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National Atmospheric Sciences Program

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Interdepartmental Committee
for
Atmospheric Sciences

FEDERAL COUNCIL FOR SCIENCE AND TECHNOLOGY
Executive Office of the President

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Preface

The Interdepartmental Committee for Atmospheric Sciences (ICAS) has been one of the standing committees (now numbering seven) of the Federal Council for Science and Technology since its establishment in 1959 under the chairmanship of Dr. Alan T. Waterman, then Director of the National Science Foundation. Its functions continue to be: (1) to survey and evaluate the national research effort in the atmospheric sciences, (2) to examine the role and activities of Federal agencies therein, and (3) to make recommendations for appropriate allocation of responsibilities among the Federal agencies. In addition to analyses and recommendations made to the Federal Council, special tasks may be assigned by the Chairman of the Council, the Science Adviser to the President.

This annual report of the Committee provides visibility to all segments of the executive branch, the Congress, and the public of the total Federally supported research in the atmospheric sciences now underway and planned for the coming budget year. In addition to the overall coordination of research programs in the atmospheric sciences provided by ICAS, responsibility for coordinating Federal programs in certain specific segments of the atmospheric sciences has been assigned to the Secretary of Commerce, who has further delegated this responsibility to the Federal Coordinator for Meteorological Services and Supporting Research. Under the cognizance of the Federal Coordinator, the Interdepartmental Committee for Applied Meteorological Research (ICAMR) reviews and coordinates in greater detail some 49% ($82 million) of the research in meteorology reported herein, and the Interagency Committee for the World Weather Program (ICWWP) reviews and coordinates in detail a different and overlapping segment of the atmospheric sciences program, the U. S. contribution to the Global Atmospheric Research Program (GARP). These programs are documented in annual reports to the Congress, the Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 1972 and the World Weather Program Plan for Fiscal Year 1972.

Another important area of Federal program coordination, that of Marine Environmental Prediction, also has been identified and assigned to the Secretary of Commerce and further delegated to the Federal Coordinator for Marine Environmental Prediction, with the advice and assistance of an Interagency Committee for Marine Environmental Prediction (ICMAREP). A very important program in this area has potential contributions to make both to the U. S. atmospheric sciences program in general and to GARP in particular. This is the National Data Buoy Development Project recently transferred from the Coast Guard to the National Oceanic and Atmospheric Administration (NOAA). FY 1972 support for this program, not included in the atmospheric sciences program, is planned to be $13 million. This program is documented in the first Federal Plan for Marine Environmental Prediction, Fiscal Year 1972.

It should be noted that the large increase in <u>total</u> funds for atmospheric sciences is due mostly to the space flight programs of the National Aeronautics and Space Administration (NASA) including three new programs, two Pioneer flights

toward Jupiter and the Mariner Venus-Mercury 73 project. The orderly modest increase for FY 72 of the remainder of the program, 10.7% and entirely for meteorological research, represents a combination of increasing emphasis on programs with an early promise of social benefits and the initiation of new efforts to solve pressing meteorological problems.

The National Science Foundation is continuing to accelerate research efforts related to the Global Atmospheric Research Program (GARP), the International Decade of Ocean Exploration (IDOE), the National Hail Research Experiment (NHRE), and the new interdisciplinary program , Research Applied to National Needs (RANN).

The newly organized National Oceanic and Atmospheric Administration is advancing its program for numerical modeling of atmospheric circulation with broad contributions to GARP, atmospheric pollution problems and climate modification. Preparations are being accelerated for U. S. participation in the first major GARP field experiment, the GARP Atlantic Tropical Experiment (GATE), and in the International Field Year of the Great Lakes (IFYGL), a cooperative program with Canada. A very important increase in capability is planned for monitoring of global atmospheric pollution and its effect on weather and climate, and for intensified investigations of hurricane modification. The latter includes plans for moving the joint DOD/NOAA Project Stormfury operations to the western Pacific in 1972.

The Federal Aviation Administration is intensifying its efforts to reduce the effects of adverse meteorological conditions upon the operating capacity of the nation's airport and airway system by greatly improving the pertinent data handling systems and by developing economically effective fog dispersal techniques and systems. Two new Air Force programs will develop a sensor and data handling system for the Air Weather Services aircraft and an air-droppable remote operating weather station. The newly established Environmental Protection Agency (EPA) plans to accelerate and expand the research activities of its Air Pollution Control Office (APCO) (formerly NAPCA) concerning the pollution problems of the atmosphere.

In view of the fact that current Federal activities in weather modification are clearly relevant to national problems involving the public interest, and that some projects are nearly ready for practical application, these activities and pertinent plans are again described in a special section entitled, Weather Modification. The total planned National Atmospheric Sciences Program for FY 1972 is summarized in three tables. Table 1 lists the total support of research in the atmospheric sciences by each agency. Table 2 lists the total support of the Federal program in the various research categories. Table 3 lists the total support of each agency in each of the research categories. The summaries are followed by descriptions of each agency's program.

Throughout this document FY 1970 funds represent <u>actual</u> funding, FY 1971, <u>estimated</u> funding, and FY 1972, <u>planned</u> funding (in thousands of dollars).

WEATHER MODIFICATION

Under the guidance of the Federal Council for Science and Technology, ICAS has been working for the past year on a new approach planned to accelerate progress in weather modification. National needs have been identified. Research efforts which have clear near term potential for meeting these needs have been selected. The selected projects have been designated as National Projects. Lead agencies have been recommended and pertinent multiagency assistance has been proposed to accelerate progress in each Project.

