An Aviation Research Facility For the Atmospheric Sciences 301

Report of the NCAR National Aircraft Facility Survey Group

Robert A. Ragotzkie, Chairman 201A/ET AL/
Fred C. Bates
John C. Bellamy
Roscoe R. Braham
Robert M. Cunningham
James G. Edinger
John W. Hinkelman, Jr.
Dwight B. Kline
Charles A. Palmer, Jr., Secretary

aviation research facility
atmospheric sciences
NCAR.

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH M01A
BOULDER, COLORADO

NCAR Technical Notes 64-1 402B

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Published by the National Center for Atmospheric Research

Boulder, Colorado

Operated by the University Corporation for Atmospheric Research

a private, non-profit corporation, sponsored by

the National Science Foundation

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FOREWORD

One of the major reasons for the establishment of the National Center for Atmospheric Research was the lack of adequate research facilities by which to observe and analyze the earth's atmosphere. Perhaps the most obvious and typical of such facilities, characteristically too costly for the average university to establish or maintain, is a versatile aviation facility, where requisite tools and technological know-how can be developed in an integrated manner to serve the atmospheric sciences community as a whole.

From the outset of planning for NCAR, beginning with the report of the University Committee for Atmospheric Research in 1959 and continuing in concert with the National Science Foundation, provision of an aviation facility has been foreseen as one of NCAR's major facility roles. With the advent of light, high-performance supercharged piston and jet aircraft, such a facility can now be developed at a fraction of the operating cost that would have been necessary when the aircraft facility was first called for. At the same time, the obvious need for additional aircraft to carry out research programs has increased. If progress in the atmospheric sciences--for scientific as well as economic reasons--is of high priority in the national interest, the roadblock of lack of facilities must be removed as soon as possible.

Recommendations of the Aircraft Facility Survey Group

As a standard part of the NCAR procedure for establishment of facilities for the joint use of universities and research organizations, a National Aircraft Facility Survey Group, composed of scientists with broad experience in the use of research aircraft and two NCAR staff members, was appointed in July 1963. The group was requested to study and report upon requirements for research aircraft and aircraft services (such as instrumentation and data-handling systems) now existing in the scientific community, and to recommend the general means for fulfilling those requirements. Specifically, the group was asked to recommend the extent to which NCAR should participate in the development of the requisite facilities.

After five months of study, the group has strongly recommended the establishment of a scientific aviation facility at NCAR. In brief, the report calls for:

1. Immediate establishment of coordination and information functions to guide interested scientists to already available aircraft; to assist in the solution of such problems as air-space reservation, approval of aircraft modification, etc.; and to publish general information on atmospheric research conducted from aircraft.

2. Immediate establishment of a training program in techniques of aircraft observation for graduate students and other workers in the atmospheric sciences.

3. Immediate acquisition and operation of research aircraft to serve the research needs of the NCAR staff.

4. Building upon the experience gained from serving NCAR in-house needs, establishment in the near future of an aviation facility that can meet the needs of a significant proportion of the airborne research needs of the university atmospheric sciences community. Specific goals for this phase of the development of the facility would be in response to developing needs within the universities, as well as the recommendations of a scientific advisory panel, to be appointed in the next two months.

<u>Contents of the Report</u>

In this publication are the report of the Survey Group and two appendices. Appendix I is a staff-conducted survey of research aircraft needs that served as the initial raw material for the Survey Group's recommendations. Appendix II, also produced by the NCAR staff, is a plan for establishment of the Aviation Facility, which was approved in general terms by the Survey Group. Both of these appendices have been included by specific direction of the Survey Group and can be considered integral parts of the whole.

The program laid out by the Survey Group is a challenging one, but after a thorough subsequent review by the NCAR staff, it appears to be a program that is realistic, responsive to needs (rather than desires) of the atmospheric sciences community, and which can be accomplished within the over-all long-range goals of NCAR. Though it must be recognized that NCAR's ability to satisfy the requirements of the Survey Group's report depends on NCAR's total budgetary situation, a start now is clearly called for, with the aim of having the facility fully operational within two years.

The University Corporation for Atmospheric Research and NCAR are deeply indebted to the members of the group for the effort and wisdom they devoted to their deliberations and recommendations.

Daniel F. Rex

Daniel F. Rex
Director of Facilities, NCAR
February 3, 1964

UNIVERSITY OF WISCONSIN
MADISON 6

DEPARTMENT OF METEOROLOGY

December 30, 1963

Dr. Daniel F. Rex
National Center for Atmospheric Research
Boulder, Colorado

Dear Dr. Rex:

It is my pleasure to transmit herewith the final report of The National Aircraft Facility Survey Group.

As a group we are unanimous in our recommendation that an aviation facility is needed by the scientific community and should be established at NCAR. We have indicated what is, in our best judgment, the most reasonable course to follow to develop such a facility. We have refrained from recommending specific operational plans for the pursuance of this course because these are entirely dependent on the specific scientific need. It is our opinion that such planning should be done by the NCAR Aviation Facility staff and then reviewed by an Advisory Panel. Instead we have attempted to set up guidelines for the logical development of a Facility which can ultimately serve the research aircraft needs of the entire scientific community.

As members of the Survey Group we wish to express our sincere thanks to the NCAR staff members who participated in our meetings for their patient efforts to provide us with information we needed and for their very able assistance in making meeting and travel arrangements.

As chairman I would be amiss if I did not acknowledge the whole-hearted participation of each member of the Survey Group in the formulation of this report. Despite their diverse organizational associations they contributed their advice and experience without restraint. It is our hope that this report will be of some value in the future planning by NCAR and that it will also serve to stimulate progress in the use of aircraft for meteorological research.

Sincerely yours,

Robert A. Ragotzkie

Robert A. Ragotzkie
Associate Professor

RAR:csa

Enclosure

FINAL REPORT OF THE NCAR NATIONAL AIRCRAFT FACILITY SURVEY GROUP

Introduction

The members of the NCAR National Aircraft Facility Survey Group were asked to analyze the national need for improved aircraft observing facilities whose primary purpose is support of basic research in the atmospheric sciences. In particular, they were asked to address themselves to the following questions:

1. What requirements, because of their particular character or extent, can not be adequately met through the efforts of individual university or research groups? It is important to distinguish between an assemblage of inherently divisible requirements and those which cannot be satisfied in parts.
2. What is the priority of need for such facilities in the light of research objectives in the field of atmospheric science today?
3. What order of relative priority should be assigned among the requirements delineated in Number 1 above?
4. In the light of current engineering capabilities, how can these requirements be met? A general plan designed to satisfy the requirements of today and of the foreseeable future is desired.
5. Considering present and expected future interests and capabilities, what agencies or groups can best implement the various aspects of the plan developed in Number 4 above?

This document is the result of the deliberations of the Survey Group.

Requirements

The NCAR National Aircraft Facility Survey Group undertook a study of research requirements for aircraft observations of atmospheric variables at the outset of its deliberations. It soon became evident that little purpose would be served by a detailed survey of needs beyond that reported upon in the UCAR "Preliminary Plans for a National Institute for Atmospheric Research" or, especially, beyond the survey conducted for NCAR in early 1963.

The "Summary of 1963 Survey of Aircraft Needs" is presented here as Appendix A in support of the following well-considered conclusions.

1. Aircraft platforms are invaluable for obtaining measurements of atmospheric variables in many kinds of experiments aimed at furthering our understanding of the atmosphere. Many such observations can be obtained at the desired places and times and in the required detail only with aircraft, and many others can be obtained much more economically with aircraft than in any other way.

2. The over-all needs for aircraft observations for atmospheric research are so many and varied that they cannot all be met by any single national facility. Rather, they can only be satisfied with aircraft flight research activities by a wide variety of organizations, such as the Air Force, Navy, Army, Weather Bureau, NASA, air lines, NCAR, individual universities, etc. Government agencies, including the military, as service organizations, carry out research among those problems which relate to their service missions. Meteorological research by commercial air lines has been directed primarily toward improvement in air commerce. Individual universities have, can, and will continue to use airplanes in research directed toward increased understanding of the atmospheric environment; however, individual universities are generally limited to the use of light aircraft. The required role of the NCAR Aviation Facility lies between the light plane capability of universities and the mission-oriented activities of Government services.

3. In view of the virtually axiomatic need to fly in the atmosphere to learn about it, and in view of its stature as being "The National Center for Atmospheric Research," it is therefore incumbent upon NCAR to establish and operate an aviation facility.

4. This NCAR Aviation Facility can and must serve many of the common needs of the national atmospheric research community in the following two basic ways. First, it must satisfy a strong need for a centralized source of information, advice, liaison and training, concerning the use of aircraft in and for atmospheric research. Second, it must also provide the operational function of instrumenting and flying aircraft in support of

atmospheric research in this region between the light plane capability of the university and the mission-oriented research of the Government.

5. This latter operational function must eventually serve several of the needs of atmospheric scientists in the several universities. It is, however, virtually impossible to delineate the specific nature of this support at this time. Such delineations must await the development of an aviation capability within NCAR, and it is strongly recommended that this prerequisite capability-in-being be established by first serving the needs of the atmospheric scientists within NCAR.

Recommendations

In view of these requirements, the NCAR National Aircraft Facility Survey Group recommends to NCAR the establishment of an aviation capability as a means for helping to meet present and future research requirements of the atmospheric scientific community. For purposes of discussion, this capability will be called the NCAR Aviation Facility. It is the view of this group that this capability more nearly fits into what UCAR has termed a national facility than an NCAR support facility. It is recommended that the following tasks be among those initially assigned to this capability.

Non-operational Functions

1. Information services. The NCAR Aviation Facility should serve as a clearing house for information concerning aircraft platforms and instrumentation. This would include the regular publication of a "newsletter" containing current information on the use, availability and development of aircraft for meteorological research by universities and other organizations involved in research activity. A listing of all platforms and systems currently in use and their characteristics should be maintained and efforts made to match possible users with available facilities. This function does not imply any budget or management control over any group or groups outside of NCAR.

2. Advisory services. As the capabilities of the Facility develop, it should serve as an advisory group on the use of aircraft platforms for atmospheric research. It is especially important that this should include

technical advice concerning standardized, or multiple-use, data recording and acquisition systems, instrumentation and sensors.

3. Liaison services. The NCAR Aviation Facility should represent the broad university and associated interests in the atmospheric sciences in active liaison with the various Federal regulatory bodies such as FAA, FCC, etc. In particular, the Aviation Facility should emphasize the needs of the research worker in the field observation of atmospheric parameters in the face of growing restriction on such activity.

