather Bureau
Philip D. Thompson, U. S. Air Force
Henry Wexler, U. S. Weather Bureau

APPENDIX P

INSTITUTE RESEARCH PLANNING CONFERENCE PARTICIPANTS

Atmospheric Chemistry

CHAIRMAN: Prof. Harold C. Urey, Scripps Institution of Oceanography

Dr. Gustav Arrhenius, Scripps Institution of Oceanography
Dr. Harmon Craig, Scripps Institution of Oceanography
Dr. James Lodge, Robert A. Taft Sanitary Engineering Center
Dr. Lester Machta, U. S. Weather Bureau
Dr. Edward Martells, Air Force Cambridge Research Center
Dr. Roger Revelle, Scripps Institution of Oceanography

Atmospheric Electricity

CHAIRMAN: Prof. Robert E. Holzer, University of California at Los Angeles

Mr. R. Bordeau, Naval Research Laboratory
Prof. Marx Brooks, New Mexico Institute of Mining and Technology
Dr. James Ford, Cornell Aeronautical Laboratory
Mr. J. Dinger, Naval Research Laboratory
Dr. Donald Fitzgerald, University of Chicago
Dr. H. Kasemir, U. S. Army Signal Corps
Mr. Leslie Smith, Air Force Cambridge Research Center
Dr. Bernard Vonnegut, Arthur D. Little Company

Atmospheric Radiation

CHAIRMAN: Prof. R. M. Goody, Harvard University

Dr. Bennedict, Johns Hopkins University
Dr. Sigmund Fritz, U. S. Weather Bureau
Dr. Warren L. Godson, Canadian Meteorological Service
Dr. Frank S. Johnson, Lockheed Aircraft Corporation, Los Angeles
Dr. Lewis Kaplan, Massachusetts Institute of Technology
Prof. Julius London, New York University
Prof. C. Harvey Palmer, Jr., Johns Hopkins University
Dr. Gilbert Plass, Aeronautics Systems, Inc.
Dr. Ralph Shapiro, Air Force Cambridge Research Center
Prof. John Shaw, Ohio State University
Prof. Verner Soumi, University of Wisconsin

Cloud Physics

CHAIRMAN: Prof. Henry G. Houghton, Massachusetts Institute of Technology

Dr. Robert M. Cunningham, Air Force Cambridge Research Center
Prof. James E. McDonald, University of Arizona
Prof. Morris Neiburger, University of California
Dr. Vincent J. Schaefer, Munitalp Foundation
Dr. Helmut K. Weickmann, U. S. Army Signal Corps Laboratory

General Circulation

CHAIRMAN: Prof. George S. Benton, Johns Hopkins University

Prof. Jacob Bjerknes, University of California at Los Angeles
Prof. Yale Mintz, University of California at Los Angeles
Mr. Jerome Namias, U. S. Weather Bureau
Prof. Sverre Petterssen, University of Chicago
Dr. Pierre Welander, University of Stockholm, Sweden
Captain Scott Williams, Air Weather Service

Hydrodynamic Analysis

CHAIRMAN: Prof. Jule Charney, Massachusetts Institute of Technology

Dr. Julian Bigelow, Princeton Institute for Advanced Study
Prof. W. Lawrence Gates, University of California at Los Angeles
Dr. Eugene Isaacson, New York University
Prof. Edward Lorenz, Massachusetts Institute of Technology
Dr. Willem Malkus, Woods Hole Oceanographic Institution
Prof. Norman Phillips, Massachusetts Institute of Technology
Prof. George W. Platzman, University of Chicago
Mr. Walter Ramshaw, United Aircraft Corporation
Dr. Joseph Smagorinsky, U. S. Weather Bureau

Hydrodynamic Models

CHAIRMAN: Prof. Dave Fultz, University of Chicago

Dr. M. L. Albertson, Colorado State College
Dr. Arnold Arons, Amherst College
Prof. Franklin I. Badgley, University of Washington
Dr. Willard H. Bennett, U. S. Naval Research Laboratory
Prof. E. R. G. Eckert, University of Minnesota
Dr. Alan J. Faller, Woods Hole Oceanographic Institution
Dr. Norman Phillips, Massachusetts Institute of Technology
Dr. Ralph Shapiro, Air Force Cambridge Research Center

Interaction of Ocean and Atmosphere

CHAIRMAN: Dr. Walter Munk, University of California

Prof. Arnold Arons, Amherst College
Dr. Andrew Bunker, Woods Hole Oceanographic Institution
Dr. Henry Charnock, National Institution of Oceanography, England
Dr. Woodrow C. Jacobs, Air Weather Service
Dr. Lewis D. Kaplan, Massachusetts Institute of Technology
Prof. Dale Leipper, Texas Agricultural and Mechanical College
Dr. Joanne S. Malkus, Woods Hole Oceanographic Institution
Dr. Willem V. R. Malkus, Woods Hole Oceanographic Institution
Prof. Yale Mintz, University of California at Los Angeles
Mr. Jerome Namias, U. S. Weather Bureau
Dr. William S. Richardson, Woods Hole Oceanographic Institution
Dr. Henry Stommel, Woods Hole Oceanographic Institution
Mr. A. Woodcock, Woods Hole Oceanographic Institution