National Projects represent a selection of about one-half of the existing weather modification research and development programs; some $9 million of a $20 million program. The planned FY 1972 program includes some increased funding for most of the National Projects as well as for the broad physical and dynamic meteorological research necessary for their continuing support.

The proposed National Projects and Lead Agencies are:

National Colorado River Basin Pilot Project - Bureau of Reclamation
To test the feasibility of applying a cloud seeding technology, proven effective under certain conditions, to a river basin for a winter season to augment the seasonal snowpack.

National Hurricane Modification Project - National Oceanic and Atmospheric Administration
To develop a seeding technology and associated mathematical models to reduce the maximum surface winds associated with hurricanes.

National Lightning Suppression Project - Forest Service
To develop a seeding technology and associated physical and mathematical models to reduce the frequency of forest fire-starting lightning strokes from cumulonimbus clouds.

National Cumulus Modification Project - National Oceanic and Atmospheric Administration
To develop a seeding technology and associated mathematical models to promote the growth of cumulus clouds in order to increase the resulting natural rainfall in areas where needed.

National Hail Research Experiment - National Science Foundation
To develop a seeding technology and associated mathematical models to reduce the incidence of damaging hailfall from cumulonimbus clouds without adversely affecting the associated rainfall.

National Great Lakes Snow Redistribution Project - National Oceanic and Atmospheric Administration
To develop a seeding technology and associated mathematical models to spread the heavy snowfall of the Great Lakes coastal region farther inland.

National Fog Modification Project - Federal Aviation Administration
To develop seeding or other technology and associated physical and mathematical models to reduce the visibility restrictions imposed by warm and cold fogs where and to the extent needed.

Each of the National Projects has a background of years of research. That research has, within the last few years, developed a combination of theoretical knowledge and associated mathematical models, supported in varying degrees by field experimental data, which indicates that technology now available is nearly ready for regular application. Organization of these activities into National Projects has been recommended, with specific multiagency participation, to insure the earliest practicable availability of operational technology.

The potential benefits to various segments of the national economy are reasonably clear, although not quantitatively precise. It appears, however, that the ultimate application of the technologies under development to the pertinent problems involved, could result in benefit-cost ratios of from 2 to 1 up to 20 to 1.

In areas served by the Colorado River Basin, where, for just the irrigation benefits, increased water is worth up to $50 per acre-foot per year, conservative indications are that the increase in runoff resulting from the planned snowpack augmentation program will amount to over 2,000,000 acre-feet at a cost of about $1.50 per acre-foot. The increased capability for power generation, alleviation of critical shortages, and salinity control are bonuses which would insure the maintenance of very favorable benefit-cost ratios.

Hurricane damage in the United States averages about $500 million per year. Recent results of the joint hurricane modification Project Stormfury indicate a potential for reducing maximum surface winds by 10 to 20%. Possible reductions in damage of considerably more than 10%, coupled with the possibility of saving even a few lives, indicate a favorable return on funds supporting Stormfury.

Over two million acres of forests in the western United States are burned annually by lightning-caused fires. To the terrible although indeterminate cost of such forest fires must be added the cost of about $100 million and some human lives each year fighting the fires. Experiments conducted over a limited area of the Northern Rocky Mountains by the Forest Service Project Skyfire indicate a reduction of over 50 percent in fire-starting lightning activity. These results promise a very favorable benefit cost ratio for a lightning suppression program.

In certain areas, such as the florida peninsula, traversed by moisture-laden but sometimes non-precipitating or very lightly precipitating cumulus clouds, increases in precipitation can be accomplished by cloud seeding. In some areas during periods of local need, such augmentation of rain can be worth $50 per acre-foot and recent experiments indicate that in limited areas, rainfall augmentation can be accomplished for less than $1 per acre-foot.

Annual hail damage in the United States amounts to over $300 million. Where limited areas of certain crops have been "protected" by commercial seeding operations, reported benefit-cost ratios have been generally better than 2 to 1. The development of adequate models of hail producing clouds and consistently effective seeding techniques should insure effective protection of high priority areas at very favorable benefit-cost ratios.

Annual snow removal costs for the City of Buffalo amount to about $2 million. Potential amelioration of associated social and economic problems in a high population density area added to the reduction of excessive snow removal costs, calls for continuing experimental efforts to delineate the capability and to develop an economically effective technology for reducing the intensity of major lake-effect snow storms.

Annual costs to the U. S. airlines of delays caused by warm fogs at airports are over $75 million. Highway and harbor fogs add considerably to this figure in terms of transportation delays, damages, injuries and deaths. Thus warm fog modification possibilities under investigation warrant intense efforts to develop effective techniques which can approach the better than 5 to 1 benefit-cost ratio for current cold fog modification activities at frequently affected airports.