4. Training. Progress in the use of aircraft for meteorological research has not kept pace with its potential. This is in large part due to lack of training in airborne, or indeed in all, phases of meteorological observation and instrumentation. The NCAR Aviation Facility should provide a focal point in alleviating this situation by providing a locale and facilities for a summer field program for graduate students in the use of aircraft for meteorological observation and research. In that program, graduate students can be offered opportunities to work as research assistants on flight programs at NCAR. It is recognized that the initiative for such a program must come from the universities concerned. Other methods for stimulating and upgrading skills in this field should also be considered as legitimate objectives of NCAR.

Operations

The development, procurement and use of platforms, instrumentation and recording systems should initially be geared to the internal needs of NCAR, keeping in view the over-all requirements of the scientific community. In the operations area, it is believed that satisfying internal NCAR needs represents the best route to a fully developed national function. It is not realistic for NCAR to enter into aircraft operation on a national scale without experience. A gradual evolution of the Facility to include operational assistance and services to the scientific community should proceed as the capabilities of the Aviation Facility group expand and become known.

Standardized recording systems are particularly needed. These systems should be capable of modular use on different platforms with a combined capability of in-flight monitoring and post-flight computer processing without manual reduction. The weight and power limitations of small airplane usage should be considered in their design. It is desirable that such instruments and systems be made available to the scientific community.

Specific operational plans must be based on the requirements of the scientific community as judged by an advisory panel.

Respectfully submitted,

Dr. Robert A. Ragotzkie, Chairman
(University of Wisconsin)*

Dr. Fred C. Bates
(University of Kansas)

Dr. John C. Bellamy
(University of Wyoming)

Dr. Roscoe R. Braham, Jr.
(University of Chicago)

Dr. Robert M. Cunningham
(Air Force Cambridge Research Laboratories)

Dr. James G. Edinger
(University of California)

Mr. John W. Hinkelman, Jr.
(National Center for Atmospheric Research)

Mr. Dwight B. Kline
(United States Weather Bureau)

Mr. Charles A. Palmer, Jr., Secretary
(National Center for Atmospheric Research)

*The conclusions in this report are those of the group members as individuals, and not as appointed representatives of their institutions.

APPENDIX A

SUMMARY OF 1963 NCAR SURVEY OF AIRCRAFT NEEDS

Background

One of the first suggestions of need for a multiple aircraft, research flight facility in the atmospheric sciences came to public attention in a report (February 1959) prepared for the National Science Foundation by the University Committee on Atmospheric Research. This report, which was the culmination of the work of a number of people representing the university community, states, "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."

Again in 1962 the Committee on Atmospheric Sciences of the National Academy of Sciences and the National Research Council, in its report to the Special Assistant to the President for Science and Technology (in NAS-NRC publication 946), stated, "In addition to the flight services referred to in section 12.2.2, aircraft and other airborne platforms will be needed for several other research purposes, and the most economical arrangement would be to provide a multi-purpose flight facility. For example, aircraft could be engaged in hurricane research during the late summer and autumn, make reconnaissance of major storms during the winter, and support severe weather research during the spring and summer. Much cloud physics and related research could be accomplished in connection with these missions and by aircraft especially assigned to such research. Through proper coordination it should be possible to provide the required air support at a relatively low cost." This report, based on a series of planning

*Based on the results of the survey by NCAR, 1963.

conferences held during the summer of 1961, again emphasizes the fact that those working in the atmospheric sciences continued to feel the need for a research flight facility.

Past Usage of Aircraft for Atmospheric Research

Aircraft have been used by numerous groups in the past as platforms from which to make atmospheric observations. Most of the use of large versatile planes was for a specific project. A scientist having an idea obtained a sponsor, usually a Government agency, which could and did furnish an airplane. The scientist then became his own expert in instrumentation for his particular purpose and spent perhaps 90% of his time instrumenting the airplane and getting prepared for a limited period of observation.

After spending a year, or perhaps two, preparing the airplane and briefing the crew, he was able to spend one or two seasons making the observations he desired. During this period the plane crew may have changed once or twice, requiring a great deal of additional effort on the part of the scientist to brief the new crews. Also it has been commonplace, especially when the planes were military, to have the planes recalled for military purposes just at the critical observational period. Finally, as soon as the project was completed, the planes were returned to the providing agency, the special instruments were removed and the scientist wrote a scientific report. Unfortunately his hard-gained knowledge of how to instrument and operate an airplane for meteorological research was rarely disseminated to those who might follow in a similar endeavor.

In the use of light single-engine or twin-engine planes for local meteorological research, the picture has been somewhat different. Sometimes the scientist could obtain the type of information he desired with very little modification to the airplane. This permitted him to rent or lease an airplane locally at small cost. In other cases it was necessary to modify the airplane appreciably and it was necessary, under these circumstances, to lease or purchase the plane. In either event, the meteorologist had more or less complete control, and he could carry out his observational program at times most suitable to him. The disadvantage of this type of operation is that the planes were necessarily quite limited. There are many desirable programs for which such planes do not have the required altitude, range, or payload capability.

In recent years the Weather Bureau has built up a research flight facility. It is controlled and operated by Weather Bureau scientists. Planes having the desired capabilities have been purchased, leased or obtained on a long-term basis by bailment from the military services. Personnel associated with the facility have been permitted to remain on the job long enough to acquire worthwhile knowledge of the project. This facility is devoted primarily to Weather Bureau purposes at this time.

The majority of military airplanes used for making atmospheric observations have been provided for operational purposes. Although these planes were not instrumented for research use, they have operated primarily in areas of sparse data and have thereby contributed a great deal to knowledge of the atmosphere. On occasion while serving their operational purpose, they have also been used as a platform from which research observations have been made. Commercial planes have been used in this way, too, and both commercial and military planes should be so used in the future.

NCAR Survey

Since NCAR's inception in 1960, NCAR personnel have discussed the requirements for an air flight facility and the problems associated with establishing such a facility with representatives of the scientific community. Some scientists have been able to discuss their requirements in great detail, but many, presumably because of the lack of available airplanes, have stated requirements only in general terms. Those who have had experience with aircraft operations in the past have pointed out some of the problems with pitfalls and have offered suggestions for new or better ways to solve some of the problems.

Late in 1962, NCAR prepared a questionnaire which it hoped would help answer the following three questions: What requirements exist now for airplanes for use as observational platforms in the atmosphere? Who has had experience with the use of airplanes for atmospheric research and to what extent can their advice be helpful to NCAR if it should establish an air facility? What types and numbers of airplanes are being used now for atmospheric research and in what way are they being used?

Ninety of these questionnaires were distributed to individuals and institutions throughout the United States. Fifty-eight responses were received. Both before and after the questionnaires were sent, NCAR personnel discussed the questions thereon with various scientists. Evaluation of the questionnaires and the discussions have given us what we feel to be a much better understanding of requirements and of the basic resources from which NCAR must draw if it is to establish an air facility.

Summary of Questionnaires and Associated Discussions

Requirements

The requirements stated by the people who answered the questionnaires and those who were interviewed are virtually as broad as the atmospheric sciences. There are requirements for the wind, temperature and moisture distribution in all types of frontal systems, jet streams, lines of convergence, cyclonic storms of all types, anticyclones (especially those of the meso-scale), thunderstorms, sea breezes, etc. There were requirements stated for study of the climatology of vast, virtually uninhabited areas by studying lakes, bogs and vegetation. In this case planes serve a dual role. They are instruments of research and the means of transportation into a trackless area. It was suggested that measurement of divergence and vorticity directly by aircraft, especially of meso-scale features, would be worthwhile. Wind stress measurements, surface radiation and albedo measurements, divergence of radiative flux up to 5000 meters, mass exchange between the troposphere and the stratosphere, detailed structure of properties of the West Coast marine layer, measurement of the spectrum of the ocean surface waves by radio techniques from airplanes, the relation of cloud patterns to wind and stability fields, rain drop size distribution, space charge, the distribution of carbon dioxide above 10,000 feet at all latitudes, and surface temperature mapping by airborne bolometers were all listed. The development and testing of airborne meteorological observing systems were stressed. The measurement of sky-glow was also mentioned. Although this is not, by any means, a complete list of the requirements which were stated, it does give an idea of the broad range of the requirements. To fulfill these requirements, flights at high levels, flights at low levels, extended flights over the ocean, flights over the Arctic and Antarctic, and flights by specially stressed planes into severe thunderstorms would all be required.

Characteristics of Planes Required

For certain of the requirements, small slow-flying planes which disturb the atmosphere as little as possible are needed. For some requirements, the ability to fly safely at low altitude over extended distances is important. For other requirements, heavy load carrying planes are needed. For other requirements, the ability to fly at high altitudes is required. High altitude, high speed and long range are all requirements of a plane for some studies of the structure of the jet stream. Ozone distribution study and sky-glow studies require the same characteristics. For some studies several planes flying in special formations are required. In general, it can be said that the ideal plane for atmospheric studies is one which will carry a heavy load, fly readily to almost any altitude, disturb the atmosphere through which it flys as little as possible, be capable of having sensors of all types placed anywhere on its surface, have very long range, and have low maintenance and operating costs. It must also be capable of operating in any kind of weather. Needless to say, not all of these characteristics will be found in any one plane. The characteristics can be acquired by using a variety of planes.

Particular Problems

Many problems in the use of airplanes for atmospheric research were brought to light in the responses to the questionnaires. It would be difficult to pick out any problem and say that it is the major problem, but problems of instrumentation and data recording are certainly extremely important ones. Availability of aircraft at the time when they are needed is also an outstanding problem. The airplane, being a complex machine which must necessarily have a high degree of safety, must undergo frequent checks, repairs and modifications. Therefore, it is frequently not available because of these mechanical problems. Also airplanes are often shared between research and some other use. This is especially true in the military services where the airplanes must be considered a part of the military operational component. Under these circumstances also, the crew usually has an operational mission which it considers to be more important than the research mission. Therefore, from the scientist's point of view, there is often a marked lack of interest on the part of the crew in scientific research. Even when the crew does become interested in the research efforts of the airplane which it flies, the scientist cannot count on this situation to remain unchanged for long, because crews are often reassigned. Although many of the problems stated here cannot be overcome by placing control of the planes in the hands of the scientist, some of them might be reduced.