Meteorological Instrumentation

CHAIRMAN: Prof. Verner Suomi, University of Wisconsin

Dr. John C. Bellamy, Cook Research Laboratories
Mr. V. S. Hardin, USAF Air Weather Service
Dr. Arnold Glaser, Allied Associates
Mr. Donald Hillary, National Hurricane Project, U.S. Weather Bureau
Mr. Herbert Jacobson, General Precision Laboratory
Mr. David S. Johnson, U.S. Weather Bureau
Prof. A. R. Kassander, Jr., University of Arizona
Prof. Edward T. Nye, University of Minnesota

Meteorological Use of Rockets and Satellites

CHAIRMAN: Dr. William Kellogg, Rand Corporation

Dr. John C. Bellamy, Cook Research Laboratories
Dr. Warren Burning, Army Ballistics Laboratory, Aberdeen Proving Ground
Mr. E. M. Cortwright, National Advisory Committee on Aeronautics
Dr. Herbert Friedman, Naval Research Laboratory
Dr. Sigmund Fritz, U. S. Weather Bureau
Dr. Arnold Glaser, Allied Associates
Prof. Verner E. Suomi, University of Wisconsin
Dr. John Townsend, Naval Research Laboratory
Dr. William K. Widger, Air Force Cambridge Research Center
Dr. Fred L. Whipple, Smithsonian Astrophysical Observatory

Ozone

CHAIRMAN: Prof. R. A. Craig, Florida State University

Dr. W. C. Chin, New York University
Dr. E. S. Epstein, Pennsylvania State University
Prof. B. Haurwitz, New York University
Mr. J. Hughes, Office of Naval Research
Prof. J. London, New York University
Dr. C. L. Mateer, Canadian Meteorological Service
Dr. W. B. Moreland, U. S. Weather Bureau
Dr. H. Newstein, New York University
Dr. G. Ohring, Air Force Cambridge Research Center
Dr. V. Oyama, New York University
Prof. R. Reed, University of Washington
Prof. V. Regener, University of New Mexico
Prof. R. Schotland, New York University

Severe Storms

CHAIRMAN: Prof. Louis J. Battan, University of Arizona

Dr. Pauline Austin, Massachusetts Institute of Technology
Mr. Robert G. Beebe, Midwest Weather Service
Dr. Tetsuya Fujita, University of Chicago
Mr. J. R. Fulks, U. S. Weather Bureau
Dr. Joachim P. Kuettner, Air Force Cambridge Research Center
Dr. Myron G. H. Ligda, Stanford Research Institute
Mr. John Sievers, National Academy of Sciences - National Research Council
Mr. Glenn E. Stout, Illinois State Water Survey Division
Dr. Morris Tepper, U. S. Weather Bureau
Dr. Bernard Vonnegut, Arthur D. Little, Inc.
Dr. Helmut Weickmann, U. S. Army Signal Corps

Statistical Methods

CHAIRMAN: Dr. Robert M. White, Air Force Cambridge Research Center

Mr. Glenn W. Brier, U. S. Weather Bureau
Dr. Aaron Fleischer, Massachusetts Institute of Technology
Prof. Thomas Gleason, Florida State University
Prof. Alan T. James, Yale University
Prof. Edward N. Lorenz, Massachusetts Institute of Technology
Prof. Hans Panofsky, Pennsylvania State University
Dr. Harry Press, National Aeronautics and Space Agency

Statistical Methods (Continued)

Mr. Bernard Shorr, Travelers Weather Research Center
Prof. Jerome Spar, New York University
Mr. Herbert Thom, U. S. Weather Bureau
Prof. John Tukey, Princeton University
Mr. Keith Veigas, Travelers Weather Research Center
Prof. George P. Wadsworth, Massachusetts Institute of Technology
Dr. Max Woodbury, New York University

Tropical Meteorology

CHAIRMAN: Prof. Herbert Riehl, University of Chicago

Prof. Noel LaSeur, Florida State University
Dr. Joanne S. Malkus, Woods Hole Oceanographic Institution
Mr. R. H. Simpson, National Hurricane Research Project, U.S. Weather Bureau

Turbulence and Convection

CHAIRMAN: Prof. Heinz Lettau, University of Wisconsin

Dr. Morton Barad, Air Force Cambridge Research Center
Dr. Harrison Cramer, Massachusetts Institute of Technology
Prof. S. Corrsin, Johns Hopkins University
Prof. Benjamin Davidson, New York University
Dr. Francois Frenkiel, Applied Physics Laboratory, Johns Hopkins University
Dr. Glenn R. Hilst, General Electric Company
Prof. Hans Panofsky, Pennsylvania State University
Dr. Harry Press, National Aeronautics and Space Administration
Major Charles F. Roberts, USAF Air Weather Service
Dr. Leo Tick, New York University

Upper Atmosphere

CHAIRMAN: Prof. H. R. Byers, University of Chicago

Mr. Herbert S. Appleman, USAF Air Weather Service
Dr. Joseph Chamberlin, Yerkes Observatory
Dr. R. M. Goody, Harvard University
Prof. Bernhard Haurwitz, New York University
Dr. William W. Kellogg, Rand Corporation
Dr. G. P. Kuiper, Yerkes Observatory
Mr. Herman LaGow, National Aeronautics and Space Administration

Upper Atmosphere (Continued)

Dr. Walter O. Roberts, University of Colorado
Dr. Alan T. Waterman, Jr., Stanford University
Dr. Fred T. Whipple, Smithsonian Astrophysical Observatory

Use of Electromagnetic Radiation as a Meteorological Probe

CHAIRMAN: Dr. David Atlas, Air Force Cambridge Research Center

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