Allocation of Funding

	FY 70	FY 71	FY 72
Department of Agriculture	290	330	330
Department of Commerce (NOAA)	1,701	2,064	4,450
Department of the Interior (Bureau of Reclamation)	4,765	6,500	6,700
National Science Foundation	3,220	4,100	5,400
Department of Defense	(1,848)	(1,485)	(1,515)
Army	793	650	700
Navy	850	585	615
Air Force	205	250	200
National Aeronautics and Space Administration	195	135	95
Department of Transportation (FAA)	-	606	1,770
	12,019	15,220	20,260

	FY 70	FY 71	FY 72	
Precipitation Modification	4,950	6,668	7,220	NOAA, NSF, BuRec.
Fog and Cloud Modification	3,103	3,351	4,771	NOAA, FAA, NASA, NSF, DOD
Hail Suppression	1,683	1,955	2,814	NOAA, NSF
Lightning Modification	705	835	736	Agric., NOAA, NSF, DOD
Hurricane and Severe Storm Modification	422	721	1,832	NOAA, DOD
Mathematical Modeling	350	700	700	BuRec., NSF
Inadvertent Modification	446	490	1,397	NOAA, NSF
Social, Economic, Legal and Ecological Studies	360	500	790	BuRec., FAA, NSF

WEATHER MODIFICATION
Agency Programs

DEPARTMENT OF AGRICULTURE
Forest Service

	FY 1970	FY 1971	FY 1972
Lightning Modification	290	330	330

Lightning Modification - The weather modification program for the Department of Agriculture is centered in the Forest Service project in lightning modification, Project Skyfire. This project is designed to test various cloud seeding techniques for their effects on the lightning characteristics of thunderstorms. Past work in this project has provided strong evidence for a significant reduction in total lightning activity and an even greater reduction in the frequency of the type of lightning stroke which has been identified as a major forest fire-starting mechanism.

Work during FY 1971 is concentrating on the reduction and analysis of additional data from field experiments in cloud seeding to establish the efficiency of various seeding techniques and equipment. Development is continuing on both airborne and ground systems for remote sensing of lightning. Work will also get underway on the addition of electrical effects to standard cloud and convection models for use in lightning storm simulation.

Building on experiences accumulated during field trials of operational cloud seeding during the disastrous forest fires in Washington State during the summer of 1970, design and development work will get underway on systems for operational employment of cloud seeding in lightning fire prevention. A national project in cooperation with several other agencies will be planned to fully develop and evaluate an operational system to be used by fire control organizations for the prevention of lightning fires and reduction of forest fire danger.

DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

	FY 1970	FY 1971	FY 1972
Hurricane Modification	347	671	1,757
Tropical Cloud Modification	355	409	676
Great Lakes Snow Modification	385	268	535
Hail Suppression	153	155	214
Lightning Suppression	85	171	171
Inadvertent Weather Modification	376	390	1,097
	1,701	2,064	4,450

Hurricane Modification - During FY 1972, NOAA plans to significantly expand its level of effort in research directed to hurricane modification and related investigations. Project STORMFURY, in cooperation with the Department of Defense (U.S. Navy) will conduct additional experiments in the Atlantic and preparations will be made to launch an intensified project in the Pacific during the summer and fall of 1972. In addition, computer modeling of hurricanes will be expanded to test the basic seeding hypothesis and guide future experimentation. Contract studies to explore the development of suitable techniques to suppress evaporation from the sea surface and to conduct an analysis of hurricane damage vs. storm intensity will be supported.

Tropical Cloud Modification - With the demonstration that substantial increases in rainfall can be produced by massive seeding of individual clouds guided by computer modeling, NOAA's Florida cumulus cloud modification research is rapidly approaching the stage where a pilot-operational project can be conducted to provide data on the application of seeding technology to the alleviation of water shortages over southern Florida. Research on the application of the dynamic seeding approach will be extended to specific target areas and multiple cloud experiments to examine the effects on mesoscale organization of cloud systems as well as rainfall. Numerical modeling of the dynamics of modified and unmodified cumulus clouds will be continued and improved with partial support by the Bureau of Reclamation.

Great Lakes Snow Modification - NOAA is planning an expanded field experiment in the Great Lakes area during the 1971-72 late fall and winter season to obtain improved data on the application of seeding technology to the redistribution of heavy snowfall. Mathematical modeling of storm conditions will be extended and the field experiments will concentrate on improved monitoring of cloud structure and tracing of seeding effects in major snowstorms. As secondary objectives, the use of seeding to stimulate snowshowers over the lakes to increase water resources and modify local climate will be investigated during appropriate meteorological situations.

Hail Suppression - Participation in the National Hail Research Experiment in collaboration with the National Science Foundation, the National Center for Atmospheric Research and cooperating universities will continue in FY 1972. NOAA's assistance to this project will include airborne mesoscale surveillance of the hailstorm environment and operation of a surface network of instruments to measure hail and associated precipitation.

Lightning Suppression - NOAA's efforts in the field of lightning suppression have been redirected to participation in a joint program with the NASA Kennedy Space Center to develop lightning detection techniques and explore the techniques for artificially triggering lightning with test rockets. This project is expected to continue in FY 1972 as a result of highly promising preliminary results.

Inadvertent Weather Modification - An increased program of geophysical monitoring with special emphasis on atmospheric constituents that may be affecting weather and climate is planned for FY 1972. In addition to upgrading the facilities at Mauna Loa Observatory, NOAA expects to establish a new "benchmark" station at a remote site in the Northern Hemisphere. The site tentatively selected is on Point Barrow, Alaska, where the prevailing winds will permit measurements in an environment free from local contamination. Increased efforts will be directed to the development of LIDAR for measurements of the vertical profiles of aersols and the initial steps will be taken to establish a program of ice nuclei measurements at selected locations throughout the United States.

Related Research - In addition to the above activities to develop and explore weather modification techniques, NOAA conducts background research in atmospheric sciences which is important to the future development of weather modification. Included is fundamental work in mathematical modeling of large scale atmospheric circulations which is vital to the problem of climate control; theoretical work on the structure, dynamics and energy processes of severe storms such as hurricanes, tornadoes, and thunderstorms; and the development of instrumentation for direct atmospheric measurements and for remote probing of the atmosphere.