Planes Now in Use for Atmospheric Research

For convenience of discussion, the planes now in use for atmospheric research have been arbitrarily divided into seven groups or categories. These are:

1. Low altitude, short range. This includes small single-engine and light twin-engine planes having a gross weight of less than about 9000 pounds. These planes are available at almost all local airports; they can be rented or leased. Their primary use has been for cloud physics and atmospheric electricity studies, but at least one group has used them for the study of surface characteristics. Since these planes will not carry a heavy payload, modification for research purposes has usually been simple compared with larger aircraft with more diversified and sophisticated instrumentation.

2. Low altitude, long range. These are normally piston-type planes which have a service ceiling below 25,000 feet. Their range is normally on the order of 3000 miles. Most such aircraft have been operated by Government agencies or with Government agency support. They have been used largely for synoptic scale studies both over the ocean and over land, and instrumentation has been that appropriate to synoptic studies. Frequently

data recording was done by a meteorological observer who accompanied the flight; however, there are also a number of such aircraft which have been equipped with automatic data recording of one kind or another. Except for the first category discussed, there are more planes ot this category in use for atmospheric research purposes than of any other category.

3. High altitude, short range. This is a jet-transport or bomber type having an altitude limit of 40,000 to 45,000 feet and a range of less than 1500 miles. The primary use made of these planes also has been in the study of atmospheric structure on the synoptic scale. Almost without exception, these planes have been operated by a Government agency, and the only one, to our knowledge, which has been in use full time for atmospheric research is the B-57 operated by the Weather Bureau Flight Research Facility. Data recording is usually automatic and, in fact, one of the problems with this type of airplane is that there may not be room in the plane for a meteorological observer during research flights.

4. High altitude, long range. There are usually jet-transport types or jet bombers having a range greater than 1500 miles and an altitude limitation of approximately 45,000 feet. These are capable of carrying a heavy load including extensive instrumentation, data recording equipment and meteorological observers. For this reason, they are very versatile, but they are also quite expensive to operate and to maintain. Almost without exception, research flights made by high altitude, long range planes are made by Government agencies. There are many instrumentation and data recording problems associated with these flights, and the flights are often made by airplanes which have another primary mission so that they cannot always be made at the most appropriate time for research purposes.

5. Very high altitude. These planes, in addition to flying well above 45,000 feet, also have long range. The U-2 is in this category. Its use is generally restricted to a special type of observation such as cloud photography from high altitude and high altitude air sampling. All of these planes, so far as we can determine, are operated by Government agencies, although some cooperative use is provided to others. There are some rather severe problems associated with the use of these planes; they are

fragile, they require a great deal of maintenance, and there is rarely any assurance that a plane will be available when it is needed for research flights.

6. High performance. These are generally jet-type fighters having high altitude capability and the capability to withstand large accelerations. They do not carry heavy payloads, and they are quite restricted as to the number of people who may accompany a flight. Their primary use in atmospheric research has been in cloud physics and in the study of severe storms. Almost all of these planes are also operated by a Government agency or with Government agency support. They are high speed planes having rather critical aerodynamical characteristics; therefore, instrumentation is usually a problem. Furthermore, the speed with which they penetrate clouds and severe storms is disadvantageous. They are also short range aircraft.

7. Special. This consists of drones, helicopters, sailplanes, etc. Since it includes such a variety of special types of airplanes, the use is also quite varied. Drones can fly into severe storms and into areas which are radioactive. Helicopters have been used, to some extent, to take soundings near the surface, particularly over the ocean, and to study other aspects of the boundary layer problem. Sailplanes have been used in the study of the development of cumulus clouds and other up-drafts and have also been used in the study of the lee-wave problem. These special types of planes usually have rather severe limitations in their operational capabilities and consequently are limited to special situations when used as research tools. Vehicles in this category have been operated by various groups and in many varied ways. None of these have been used extensively. The problems associated with this category are as varied as the category. The primary problems probably are instrumentation and data recording.

Availability versus Requirements

This survey has shown that there is a good deal of time available on existing instrumented planes. It has also shown that many of the requirements could be met by using existing planes as they are now instrumented. There are other requirements which cannot be met in this same way, but with a small amount of additional instrumentation, they might be met. Matching requirements and research flight time may be one feasible way, then, of fulfilling the needs of some scientists. The problem of recording data has been handled on an ad hoc basis almost entirely. There is a lack of general agreement as to when data should be recorded in an analog form and when in digital form. Consequently, it may be that the problem of recording data in a manner unsuited to a particular scientist's needs may prevent him from using what otherwise would be available flight time.

The Weather Bureau Research Flight Facility and military groups can provide and have provided multiple plane flights for meteorological research. There is also the possibility of bringing together several groups, each having a single airplane and carrying out flights of multiple aircraft. The desirability of such multiple plane experiments is obvious.

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APPENDIX B

PLAN FOR AN AVIATION FACILITY FOR THE ATMOSPHERIC SCIENCES

The document entitled "Plan for an Aviation Facility for the Atmospheric Sciences" was prepared under the direction of Mr. John Hinkelman of NCAR at the request of the National Aircraft Facility Survey Group. Its purpose was to provide an initial plan designed to implement the recommendations of the Survey Group.

All members of the Survey Group have examined this plan and are in agreement with it on a general level but not necessarily with respect to all details. It is reiterated here that the details of any operational plan must be based on the aviation requirements of the scientific community as judged by an advisory panel.

APPENDIX B

PLAN FOR AN AVIATION FACILITY FOR THE ATMOSPHERIC SCIENCES

Section I. Plan of Implementation for Joint Use

Introduction

A vital part of the NCAR mission is to develop major research facilities serving broad university and associated interests in the atmospheric sciences, and to make these facilities available to the scientific community at large. An urgent need exists for the establishment of such a facility to provide essential aviation services that are beyond the practical reach of individual research groups.

This report describes a proposed plan for the establishment of a national aviation facility. It considers, first the basic requirement for the facility, its mission, organization, and management. Next, the foreseen technical program and facilities are outlined. Finally, proposed implementation and budgetary plans are presented. The plan summarizes the current thinking of the NCAR National Aircraft Facility Survey Group as to what constitutes an achievable and productive program for the first several years' operation of the facility.

Requirements

The requirement for establishing the facility stems from the following factors:

1. Aircraft platforms are invaluable for (1) carrying out scientific measurements of atmospheric variables for research purposes, and (2) conducting experiments aimed at furthering our understanding of the atmosphere. There is a definite research need to observe the three-dimensional structure of the atmosphere with much higher resolution than that provided by the current observational network, both at the ground and to great altitudes. The cost of achieving any appreciable improvement in resolution using fixed ground installations and balloon sounding systems is excessive.

Aircraft, properly instrumented are capable of providing very high resolution in the troposphere and lower stratosphere at a much lower cost. In addition, aircraft observational platforms are useful for indirect measurements of upper atmospheric parameters relating to the ionosphere and above.

2. No one group is responsible for coordination within the scientific community of the common problems that arise in research aircraft operations--airspace use, aircraft bailment, space availability on aircraft in use, frequency allocation, observer training, etc.

3. There is no focal point for the development of aircraft research instrumentation (sensors, recorders, storage) which is of common interest to that part of the scientific community engaged in atmospheric research. Instrumentation currently available is not adequate to obtain the research data required.

4. Adequate and economical platforms are generally not available when required to carry out necessary basic research programs.

The primary requirements therefore include coordination and services, the development of airborne instrumentation, recording and data-processing systems that sense and convert analog quantities into the form needed by research scientists for theoretical studies, and the provision of aircraft platforms. Detailed research data requirements are contained in Section II of this study. The currently-known measurement requirements and the geographical scope of coverage needed are summarized therein.

<u>Facility Mission</u>

The charter, or mission, of the aviation facility is to:

1. Serve as a coordinator within the scientific community (universities, other research agencies, NCAR itself) of the use of aircraft instrumentation platforms in atmospheric research projects.

2. Provide services to atmospheric research projects of the scientific community that can be best handled by a centralized source.

3. Conduct research and development of instrumentation, recording and data reduction techniques and devices that have common interest to the various groups in the scientific community involved in research flights of aircraft platforms.

4. Provide facilities, instrumentation, aircraft flight support, and data reduction, initially to internal NCAR atmospheric research projects requiring aircraft platforms, and eventually, as the capability develops, to universities and/or other research groups.

Coordination in atmospheric research from instrumented aircraft is desirable because research funds are limited and investigations should be both as broad as possible and non-repetitive in the interest of efficiency. A simple, but effective, means of assuring such efficiency lies in informing all investigators of the activities and results of others. Besides this information exchange function, the facility can also apprise the entire field of available aircraft, instruments, flight space and data to help assure that maximum use is made of all research facilities and flight time. This latter coordination function is similar to the "help wanted" and "positions available" sections in newspaper advertising. In other words, the facility should serve as a clearing house for information concerning aircraft platforms and instrumentation. This would include the regular publication of a newsletter containing current information on use and development of aircraft for meteorological research by universities and other organizations involved in this kind of research activity. A listing of all platforms and systems currently in use and their characteristics should be maintained and efforts made to match possible users with available time. This coordination function does not imply any management control over any group or groups outside of NCAR.

The centralized source of services to the community would involve advisory, liaison and training functions. The facility would serve as an <u>advisory</u> group on the technical aspects of the use of aircraft platforms, including the evaluation of existing airborne sensors and instrumentation systems and components. A centralized source of services to investigators is desirable, also, because many service functions involve <u>liaison</u> with Government agencies and are more effective if handled centrally. The facility should represent the broad interests of the scientific community to regulatory bodies such as FAA, FCC, etc. In particular, the facility could serve to emphasize the needs of the researcher to observe his medium in the face of growing restriction on such activity.

Progress in the use of aircraft for meteorological research has not kept pace with the rest of the field, largely due to lack of <u>training</u> in all phases of meteorological observation and instrumentation. The facility could provide leadership in remedying this situation particularly with regard to aircraft by setting up field programs in the use of aircraft for meteorological observation and research for graduate students. This function would be carried out with the cooperation and assistance of the universities concerned. In addition, graduate students would be offered opportunities to work as research assistants on flight programs at NCAR. Any other methods for stimulating and upgrading skills in this field should be considered as legitimate activities of the facility. Eventually a common source of data reduction services for aircraft research projects may be desirable.

There are many problems in aircraft instrumentation, recording and data reduction which have common interest to various groups in the scientific community. It is logical that the aviation facility concern itself with the research and development aspects of these common problems. Such work would tend to free university talent which could be applied to specific problems of a general interest to the scientific community. The development of a standard recording system is desirable, such a system to be capable of modular use in different platforms with a further capability of computer processing without manual reduction. Suitable arrangements should be made to make such instruments and systems readily available to the scientific community.

The aviation facility would have as an initial part of its mission the support of NCAR research projects from aircraft platforms. The support provided includes the functions of research, development, operations and data reduction, and the facilities, equipment and personnel needed to carry out these functions. The common coordination, services, and research and development provided to support both NCAR and other facets of the scientific community will help to assure that NCAR research operations are performed smoothly and efficiently. In the operations area, it is believed that satisfying the internal needs of NCAR represents the best course towards the national functions and that it is not realistic for NCAR to advertise that it can provide aircraft operation for others until it has gained experience. Evolution of the facility to include operational assistance and services to the scientific community will proceed as the capabilities of the flight facility group expands and will be based on the requirements of the scientific community as adjudged by the advisory panel. It is envisioned that this plan will be updated by the Facility Director yearly or as requirements change and will be submitted to the advisory panel for approval.

Facility Organization

To meet these responsibilities, the organization and management structure shown in Figure 1 is necessary. The organization reflects both specific mission (research project) tasks and the open-sided functional responsibilities that exist regardless of specific projects. Several items in the organizational framework require explanation: the scientific advisory panel, for instance, is planned as the formal mechanism for liaison between the facility and the scientific community (including NCAR).

The Services group will provide the centralized coordination required for expeditious processing and dissemination of instrumentation, platform, airspace and frequency use information; in addition, it will provide liaison with regulatory bodies and assist as necessary in the negotiations that attend procuring flight time on Government aircraft or other aircraft or facilities to the scientific community for atmospheric research. This group will be responsible for establishment and coordination of a university student training program within the facility and with other segments of NCAR.

Even though formal authorization of a major facility project would be given by the advisory panel, most of the coordination problems that crop up in research projects can be handled at the facility level. Individual project engineers would be responsible for such resolution as well as for directing the facility aspects of a particular project for a university or

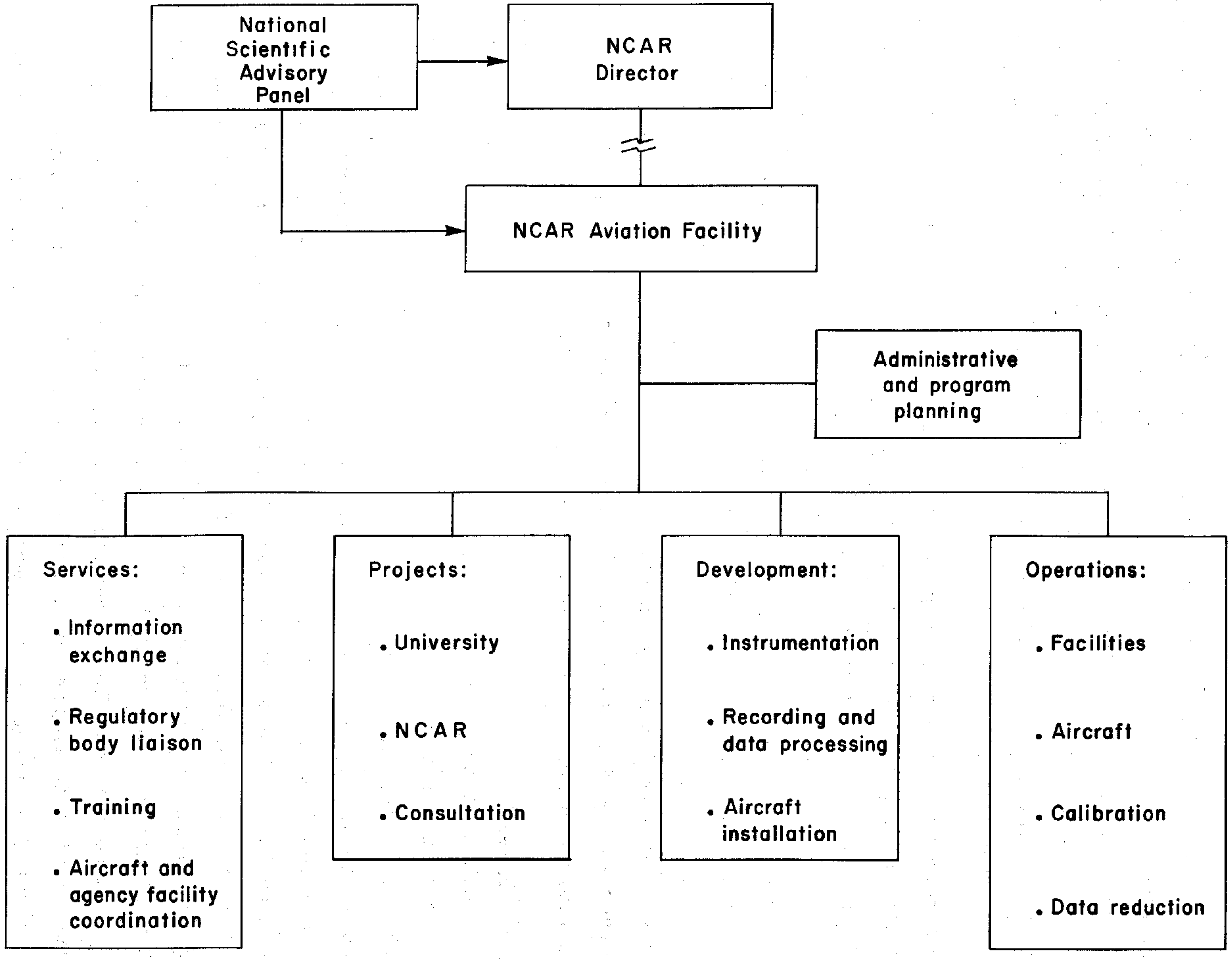

Figure 1. NCAR Aviation Facility Organization

NCAR scientist. Each facility project conducted will have an NCAR project engineer and project counterpart from the particular scientific group concerned who will jointly be responsible for the results of the project. The project function will also provide technical consultation to university scientists and NCAR with problems in instrumentation, recording or aircraft operations.

Two functional groups are shown, Development and Operations. Development would be responsible for the development of instrumentation, recording and data processing and aircraft installation design. This group would also construct one- or two-of-a-kind devices; for large quantities, an outside manufacturing source would be sought, in the interest of economy and efficient use of facility personnel. The Operations group would be responsible for aircraft facilities and aircraft, aircraft installations, test scheduling pre- and post-flight calibration, and data reduction. Aircraft maintenance and modification services would probably be provided by contract through a private aircraft-service organization.

Technical Program

The technical program of the facility is aimed at achieving a capability for high-quality scientific operations in the shortest possible time. To do this in a systematic and economical manner requires that the sequence of steps shown in Figure 2 be followed. The first step is determining operational requirements; much of this work has already been done, both by the Facility Survey Group and by NCAR itself (Section II). The completed job will define the envelope of operational flight conditions and of data sensing, recording and processing needs. Initially the flight requirements of NCAR will dictate the type(s) of aircraft procured and the facilities needed to support them. These requirements are stated in Section II and include two light twin-engine supercharged aircraft of the Beech Queen Air and/or Cessna 320 categories by summer of 1964, and a light twin-jet aircraft by the summer of 1965. These aircraft would be available to assist in other than NCAR programs as determined by the advisory panel. The data requirements envelope (also detailed in Section II) will determine that instrumentation which is common to most flights and lead to specification