Precipitation Management

During FY 1972 the Bureau of Reclamation, through its Division of Atmospheric Water Resources Management, will continue development and adaptation of cloud seeding technology for early use in critical water areas. Because of pressing water needs, the preliminary planning and associated studies for operational application of available, feasible techniques will be emphasized. Planning for a fourth Western pilot project will be continued. Western and Eastern field experiments and studies will be adjusted to concentrate on new problems, and the engineering development of an advanced recognition-seeding system will be undertaken. Means of assistance to commercial and other operational seeding projects to improve their effectiveness and provide associated learning opportunities will be investigated.

	FY 1970	FY 1971	FY 1972
Pilot Projects	850	1,700	1,600
Experimental Field Activities	2,700	3,200	3,400
Research and Development	550	550	550
Planning and Environmental Investigations	100	600	600
General Program Support	565	450	550
TOTAL	4,765	6,500	6,700

Pilot Projects

Colorado River Basin Pilot Project--This project was established in FY 1970 in the San Juan Mountains of Colorado. Seeding began over a limited initial target area in FY 1971 and will continue in FY 1972 with a randomized 24-hour experimental seeding unit. The purpose of this project is to provide sound scientific and engineering evaluations of precipitation increases over large areas by an operational-type application of developed cloud seeding techniques. It is anticipated an average of up to 250,000 acre-feet of new water may be added to the Colorado River annually by this randomized research project.

North Dakota Pilot Project--The pilot project, begun in 1968 to operationally test seeding of groups of summer cumulus clouds and convective storms over western North Dakota, will continue in FY 1972. The supplemental evaluation instrumentation, not possible in FY 1970, will be installed in FY 1971 and operated in FY 1972. This pilot project is under the scientific guidance of the South Dakota School of Mines and Technology.

Pyramid Lake Pilot Project--This pilot project was initiated in FY 1971 to test ground seeding of winter orographic storms for increasing streamflow in the Truckee River. Increased streamflow will help reverse the receding water level

in Pyramid Lake. This project is under University of Nevada guidance and includes a project area on the lee side of the Sierras in California and Nevada.

North Platte Pilot Project--Planning for this new pilot project will be continued in FY 1972 based on research studies by the University of Wyoming. Scientific findings from its Elk Mountain experiment will be incorporated in the project. The water supply problems facing Reclamation and non-Federal irrigators along the North Platte River are among the most critical in the West.

Experimental Field Activities

South Dakota--Develop modification techniques for increasing precipitation from convective cloud systems over Northern Great Plains, numerical cloud modeling, data acquisition and analysis systems, regional climatology and instrument development.

Wyoming--Cloud physics research at the Elk Mountain Observatory in cap and orographic clouds for determining seedability criteria and potential new water yield and continued planning and climatology studies for larger scale orographi seeding in the Wind River Range and North Platte Project.

Nevada--Research on Sierra wave cloud modification for enhancing precipitation yields, study of droplet formation and growth, aircraft instrumentation and rea time data analysis-display systems development, study of mesoscale flow of wint and summer clouds. These systems will be an important part of joint experiment and the Pyramid Lake Pilot Project.

Utah--Expanded airborne and ground winter seeding research program and evaluat of seeding effects in the highly instrumented experimental area developed in t Wasatch Mountains. Aircraft seeding feasibility will be determined. Salt Lak City area air pollution effects with a seeding experiment will be studied.

Flagstaff, Arizona--No summer experiment will be held, but detailed analysis o existing results for cloud development, precipitation, modeling of cumulus development, and investigation of cloud particle growth.

California--Operate dense network of data acquisition stations in a Southern Sierra drainage, analyze water budget of storms crossing region to evaluate an determine feasibility of operational modification, and coordinate seeding and evaluations with commercial operators and other research groups during summer and winter seasons.

Washington--Develop and field test airborne and ground seeding methods to shif precipitation across Cascade Range from areas of excess to areas of deficit wi emphasis on study of cloud physics mechanisms involved in cloud modification.

New Mexico--A ground-based seeding experiment located in Jemez Mountains for developing and evaluating techniques to augment water supplies in Rio Grande Basin by seeding winter storms.

Montana--Study seeded characteristics of winter storms over and east of Bridger Range to evaluate cloud physics changes and downwind effects of precipitation over orographic barriers.

Texas--Experimental seeding of groups of warm and cold type clouds in the San Angelo area to learn best techniques for increasing rainfall over a multi-county area. Cloud group physical models will be developed from this and other experiments.

Eastern--A summer field experiment planned in FY 1971 to test seeding techniques for augmenting streamflow during low flow periods will be started. Synergistic effects of seeding in conjunction with watershed conservation methods will be studied.

Research and Development

New efforts undertaken in FY 1972 include: Research on more effective and inexpensive seeding systems including rocketry, organization of the basic work in modeling precipitation processes into a computerized system for engineering precipitation management, a prototype real-time data display system will be built and preliminary field tests begun, increased use of the Advance Technology Satellite (ATS) and the Earth Resources Orbiting Satellite (EROS) Programs for precipitation management decisions will be studied and special application equipment developed, instrumentation on several existing experiments will be extended to provide test beds for new developments, present aircraft instrument systems will begin a complete engineering redesign effort for meeting increasing data needs, and radiation techniques for snow measurement will be developed to operational status.

Key research continuing in FY 1972 includes studies on the physics and dynamics of modifying groups of clouds to increase areal precipitation, development of remote sensors and ice protection for anemometers, and development of important statistical evaluation techniques, particularly involving watershed hydrologic parameters.