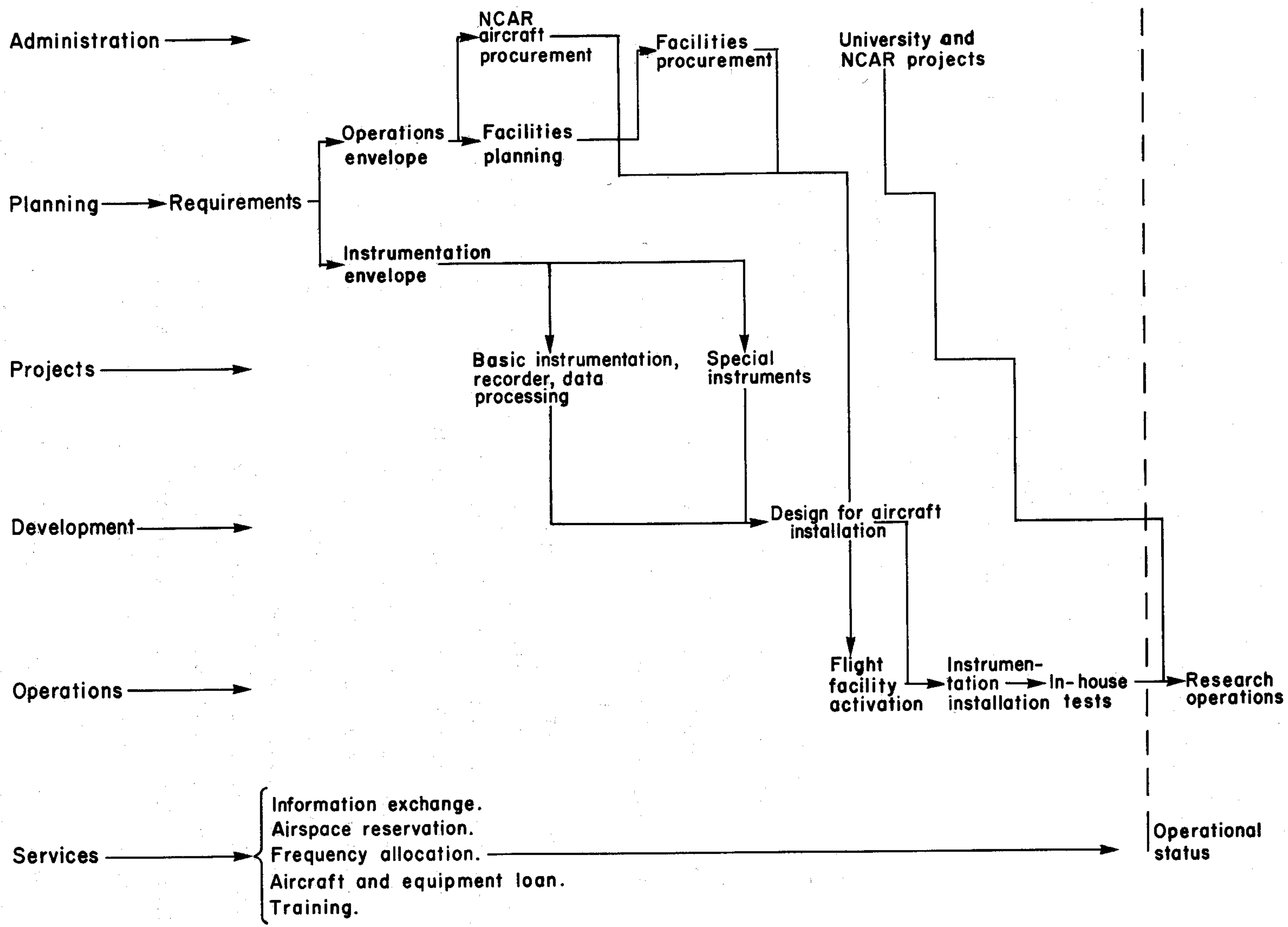

Figure 2. Sequence of Steps in Technical Program

of a standardized bench-mark instrumentation system. The next step is to specify the recording and/or transmitting method to be employed with this instrumentation system which will probably include such parameter measurements as X, Y, Z positions, velocity, wind, temperature and dew point. The data recording and processing method adopted will then become the standard for all sensors and data reduction projects; that is, the basic instrumentation package will be capable of accepting the outputs of specialized sensors, recording and processing them providing they satisfy the input characteristics of the system. This philosophy is very similar to that employed with radio telemetering under the Inter-Range Instrumentation Group standards. In some cases, scientists will wish to fly "bread-board" instrumentation without tying it into the standardized recording system. A separate recorder, suited to the particular instrument being tested, will be installed temporarily for this type of test.

NCAR requirements for an operating flight facility in the Boulder area are contained in Section II.

Section III summarizes the types of instruments being considered for general use on facility aircraft. A detailed layout of the instrumentation development program of the facility must be prepared containing a more definitive statement of instruments, recording techniques, formatting, etc.

Having decided on the aircraft to be procured, the developed basic instrumentation system should be designed so as to allow installation in any of the aircraft. As soon as the aircraft and their support facilities are available, the basic instrumentation package will be installed, calibrated, and subjected to flight tests under a variety of flight envelopes. Post-flight calibration and data reduction will confirm the package's operation and dictate when it is ready for operational use. Enough units should then be procured or constructed to outfit each airplane and provide one spare unit.

Because of the lead time required in flight test projects, it is likely that the facility will begin to accept authorized NCAR and possible university research programs during the testing of the aircraft-instrument package combination. By the time testing is completed, operations will be able to accommodate the tasks levied by specific research projects.

The development and test of the basic instrumentation system, besides serving a very valuable purpose in getting the facility into operation, will also provide a complete dry-run for facility's personnel in which to refine working relationships and operating procedures.

Implementation Plan

The implementation plan for the facility is shown in Figure 3; major milestones are:

- requirements completion;
- coordination, services and training functions;
- aircraft and facilities procurement decision;
- standard instrumentation system specification;
- facilities activation;
- instrumentation system flight test initiation;
- instrumentation system operational status.

Coordination services, and the NCAR flight facility and aircraft should be functioning by spring 1964, and the basic instrumentation system should reach operational status by July 1965. Beyond 24 months the facility should be operating in a routine manner with a fully established organization. The greatest hurdle -- a highly reliable, moderate accuracy basic instrumentation system -- should not defer this schedule if firm requirements are established early in the facility's development and adhered to subsequently.

During the instrumentation system flight tests, special research instruments would be carried on the aircraft provided they do not interfere with the test objectives of the flights. As indicated in Section II, the flight operating base initially would be located in the Boulder area to facilitate NCAR work and to remain remote from the high density Denver terminal area. The research aircraft that are procured for the facility will be capable of operating from relatively short runways--around 5000-6000 feet--even at the Boulder altitude.

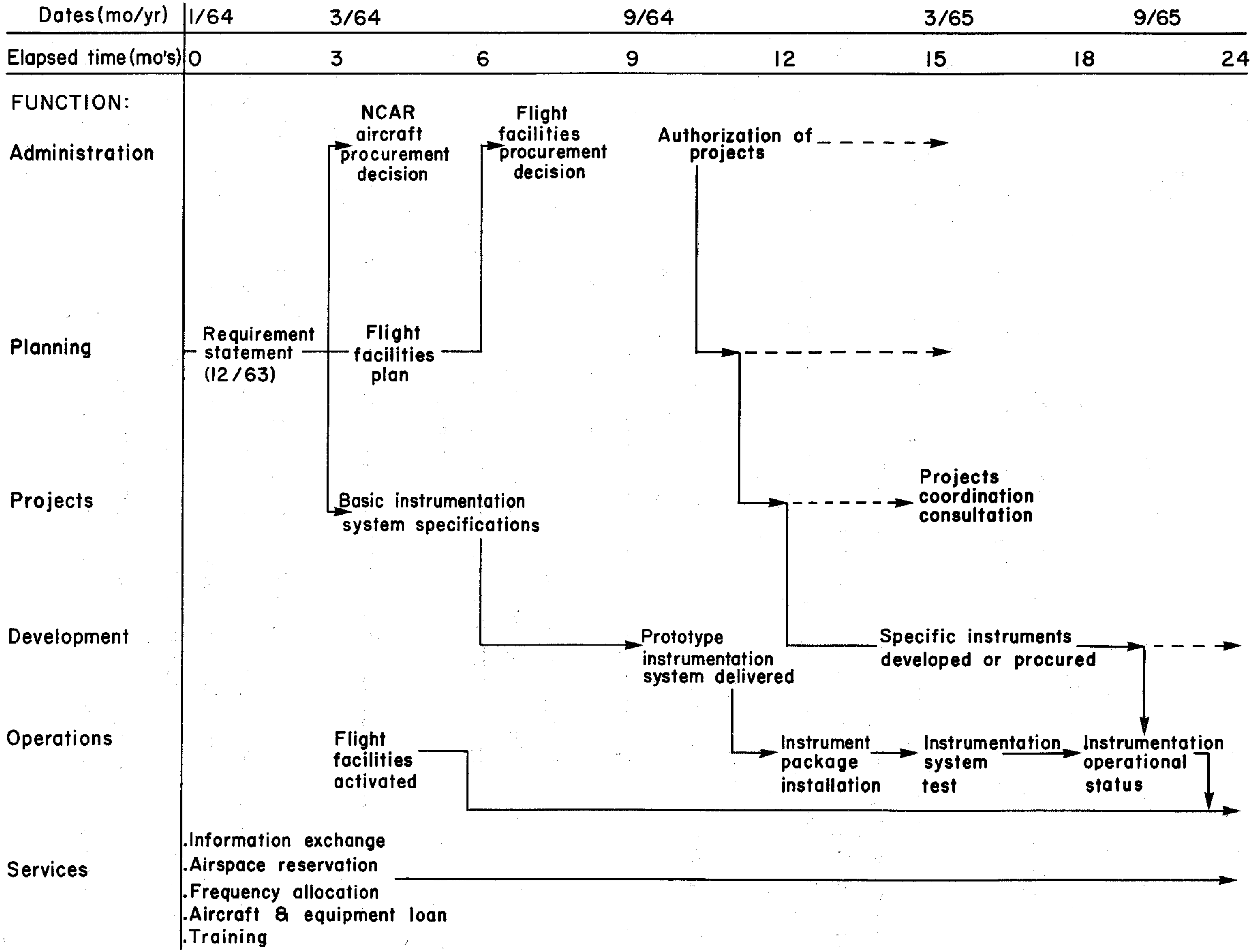

Figure 3. Implementation Plan

Facility Staffing

To put the facility in complete operational status within 18 months will require the following staffing:

Function	Type of Personnel	No. of Personnel Year 1	Year 2
Aviation facility management	Director and secretary	2	2
Administration and program planning	Administrative and technical assistant to Director		1
Services	Administrative/meteorologist	1	2
Projects	Project engineer	2	3
Development	Instrumentation engineer, electronics engineer, mechanical engineer-designer, electronics technician, laboratory assistant	3	5
Operations	Flight program engineer, assistant flight program engineer, aircraft maintenance technician, electronics technician	3	4
Total		11	17

The following personnel should be recruited immediately:

1 instrumentation engineer
1 electronics engineer
1 services meteorologist/administrator
1 flight program engineer
2 project engineers.

Project engineers will (1) plan initial university coordination, liaison and training, (2) manage NCAR projects, (3) furnish consultation to these groups and (4) will have the responsibility for ensuring that the bench-mark instrumentation system development program will meet research requirements. Development personnel will conduct the technical work involved in creating the bench-mark system. The flight test engineer will direct the design of the flight facility and work toward having the facility active within 12 months.

In the second year, staffing will be increased to handle NCAR and university projects and the development associated with them as well as to activate actual test operations, pre- and post-flight calibration and data reduction. Beyond Year 2, it is expected that staffing would approach a constant level of about 17 personnel unless user demand necessitates procurement of additional aircraft, adding primarily to the Operations load.

Budgetary Plan

In order to carry out the implementation plan, it is estimated that budget support as shown in Figure 4 will be required. There is a large initial investment in aircraft, facilities and instrumentation system development and procurement. By FY 1966 the requirement levels off to primarily operating costs to maintain and service aircraft, conduct flight tests and post-flight data reductions, and continuing engineering efforts in instrumentation recording and data processing.