Planning and Environmental Investigations

Reconnaissance studies incorporating cloud seeding augmentation with regional water resources planning, particularly the West Wide water planning, will be continued in FY 1972. Economic and engineering decision-making criteria will be formulated for evaluating precipitation modification for water augmentation as an alternative or accompanying means in natural resources management and development.

The large field investigation of the ecological effects of additional snowfall, begun in FY 1971, in the San Juan Mountains in connection with the Colorado River Basin Pilot Project will be continued. The avalanche potential appraisal program will also be continued as a part of the pilot project.

The dilution potential of precipitation management in water pollution will be studied through comprehensive watershed river basin models. Basic social responses to precipitation management will be investigated in critical water area where early operations are likely. Statewide comprehensive studies on the effect of precipitation management in the Northern Plains will be expanded. These comprehensive studies will include economic-environmental effects with special emphasis on soil moisture retention and plant disease/insect population vectors. These studies will assist operational programs being planned for the region.

General Program Support

The series of "Skywater Conferences" on specific problems in developing and applying precipitation modification will continue in FY 1972. Six of these conferences have been held through FY 1971. Reports of findings from the Bureau of Reclamation's program, including contractor reports, proceedings of the Skywater Conferences, and the program's annual report will be widely distributed. Provisions will be made for long-term leases for high performance aircraft and crews to be scheduled for use throughout the program and in cooperative projects with other agencies. Public information efforts, including completion of a new motion picture on cloud seeding progress, will be emphasized in FY 1972.

Field support for pilot projects and field experiments includes snow course measurement and analysis, streamflow measurement, watershed studies of geology, vegetation, and use history; and radar calibration. Improved methods and equipment for precipitation measurement and analysis such as snow pillows, rate sensors, and remote snow samplers will be developed. Mobile equipment and instrumentation will be used more extensively to support seasonal field experiments and cooperative experiments and to survey meteorological characteristics at promising sites for new experiments and pilot projects.

Operational Planning and Assistance

Meetings will be sponsored with Bureau of Reclamation's regional offices and other natural resource groups to begin investigating in detail possible applications of precipitation management. The background water yield potential studies and preoperational data and site surveys begun in FY 1971 for possible operational projects will be extended. Legal studies on water ownership, Federal liability, operating authority, and regulations will be initiated, using the Colorado River and the Colorado River Basin Pilot Project as test cases. Studies will be initiated in Western States formulating organizational operating mechanisms and procedures for operational use of cloud seeding.

Investigation into the furnishing of equipment, instrumentation, and scientific assistance to operational projects to increase the effectiveness of the seeding activities and to provide a learning and evaluation opportunity will begin. A cooperative approach to coordinate research and operational seeding activities will be developed on a regional basis.

Program Assistance and Coordination

NCAR will continue to actively assist in the development and modification of radar equipment and nuclei counters. NASA is providing technical information assistance to program participants and, through the Geological Survey-EROS program, coordinates use of satellites for weather modification decision-making. Formal and informal communication is maintained with NOAA's Research Laboratories to insure that instrument and equipment developments of each organization are mutually supporting. The technical libraries of NOAA in Boulder and Interior in Denver will continue to be open to both organizations. It has been agreed that Interior emphasis will be on the practical aspects of modification; NOAA's on the broad aspects of all facets of weather modification.

NATIONAL SCIENCE FOUNDATION

	FY 1970	FY 1971	FY 1972
Precipitation Augmentation	-	250	300
Fog and Cloud Modification	810	800	1,000
Hail Suppression	1,530	1,800	2,600
Lightning and Electricity Modification	300	300	200
Mathematical Modelling	250	600	600
Legal, Social and Ecological Studies	260	250	400
Inadvertent Modification	70	100	300
	3,220	4,100	5,400

The Foundation will continue to support basic and applied research in weather modification at universities, the National Center for Atmospheric Research and nonprofit institutions under the broad authority of the National Science Foundation Act of 1950 as amended by Public Law 90-407. It is the policy of the Foundation to support those areas of research which will provide other Federal agencies with the necessary fundamental knowledge needed to develop their mission capabilities in the areas of weather modification.

Precipitation Augmentation

The Foundation's efforts in precipitation modification will be accomplished primarily through support of the Colorado State University research at Climax, Colorado which has been devoted in the past primarily to the modification of orographic cloud systems. In FY 1972, attention will be directed toward the convective cloud structures which form over the Rocky Mountains since these systems are normally fixed by the topographic features and can be expected to reoccur in a reasonably reproducible cycle over several summer months. The successive step by step process developed over the past 10 years on orographic processes will now be applied to these convective systems with the intent of developing a set of criteria which will determine the conditions required for successful precipitation augmentation.

Fog and Cloud Modification

Research under this category is largely related to the understanding of those cloud microphysical processes upon which fog dissipation or precipitation depends. Much of this research is laboratory related and is concerned with the mechanisms of both condensation and freezing nuclei with respect to ice crystal growth, condensation, coagulation, accretion, evaporation, scavenging and other properties of atmospheric hydrometeors. In many instances, data are obtained in the laboratory and verified by actual observations from mountain top observatories or aircraft. The objective of this research is to understand these mechanisms well enough to apply this knowledge to the calibration and standardization of field equipment and procedures and to provide reliable inputs for the purposes of mathematical model development.

Hail Suppression

The primary emphasis of the Foundation's weather modification program is to provide support to the National Center for Atmospheric Research (NCAR) in conducting the first full observational year of the National Hail Research Experiment which will be conducted in northeastern Colorado over a five year period starting in the summer of 1972. This experiment is based upon the plan prepared by NCAR and coordinated with ICAS at the April 1969 meeting. The plan of operation involves the use of instrumented aircraft, including a specially protected aircraft capable of penetrating the zone of hail formation, a number of specially designed doppler and dual wavelength radars, ground meteorological networks, stereophotography, lidar, and telemetry networks which will permit coordinated measurements and correlation of observed parameters through a computerized storage and display system. Storms passing over a 600 square mile "protected" area will be monitored and those which show evidence of hail formation will be seeded on a randomized basis with silver iodide delivered to a specified area of the storm cell by rockets or pyrotechnic cannisters released from aircraft. The effect of the seeding upon the dynamics and microphysics of the hail cell will be observed and related to the many mathematical models which have been proposed to explain hailstorm behavior. It is expected that these observations will provide the data for choosing the most promising of these models and the eventual development of a realistic mathematical model which can be used to forecast hail generation and indicate the means for suppressing the growth of large hailstones. Statistical tests of hail suppression success within the protected area will be correlated with case studies of specific storms in order to provide physical significance to the statistical data. Cooperative research will be conducted in the area by participating universities under NCAR field management, and other cooperative observations and services will be provided by the Department of Commerce, Department of Interior, Department of Agriculture, Department of Defense, Department of Transportation and the Atomic Energy Commission.

Lithtning and Electricity Modification

Most of the Foundation's research in the modification of cloud electricity is directed toward a study of the basic concepts which relate cloud electricity to precipitation and the possibility of inducing or augmenting rainfall by electrical charge injection. Observations and experiments are conducted from mountain top observatories or an extensive network of ground sensors and radars in the vicinity of the New Mexico Institute for Mining and Technology in Socorro, New Mexico. Electrically active cloud systems are probed by means of rockets and balloons carrying the electrical field measurement equipment. Charge injection into the base of building cumulus is being attempted experimentally by means of charged wire networks, vertical wind tunnels, and vortex generators. Work on the electrical behavior of charged droplets is also being performed at NCAR.

Mathematical Modelling

In the area of weather modification, mathematical modelling is being conducted in universities and at NCAR on the dynamic and microphysical processes of convective storms which give rise to the formation of hail, winds, and lightning. Numerous models have been devised by several groups which simulate many of the observed characteristics of severe storms, but unfortunately actual experimental data from real storms are not available to provide a critical test of validity. As field observations are made during the National Hail Research Experiment and further laboratory data on microphysical mechanisms are obtained, they will be used to refine the models and test their ability to accurately forecast the results of modification.

Legal, Social, and Ecological Studies

The increased incorporation of studies involving the legal, social, and ecological aspects of weather modification into specific project objectives will be continued. The social and economic study of hail suppression will be incorporated into the National Hail Experiment (NHRE), and close cooperation will be maintained with the International Biological Program group who share the Pawnee Grasslands with NHRE and will monitor any ecological change which might take place during the duration of the experiment. Further technology assessments such as the Stanford Research Institute study of orographic snowpack augmentation will be undertaken as the occasion arises. Individual university research in the social, legal, economic and ecological aspects of weather modification will continue to be encouraged.

Inadvertent Modification

Research on the effects of atmospheric pollutants, large thermal sources such as cities, large expenses of concrete or asphalt heated by the sun, and dust carried aloft by winds from desert or dust bowl areas upon the processes of precipitation and cloud growth will continue to be studied. Laboratory and field measurements will be complemented with mathematical models in an attempt to establish the link between cause and effect, and means for reversing undesirable trends will be studied. The efficiency of condensation and ice formation in clouds as a scavenging technique for particulates in the atmosphere will continue to be studied.

	FY 1970	FY 1971	FY 1972
Fog and Cloud Modification	1,743	1,401	1,405
Lightning Modification	30	34	35
Hurricane and Severe Storm Modification	75	50	75
	1,848	1,485	1,515

The Weather modification effort within Defense will be directed principally in three areas, warm and cold fog modification, tropical cyclone moderation, and cloud physics modelling. Some additional work will be done in the areas of stratus cloud dissipation, cumulus augmentation and dissipation, seeding materials investigations, and development of investigative instrumentation.

Recent success in an Air Force program of cold fog dissipation has resulted in the decision to begin operational programs for clearing cold fog from air fields which experience significant amounts of this element. Additional efforts will be expended by all three services on the problem of warm fog removal.

The Defense effort in the field of tropical cyclone modification is carried on primarily by the Navy. The major effort to be conducted will be a continuation of PROJECT STORMFURY, in association with the Department of Commerce. Plans call for more seeding experiments essentially like that conducted on HURRICANE DEBBIE in 1969. The lack of cyclones suitable for seeding in CY 1970 seriously hampered this work. Consideration is being given to transferring the project to the Pacific area at some future time, since there are generally more suitable cyclones per year which might be successfully seeded. No decision regarding this matter has as yet been reached. Both the Air Force and the Navy are working on the problem of numerical modelling of tropical cyclones to determine the most efficient location and degree of seeding to achieve moderation of the maximum winds associated with typhoons and hurricanes.

For the future, plans are being drawn for Department of Defense participation in the proposed National Projects for Weather Modification. The extent of this effort will be governed primarily by fiscal constraints. However, since many of the objectives of the National Projects, fog dissipation, hail and lightning suppression, precipitation redistribution and tropical cyclone modification, are matters of prime interest to the Department of Defense, it is anticipated that the Military Services will contribute a significant share of the efforts in their support.