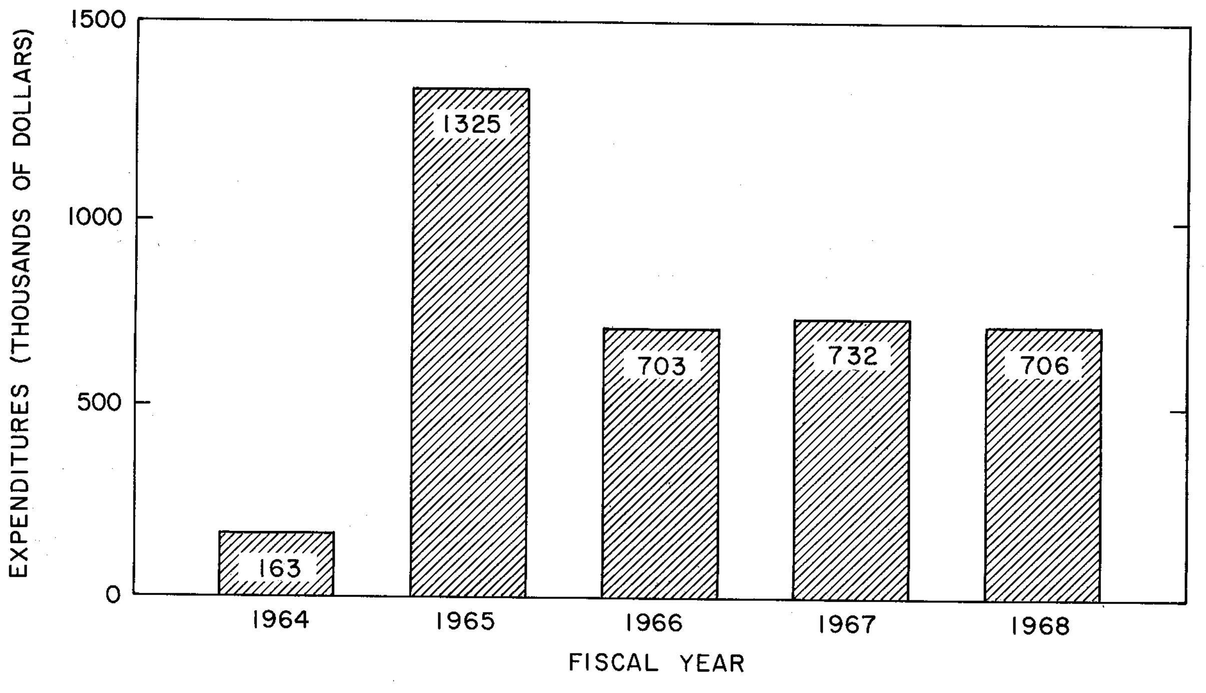

Figure 4: Five—Year Budgetary Plan

Table I presents a breakdown of the budgetary plan according to fiscal years and by functions within the facility. Direct labor costs (1) do not include overhead or a pro-rated burden. Purchased equipment under projects (2) includes items bought to satisfy an NCAR or university project and not developed in-house. Item (3) is for purchase of two complete sets of aircraft instrumentation based on the design developed in-house in FY 64 and 65. Item (4) covers the purchase of three aircraft--tentatively, two in the Cessna 320-Beech Queen Air 80 class, and one in the Jet Commander class. Purchased services (5) include travel, car rental and so forth, but the main item is contracted aircraft service and maintenance under Operations. The bulk of Purchased Parts, Materials and Supplies is likewise expendable for Operations. These figures assume that an NCAR computer will be available, as a support facility, to the aviation facility for data reduction and processing operations.

Table I. Budgetary Plan Breakdown

Function	Cost ($ thousands)				
	FY 64	FY 65	FY 66	FY 67	FY 68
Direct labor(1):	(8 personnel)	(13 personnel)	(15 personnel)	(17 personnel)	(17 personnel)
Management	15	20	20	20	21
Adm. & Planning	4	10	10	12	13
Services	10	30	32	40	42
Projects	10	32	36	40	42
Development	10	32	40	40	42
Operations	10	36	40	45	48
Purchased equipment:					
Projects	-	-	10(2)	20	30
Development	40	60	165(3)	120	50
Operations	-	700(4)	20	25	25
Purchased services(5):					
Adm. & Planning	5	5	5	5	5
Services	3	5	5	5	5
Projects	3	5	5	5	5
Development	3	5	5	5	5
Operations	30	125	180	200	210
Purchased parts, materials & supplies:					
Projects	5	10	5	5	5
Development	5	100	25	45	45
Operations	10	150	100	100	110
Total	163	1325	703	732	706
Cumulative total	163	1488	2191	2923	3629

APPENDIX B, SECTION II

AVIATION FACILITY REQUIREMENTS WITHIN NCAR

SUMMARY

While an NCAR aviation facility may be called upon to support the research efforts of many universities and private research groups, there is an immediate need for aircraft support within NCAR itself. The needs for such an aircraft support facility stem largely from the research problems to be solved and their relative priority for solution. A resume of the scientific problems and program areas which require special flight services are contained in pages 34 through 37 . The research activities are summarized below:

1. Cloud Electrification and Precipitation--the study of cloud electrical emissions, especially those of growing cumulus, using an airborne radio receiver system. The basic need is to be able to stay in close proximity to the growing cloud, especially its top.

2. Cloud Nuclei and Thunderstorms--the study of thunderstorm processes using dropsonde probes. To obtain time-space profiles, the use of two aircraft is highly desirable.

3. Vertical Ozone Distribution--vertical distribution to be determined by scattered skylight in the .28 - .7 region using a spectrophotometer.

4. Atmospheric Chemistry--sampling of both gaseous and particulate constituents of the atmosphere from aircraft platforms, followed by chemical analysis on the ground.

5. Isotope Geophysics--aerosol and gas samples from aircraft platforms in the upper atmosphere, followed by laboratory analysis.

6. Shock Wave Effects on Particulates--experimental sweeping of cloud volumes with shock waves, to study effects on atmospheric particulates.

7. Solar Eclipse and Ionospheric Studies (High Altitude Observatory)--jet aircraft optical observations of solar eclipses.

The flight profiles required to support these activities are summarized in the table. Quantitative estimates of the flight envelopes and measurement capabilities required are detailed in phenomenological form on pages 38 through 43.

The flight profiles required to support:

	Range (miles)	Altitude (thousand feet)	Speed (knots)	Flight time (hours)	Payload (pounds)	Hours/ Year
Cloud electrification	-	10-30	-	3	600	225
Thunderstorm	-	25-50	-	3	400	120
Ozone distribution	1500	25-40	-	-	600	200
Atmospheric chemistry	100-1000	0-40	-	2	200	60
Isotope geophysics	100-1000	0-40	-	2	200	60
Shock wave studies	100-1000	0-55	800+	1+	-	30
Solar eclipse	2000	40+	600	4+	2000	-

All projects except Ozone Distribution, Isotope Geophysics, and Shock Wave Studies could employ aircraft support profitably now; the Ozone Distribution, Isotope Geophysics and Shock Wave project requirements will not be pressing until late in calendar 1965. Requirement for Solar Eclipse studies exist today and must be handled on a special project basis.

Analysis of NCAR aircraft support needs indicates that two available aircraft approximately satisfy all needs; through FY 1965 these are:

1. Cessna 320-B Skyknight
2. Beech Queen Air 80.

Both are twin-engine; the 320 has a service ceiling of 28,000 feet and the Queen Air, 35,000 feet. The Cessna is an economical answer to the needs of the Atmospheric Chemistry project and early flights for the Thunderstorm project. It would also satisfy the majority of new research project requirements during the early investigative stages. The Beech Queen Air, with its greater payload and range, is suited to the Cloud Electrification and more elaborate Thunderstorm project flights, as well as being suitable for early stages of the Ozone Distribution project. Operating together these aircraft can also satisfy the two-plane flight requirement of the Thunderstorm project when space-time cross sections of thunderstorm clouds are needed. A turbo-jet aircraft will be required for advanced stages of the Ozone Distribution and Isotope Geophysics projects by late FY 1965 or FY 1966, and the use of a supersonic vehicle will be necessary on a short-term basis for the Shock Wave studies.

	Range (miles)	Service ceiling (thousand feet)	Cruise speed (knots)	Flight time (hours)	Payload (pounds)
Cessna 320-B	800	28,000	180	4	400
Beech Queen Air 80	1300	35,000	210	7	1000+

The 320-B is priced at $70,000; the Queen Air at $120,000. Allowing for the installation of added navigation equipment, a total investment of about $240,000 is indicated.

These aircraft are proven, dependable types for which service and overhaul services are available at Denver. Both are available for either direct purchase, lease, or lease with option-to-buy. They are an economical answer to NCAR's in-house aircraft support requirements and can, in addition, satisfy a sizeable portion of the university requirements thus far informally identified.

SCIENTIFIC PROGRAMS REQUIRING AIRCRAFT

Cloud Electrification and Precipitation (Sartor)

Detailed studies of individual clouds and the electrification process associated therewith, specifically the interaction of electrification with precipitation growth are currently under way.

Laboratory results and preliminary flights at Key West, Florida in the 1963 summer have shown that radio emission is obtained from growing cumulus clouds even when they are in a completely liquid state. Extensive field data with more sensitive receivers are necessary in order to study warm cloud electrification in finer detail and to gather data on cloud electrification in general. Cumulus clouds that are developing will be studied by collecting radio emission and ambient atmosphere parameter data while circling their periphery and flying "over the tops." Radio frequency interference is a major problem; to avoid this interference, the aircraft must be specially shielded. Aircraft platforms are required that have space for nose instrumentation and sampling, a rate of climb sufficiently great (2000 ft/min) to allow the aircraft to "stay on top" of developing clouds to altitudes of approximately 30,000 feet, with flight durations at altitude of 3 to 4 hours. The aircraft will be required on a year-round basis starting in 1964 and will fly considerable distances over water. A supercharged twin engine aircraft with a payload of 5-600 pounds is required for about 65 to 80 flights (225 hours).

Cloud Nuclei and Thunderstorms (Squires)

Steady state theory of thunderstorm updrafts is being investigated; present work is aimed at improving the profile resulting from lateral turbulent transfers, so that the model is no longer homogeneous horizontally. There is much evidence that a good deal of the vertical motion in thunderstorms is concentrated in narrow and relatively laminar adiabatic updrafts embedded in a turbulent environment.

Aircraft are required to conduct a dropsonde program in building cumuli and cumulonimbi clouds. Dropsonde measurements of this type have been considered by several scientists but never attempted (except perhaps in Russia).

Engineering and manufacture of test dropsondes and associated ground equipment is now under way. Development work is proceeding on the mechanisms for releasing the sondes, controlling falling speeds, and locating them in the vertical and horizontal. Several sondes dropped in rapid succession will give a two-dimensional pattern of observations. This will require at least two aircraft. Initially, light twin aircraft (supercharged) will be used to release the sondes over developing clouds to 25-30,000 feet. Eventually, aircraft with at least a 50,000 foot capability will be required. About 30 flights of 3 to 4 hours duration per year will be required (120 hours).

Vertical Distribution of Ozone (Dave)

Basic research in the stratospheric region requires complete vertical soundings of ozone distribution from 25,000 to 100,000 feet. A substantial part of the ozone problem can be solved by flying high resolution spectrographic equipment at medium altitudes--above the majority of water vapor in the atmosphere. Measurements of the scattered skylight at several wavelengths will be made by an ultraviolet spectrophotometer. A concrete requirement exists for a jet aircraft with a 30,000- to 40,000-foot altitude capability to conduct this experiment; however, propeller aircraft with at least a 25,000- to 30,000-foot capability will be utilized initially. Range for jet aircraft would be 2000-3000 miles; for propeller aircraft, a 1500-mile range will be useful. Uninterrupted flight path intervals of at least 10 minutes are required. It will be necessary to sense aircraft aspect or altitude to establish zenith orientation of the instrument optical axis. Accurate position, altitude, flight vector, and ambient pressure and temperature are required. Special optical windows of fused quartz or vycor requiring extensive aircraft modification are planned. Aircraft utilization per year will be about 25-40 flights of 4-5 hours duration (200 hours).

Atmospheric Chemistry (Lodge)

The NCAR program will require aircraft platforms to participate in atmospheric sampling programs. Both gaseous and particulate sampling will be accomplished. Carbon dioxide, ozone, air pollutants, and trace gas measurements are included in the atmospheric chemistry program. It is anticipated that measurements from jet aircraft altitudes to the surface over flight paths varying from approximately 100-500 miles may be needed. It is estimated that 25 flights of 2-3 hours would be required (60 hours).

Isotope Geophysics (Martell)

Investigations of distribution and reaction of trace gases and aerosols in the atmosphere will be carried out using methods of stable and radioisotope and neutron activation analyses. Emphasis will be placed on upper atmosphere studies by laboratory analysis of aerosol and gas samples collected by aircraft and other upper air sampling systems. Large-scale atmospheric transport and mixing processes will be evaluated. Isotopic analysis of stratospheric water vapor should give insight into the origin of the excess water in the high stratosphere and other features of the atmospheric water cycle. Distribution of aerosols and gases of common origin will give insight into the role of attachment, growth and sedimentation on aerosol transport. It is estimated that 20 flights of about 2-3 hours duration will be required (60 hours).

Shock Wave Effects on Meteorological Particulates (Goyer)

Explosive charges are used to generate shock waves in clouds in an effort to reduce crop damage from hail, mostly in Italy, Austria and France. In spite of the continuous recurrence of such reports in the literature, no fundamental study of such effects has ever been performed. The few results of exploratory research in this area published in the modern literature need to be confirmed. The development of modern technology makes new tools and new methods available for such research. Shock-tubes and explosive technology permit the generation of shock waves of known strength and known duration applicable to the study, in the laboratory, of their effect on meteorological particulates. The development of the supersonic aircraft, and its supersonic boom, makes possible the sweeping of enormous volumes of clouds with shock waves and opens a new area in field investigations. If shock waves have an effect on meteorological parameters, an obvious corollary to this study is the study of the effect of lightning flashes on such particulates. It is estimated that approximately 10-15 flights of 1-2 hours duration utilizing supersonic aircraft will be required (30 hours).

Aerocolloidal Systems (Rosinski)

This program includes theoretical work on a modification of Bowen's hypothesis, and the examination of possible means of downward transport of particles which could serve as freezing nuclei in the atmosphere. The possibility of a causal connection between meteor activity and noctiluscent clouds is being studied. Aircraft platforms are required for a number of horizontal particulate sampling flights at approximately 22 and 80 kilometers.

Solar Eclipse and Ionospheric Studies (High Altitude Observatory)

Beginning in 1954, the use of aircraft for solar eclipse observations has been slowly developing. Many problems have had to be solved and others remain, but now it is clear that the independence of clouds achieved by a jet aircraft can approximately balance the cost of multiple ground expeditions to obtain the same observations. In addition, the aircraft provides a longer eclipse, reduced atmospheric absorption, especially in the water vapor bands, and perhaps some real gains in equipment reliability since the equipment is shipped to the eclipse path in operating condition.

The requirements for a jet aircraft to make eclipse observations are not, at present, difficult. Good optical windows and an inertially guided platform inside the cabin are the basic needs. A star tracker would eliminate the inertial platform, but at the moment the platform looks better. At aircraft altitudes there seems to be no need for ultraviolet transmitting windows, but there is a need for infrared transmitting windows. Other requirements (e.g., stabilized power, etc.) will probably be similar to those for any other scientific use of the aircraft. Approximately 15 hours flight time in DC-8-type aircraft will be required per year.

AIRCRAFT CAPABILITY AND MEASUREMENT REQUIREMENTS

Table II represents the requirements for research aircraft flight envelopes and measurement capabilities in a quantitative form according to:

- the parameter measurement needed;
- the units and range of parameter values anticipated;
- the required accuracy of the measurement;
- the geographical (X, Y) coverage of the sampling;
- the vertical range (Z) of the sampling;
- the reference for the requirement.

For each item listed, a reference number is shown; the reference is further explained in the Reference List following the tables. Finally, required flight envelopes and measurement capabilities are combined to give an estimated space-time-measurement picture in Figure 5.

Figure 5 suggests the flight capabilities of the aircraft that would be required to make the measurements in Table II, and is a prerequisite to determining a plan to meet these needs and recommending how the plan can best be implemented.

Table II. Requirements for Research Aircraft Operations

MEASUREMENT	RANGE	ACCURACY	GEOGRAPHICAL AREA	ALTITUDE	REF.NO.
Mass Transport					
Wind: X, Y components	0-200 knots	± 1 knot	1000-4000 mile radius	0-80,000 feet	2, 3, 8, 12
Vertical wind spectrum	0-80 ft/sec	± 1 ft/sec	1000 mi radius	0-80,000 feet	3, 8, 12
Water vapor	0-10 gr/m^3	± 1% actual	1000 mi radius	0-80,000 feet	3, 8, 11
Pressure	10-1100 mb	.1% actual	1000 mi radius	0-80,000 feet	3, 8, 12
Precipitation location and intensity	0-100 nautical miles	± 1 nautical miles	100 mi radius	0-50,000 feet	3
Cloud location and extent	0-100 nautical miles	± 1 nautical miles	100 mi radius	0-50,000 feet	3, 7, 8, 9

MEASUREMENT	RANGE	ACCURACY	GEOGRAPHICAL AREA	ALTITUDE	REF.NO.
Aircraft Coordinates					
X, Y position	0-1000 nautical miles	$\pm$ 1 nautical miles	--	0-80,000 feet	3
Altitude (above sea level)	0-80,000 feet	$\pm$ .5% actual	--	--	3
Altitude (above ground level)	0-80,000 feet	$\pm$ .5% actual	--	--	18
True air speed	0-500 knots	$\pm$ 1 knots	--	0-80,000 feet	18
Heading	0-360 degrees	$\pm$ .5 degrees	--	0-80,000 feet	18
Particle Physics					
Particle size spectrum	.01 - 1μ 1 - 10μ 10 - 100μ 100 - 1000μ	$\pm$ 1% actual	100 mi radius	0-30,000 feet	3, 11 14
Liquid water content	0-10 gr/m^3	$\pm$ 1% actual	100 mi radius	0-30,000 feet	3
Water vapor content	0-10 gr/m^3	$\pm$ 1% actual	100 mi radius	0-30,000 feet	3
Aerosol and precipitation sampler	--	--	100 mi radius	0-30,000 feet	4, 5
Radioactive particle spectrum	Count rate of α, β particles	$\pm$ 1% actual	1000 mi radius	0-80,000 feet	8, 9, 12

MEASUREMENT	RANGE	ACCURACY	GEOGRAPHICAL AREA	ALTITUDE	REF.NO.
Chemical Composition					
O_3 concentration	0-20 $\frac{\text{cm} \times 10^{-3}}{\text{Km}}$	± 1% actual	1000 mi radius	0-80,000 feet	13, 15
CO_2 concentration	.01 - .1 $\frac{\text{gr}}{\text{m}^3}$	± 1% actual	1000 mi radius	10-30,000 feet	2, 13
Electromagnetic Radiation or Fields					
Temperature (ambient)	+30° to -100° C	± .1°	1000 mi radius	0-50,000 feet	3, 11, 12
Incident radiation (or reflected)	0-2 $\frac{\text{langley}}{\text{min}}$	.01°	1000 mi radius	0-50,000 feet	2, 6
Net radiation	0-2 $\frac{\text{langley}}{\text{min}}$	.01°	1000 mi radius	0-10,000 feet	2
Electric field	0-300 $\frac{\text{V}}{\text{m}}$	± 1% actual	100 mi radius	0-30,000 feet	3, 4, 7
Radio frequency cloud emissions (including sferics)	Power spectrum of received energy	Relative	100 mi radius	0-30,000 feet	16
Electrical conductivity	10^{-14}-10^{-11} $\frac{\text{mho}}{\text{m}}$	± 1% actual	100 mi radius	0-30,000 feet	17
Electrical charge	0-100 $\frac{1}{\text{cm}^3}$	± 1/cm^3	100 mi radius	0-30,000 feet	3