	FY 1970	FY 1971	FY 1972
Fog and Cloud Modification	195	135	95

NASA (in cooperation with the Navy) has supported Cornell Aeronautical Laboratory in a continuing program of warm fog studies. Ground and flight data from Elmira, New York have been analyzed to determine valley radiation fog characteristics before, during, and after formation. Laboratory experiments will be made to test new fog dissipation materials, to determine effects of various pollutants on fog, and to investigate treatment of condensation nuclei with evaporation retardants. Refined computer models of fog formation will emphasize the evolution of fog drop size distribution and involve validation of modeling concepts using previous field test data. Tentative plans for FY 1972 are to study coastal advection fogs over flat terrains using ground/tower measurements and to improve the basic computer models.

DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration

	FY 1970	FY 1971	FY 1972
Fog and Cloud Modification	-	606	1,595
Economic and Legal Studies	-	-	175
		606	1,770

Due to the rapid expansion of aviation in the foreseeable future (a 300% increase is expected by 1975 in air carrier passenger miles and also in total aircraft operations), the capacity of the current 11,000 airports in the United States will be taxed heavily. As a result, ways and means must be found to increase the airport and airway system capacity to accomodate this expansion in aircraft operations. This can be done in a number of ways such as speeding up the landings and take-offs, faster passenger handling at terminals, development of all-weather landing systems, and, meteorologically, the reduction of adverse weather and environmental effects on airside operations. A systems engineering management plan has been developed by FAA which will meet the requirements for increased airport and airway system capacity. An essential element in this plan concerns modification of fog and other adverse weather which affects system capacity. It is to this requirement that the FAA Weather Modification Program is addressed.

Our first effort will be in the area of fog dispersal at airports. When the Runway Visual Range (RVR) drops below minimums, aircraft flights are often cancelled, delayed, diverted or overflown. Based on 10 years of climatological data, a sampling of airports where Category II (RVR 1200-2400 feet) and Category III (RVR less than 1200 feet) conditions were present to interfere with aircraft operations delays varied from 15 hours per year at Syracuse, N. Y. to 189 hours at Seattle, Washington. For the three busiest U. S. airports, the data were:

O'Hare Field - 46 hours
JFK, New York - 60 hours
Los Angeles - 136 hours

Approximately one flight operation per minute is carried out at the above airports. Consequently, nearly 14,500 flight operations per year were not carried out due to CAT II and CAT III conditions at the above airports. This represents a large loss of revenue, missed connections, delays in aircraft checks, passenger inconvenience and re-scheduling of aircraft maintenance work. An estimate by the Air Transport Association of losses due to fog for the nation's airlines is $75 million per year.

The goal of the FAA effort in fog modification will be to develop fog dispersal systems which will operate efficiently, meet aviation requirements and be economically beneficial.

There are many experimental techniques and chemical agents which are being used to dissipate fog. Various degrees of success have been attributed to sodium chloride, calcium chloride, polyelectrolytes, urea, ammonium nitrate, solid carbon dioxide and silver iodide. However, no authoritative handbook or reliable published data exists today on just exactly what these and other fog dispersing agents can do. This is an area of R & D which will be investigated.

The FAA fog modification program plans to install and operate a prototype propane cold fog dispersal system at a U. S. airport which has a high incidence of supercooled fog and will utilize French technology and consultation support. Currently, the Department of Transportation has a memorandum of understanding with the Ministry of Transport of France Concerning R & D cooperation in the area of fog dispersal techniques and equipment. Test and evaluation of the prototype system will then lead to an FAA selection order into the National Airspace System which will make the propane cold fog dispersal system a part of the agency hardware inventory that meets operational requirements.

The current status of warm fog modification systems R & D is that we must first specify the aviation operational requirements and then operationally efficient systems must be developed which meet these requirements and are economically beneficial. Evaluation of the operational efficiency of these systems will then be done as well as the evaluation of their economic benefits.

Studies will be made of the impact of wind velocity and direction on energy requirements for plume recycling, plume stability, and the location and direction of fog dispersal units. Since visibility is related to the liquid water content of fog, the impact on operational efficiency of energy requirements to change liquid water content will be determined. An Engineering Requirement has been prepared which will provide for measurement, instrumentation and description of fog dispersal operations. Visibility improvement will be documented and the number of aircraft landings and take-offs due solely to the fog dispersal effort will be recorded.

Our program will also include studies to answer such questions as: how large should the defogged area be, and what are the pilot's requirements concerning ceiling and visibility for a safe approach and landing, and what is the impact of a cross-wind fog dispersal plume on the aircraft?

The development of economic requirements for an effective fog dispersal system will be based on an economic analysis of 41 major airports in the U. S. A ten year climatology of the incidence of visibility less than one-half mile and ceiling less than 200 feet at each airport will be used to determine the number and type of aircraft affected, the number of passengers affected and the cost to the airlines and passengers. The economic benefits resulting from fog dissipation will be determined. This study is now in progress and a report is due early in 1971.

In order to determine if the fog dispersal system is economically beneficial, an analysis of terrain effects on the cost of a ground-based fog dispersal system will be made at 49 Category II airports (RVR 1200 to 2400 ft.). This analysis will include 3000 feet of runway approach, terrain and obstacle features, and runway approach profile.

A systems engineering study will be made to translate requirements into hardware, which may be a thermal system prototype design or a nuclei condensation system prototype design or a combination of these or others. The prototype system will be tested and evaluated.