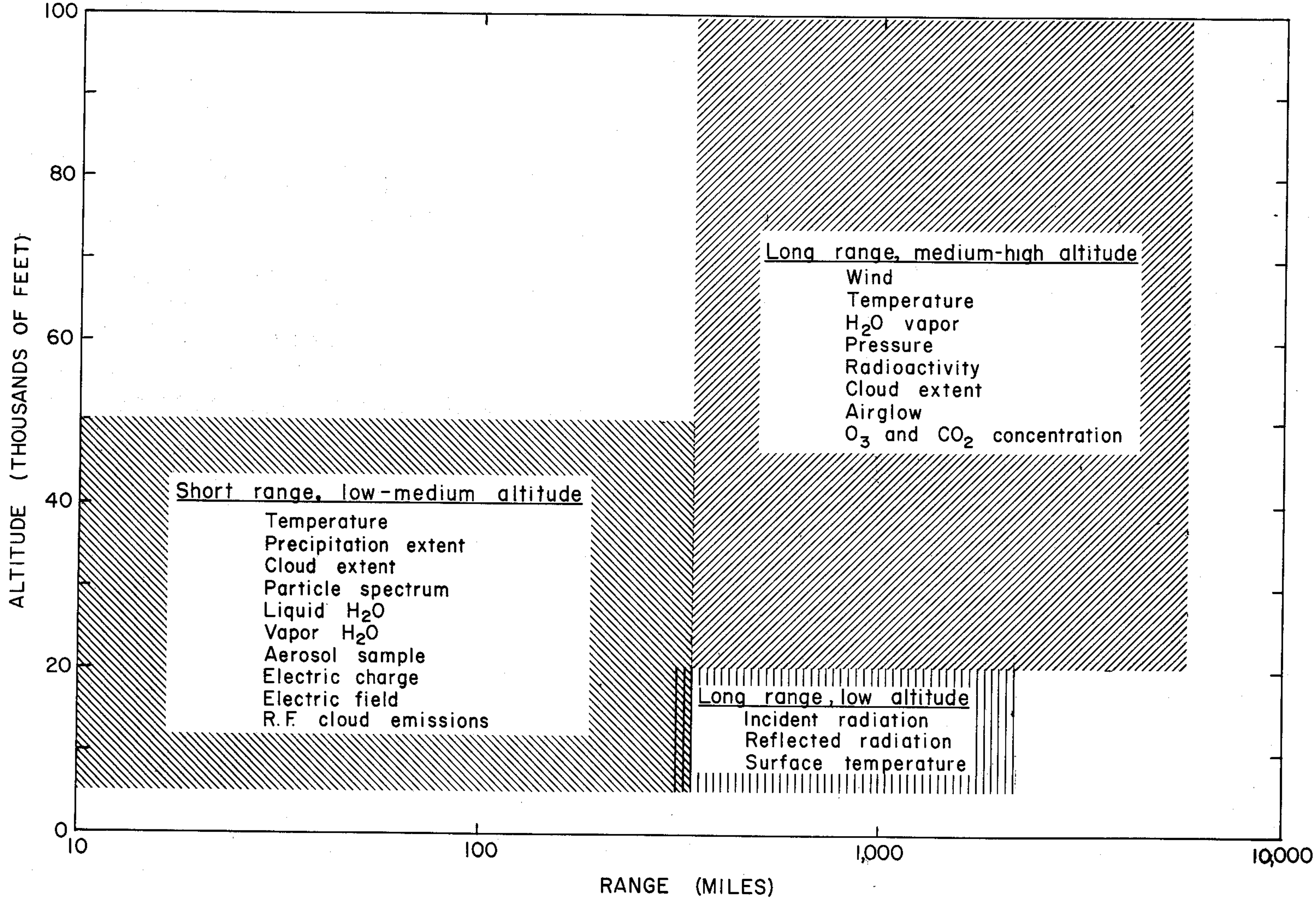

Figure 5: Relation of Required Measurement to Horizontal and Vertical Areas of Interest

The scientists listed below have indicated (in replies to the NCAR questionnaire of September 1962) specific measurement requirements which are included in Table II. In most cases, the scientist stated the parameters and geographical and vertical extent of interest; range and accuracy of the measurement have been added using estimates derived from the literature.

<u>Reference List</u>

1. Keeling, Scripps Institute of Oceanography, 18 October 1962
2. Bryson, University of Wisconsin
3. Van Thullenar, National Severe Storms Project
4. Saucier, University of Oklahoma
5. Rosinski, National Center for Atmospheric Research
6. Davidson, New York University
7. Stout, Illinois Water Survey
8. Endlich, Stanford Research Institute
9. Simpson, U. S. Weather Bureau
10. Roach, National Bureau of Standards
11. Miller, San Jose State College
12. Riehl and Reiter, Colorado State University (est. from jet stream energy problem)
13. Bean, National Bureau of Standards
14. Dingle, University of Michigan
15. Kroenig, University of Minnesota
16. This requirement arises in the study of the coalescence of cloud drops and (sferics) and lightning mechanism in clouds.
17. A standard electric parameter although not mentioned in questionnaire responses.
18. Required for data analysis purposes even though not mentioned specifically in questionnaires.

FLIGHT FACILITY REQUIREMENTS

The purpose of this document is to describe the physical characteristics of the flight facility to be established in the Boulder area to support NCAR flight requirements. Other facilities, either temporary or permanent, may be established in the future at other locations, if and when the need arises.

The operational considerations involved are: 1) the number of aircraft to be housed; 2) the characteristics of the aircraft; 3) maintenance and servicing required; 4) aircraft modification and installation services needed; 5) amount of personnel, scientific, engineering and other, to be accommodated; 6) needed laboratory space for airborne equipment; 7) traffic density in the area; 8) NAVAID and instrument landing system availability for all-weather NAVAID operations; 9) proximity to NCAR. Practical experience dictates that facilities for routine maintenance, including mandatory inspections, be available at the site chosen. Aircraft modification and installation services should also be available. Since it is planned that servicing and maintenance will be contracted, contracted personnel can be stationed at the site economically only if the work load is adequate to give them a full-time job. Otherwise the site chosen must be one at which contract work can be done in conjunction with other similar work. In other aircraft programs, airplane problems--maintenance, servicing, inspection and overhaul--have been as serious as the scientific problems. For this reason, it is important that these airplane problems be handled on a scheduled basis and expeditiously so that most of the available flight hours can be used for scientific purposes.

The number of aircraft to be housed locally will vary with the season, but a minimum complement of two lightweight twin-engine aircraft and a jet Aero Commander type is anticipated. Room should be available for several additional light-twin aircraft. Required hangar space, including maintenance and service areas is 12,000 square feet minimum and 16,000 square feet average if other aircraft are to be accommodated. Assuming light twin-engine and light jet aircraft are utilized, a 5000-foot runway would be adequate, with 7000 feet preferred. The field must have night landing capability, but not necessarily Instrument Landing System, since in the few cases where research flights would encounter unanticipated Instrument Flight Rules landing conditions, a diversion to Denver's Stapleton Field could be made.

The normal personnel complement at the flight facility, including service contractor personnel, would be about five from Operations, an average of one from Development, and two from NCAR or university research staffs--a total of eight, average. This might expand to twice that number in the busy summer months. Therefore, the total office space needed would be about 1000 square feet, a little too much on the average and a little squeezed under maximum-use conditions. An additional 600 square feet of space will be required for laboratory use--instrumentation repair, modification and calibration--and for aircraft maintenance. This is the equivalent of up to twenty workbench positions.

If the instrumentation system chosen for NCAR aircraft involves post-flight data read-out and reduction, this work might also be done at the facility. Whether it is or is not depends upon the extent to which other NCAR facilities require the use of the data reduction equipment. If it turns out to be strictly an aviation facility problem, the equipment location at the facility would be desirable. It would require an additional 200 square feet of laboratory-type space.

Utilities needed at the facility include: electric power: 110-220 volts, 60-cycle; 28 volt DC; and probably 120 volt, 400-cycle, 3 phase; water; heat; gas for lab use (bottled gas can be used). The laboratory equipment should include a frequency standard (WWV accuracy), voltage and current transfer standards, temperature bath and platinum temperature probe, a small temperature-humidity-pressure chamber and sensors, a film processing tank (if not available more conveniently at NCAR).

The facility should be equipped with transmit-receive equipment for VHF frequencies so that the facility can make direct contact with research aircraft on local flights. The facility site should be chosen so that an FAA certified instrumentation and repair station is nearby.

All of the features of an ideal facility location are satisfied by Denver's Stapleton Field, including an ILS. However, Denver is a high density traffic area with very little uncontrolled air space. Assuming that research flights would rather stay out of controlled air space, a location to the north and east of Denver would be desirable, but there are no acceptable, existing locations. Therefore, a cursory inspection suggests that both Jefferson County and Boulder Municipal Airport are acceptable because of their proximity to NCAR and their short distance from Denver (with all of its facilities and contracted services). The acceptability of either from the stand-point of hangar space (would it have to be constructed?), utilities, etc. requires a detailed look. The office and lab areas should be accessible to the hangar area by at least a covered walkway so that operations are not hindered by weather.

An M-33 aircraft-tracking-radar-system will be available as part of the ground environment at the local flight operating base and as necessary at field operating sites.

APPENDIX B, SECTION III

RECOMMENDED INSTRUMENTATION AND RECORDING TECHNIQUES

Instrumentation

Field of Investigation and Parameter to be Measured	Measurement Technique
Mass Transport -	
Wind: X, Y Components	Doppler radar
Vertical wind spectrum	Accelerometer
Water vapor content	Dew point hygrometer
Pressure	Aneroid cell
Precipitation location and intensity	Radar
Cloud location and extent	Photography
Refractive index	Microwave refractometer
Aircraft Coordinates -	
X, Y position	Radar and/or multiple distance measuring equipment
Altitude (above sea level)	Aneroid cell
Altitude (above ground level)	Radar altimeter
Time air speed	Aneroid cell and temperature probe
Heading	Directional gyro
Cruise speed	Doppler radar
Particle Physics -	
Particle size spectrum	Mie scattering
Liquid water content	Hot wire
Water vapor content	Dew point hygrometer
Aerosol and precipitation sampling	Filter trap
Radioactive particle spectrum	Geiger counter

Field of Investigation and Parameter to be Measured	Measurement Technique
Chemical Composition -	
O_3 concentration	Regener cell or spectrograph
CO_2 concentration	Spectrograph
Electromagnetic Radiation or Fields -	
Temperature (ambient)	Reverse flow platinum element thermometer
Temperature (surface)	Radiometer
Incident, reflected, or net radiation	Radiometer
Electric field	Field mill
Air glow	Photography, Radiometer
R. F. cloud emissions	Wide band receiver
Sferics	Directional receiver ($\sim$ 500 Kc)
Electrical conductivity	Radioactive source
Electrical charge	Isolated filter
Potential gradient	Radioactive probe

Recording

Analog	Tape or T/M (PM/FM)
Digital	Tape or T/M (PAM)
Combined Analog and Digital	Tape or T/M (PAM/FM)

ERRATA

p. vi, Contents of the Report, line 2: for "Appendix I," read "Appendix A."

p. vi, Contents of the Report, line 4: for "Appendix II," read "Appendix B."

p. 33, line 7: for "pages 34 through 37," read "pages 36 through 39."

p. 33, item 3, line 2: for "the .28 - .7 region," read "the .28 μ - .7 μ region."

p. 34, lines 3 and 4: for "pages 38 through 43," read "pages 41 through 43."

p. 39, Aerocolloidal Systems, lines 4 and 5: for "noctiluscent," read "noctilucent."