PROGRAM SUMMARIES

Tables 1, 2 and 3

Table 1

National Atmospheric Sciences Program Summary
(in thousands of dollars)

	FY 1970	FY 1971	FY 1972
Agriculture	1,120	1,191	1,228
DOC			
NBS	2,023	2,191	2,337
NOAA	17,485	21,712	28,427
OT	640	670	700
DOD	(55,344)	(48,796)	(53,525)
Army	13,111	11,824	12,240
Navy	3,928	3,710	3,690
Air Force	24,692	23,817	27,575
ARPA	10,683	7,945	8,870
DASA	2,930	1,500	1,150
EPA	6,560	7,957	8,325
Interior (Bu.Rec.)	4,765	6,500	6,700
AEC	8,894	8,399	8,545
DOT (FAA)	1,355	2,645	5,109
NASA	174,161	180,298	317,194
NSF	30,190	37,000	46,500
TOTAL	302,537	317,359	478,590

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House (Incl. gov't laboratories)	82,760	84,576	101,371
Industry (Profit)	161,913	166,879	303,403
Universities	34,210	37,427	40,786
Other (Incl. non-profit laboratories)	23,654	28,477	33,030

Table 2

National Atmospheric Sciences Program Summary
(In thousands of dollars)

	FY 1970	FY 1971	FY 1972
Meteorology			
Agriculture	1,120	1,191	1,228
NBS	734	808	838
NOAA	14,621	19,117	25,832
OT	106	240	280
DOD	(24,155)	(23,511)	(29,724)
Army	11,698	10,579	11,198
Navy	3,141	2,912	2,890
Air Force	7,316	8,420	12,636
ARPA	2,000	1,600	3,000
EPA	6,560	7,957	8,325
Interior (Bureau of Rec.)	4,765	6,500	6,700
AEC	6,406	6,094	6,254
DOT (FAA)	1,355	2,645	5,109
NASA	42,450	52,278	51,646
NSF	19,120	24,000	30,500
Total Meteorology	121,392	144,341	166,436
Aeronomy			
DOC			
NBS	1,233	1,303	1,405
NOAA	2,864	2,595	2,595
OT	534	430	420
DOD	(31,189)	(25,285)	(23,801)
Army	1,413	1,245	1,042
Navy	787	798	800
Air Force	17,376	15,397	14,939
ARPA	8,683	6,345	5,870
DASA	2,930	1,500	1,150
AEC	2,488	2,305	2,291
NASA	5,830	6,546	3,825
NSF	9,340	11,100	13,900
Total Aeronomy	53,478	49,564	48,237
Planetary Atmospheres			
DOC (NBS)	56	80	94
NASA	125,881	121,474	261,723
NSF	1,730	1,900	2,100
Total Planetary Atmospheres	127,667	123,454	263,917
PROGRAM TOTAL	302,537	317,359	478,590
TOTAL Less Planetary Atmospheres	(174,870	(193,905)	(214,673)

	Agriculture			NBS			NOAA		
	FY 1970	FY 1971	FY 1972	FY 1970	FY 1971	FY 1972	FY 1970	FY 1971	FY
Meteorology									
Physical Meteorology	293	290	305	189	194	197	1,244	1,545	
Dynamic Meteorology	50	50	50	125	140	147	3,828	5,492	
Observation	30	30	30	395	449	469	3,093	3,294	
Description	457	491	513	25	25	25	2,157	2,798	
Prediction							1,840	2,264	
Modification	290	330	330				1,701	2,064	
Dissemination							107	107	
Systems							651	1,333	
Support								220	
Total	1,120	1,191	1,228	734	808	838	14,621	19,117	2
Aeronomy									
Aurora and Airglow							246	239	
Ionospheric Physics				640	723	793	929	886	
Atmospheric Chemistry				94	99	105	294	324	
Atmospheric Structure								21	
Energetic Particles							236	43	
Atmospheric Geomagnetism							182	136	
Solar Terrestrial Studies				499	481	507	402	353	
Dynamic Aeronomy									
Instrumentation, General							86	135	
Instrumentation, Rockets							29	69	
Instrumentation, Satellites							106	110	
Support							354	279	
Total				1,233	1,303	1,405	2,864	2,595	
Planetary Atmospheres				56	80	94			
PROGRAM TOTAL	1,120	1,191	1,228	2,023	2,191	2,337	17,485	21,712	2
In-House (Incl.Gov't Labs)	790	861	898	1,998	2,166	2,312	15,120	19,420	2
Industry (Profit)	20	20	20				800	826	
University	310	310	310	25	25	25	1,327	1,187	
Other (Non-Profit Labs)							238	279	

	DASA			EPA			Interior		
	FY 1970	FY 1971	FY 1972	FY 1970	FY 1971	FY 1972	FY 1970	FY 1971	F
Meteorology									
Physical Meteorology				4,800	5,339	5,400			
Dynamic Meteorology									
Observation				640	540	787			
Description				1,030	2,028	2,088			
Prediction				90	50	50			
Modification							4,765	6,500	
Dissemination									
Systems									
Support									
Total				6,560	7,957	8,325	4,765	6,500	
Aeronomy									
Aurora and Airglow	800	300	100						
Ionospheric Physics									
Atmospheric Chemistry	900	900	1,050						
Atmospheric Structure	400	300							
Energetic Particles	200								
Atmospheric Geomagnetism									
Solar Terrestrial Studies									
Dynamic Aeronomy									
Instrumentation, General									
Instrumentation, Rockets	630								
Instrumentation, Satellites									
Support									
Total	2,930	1,500	1,150						
Planetary Atmospheres									
PROGRAM TOTAL	2,930	1,500	1,150	6,560	7,957	8,325	4,765	6,500	
In-House (incl.Gov't Labs)	2,480	1,290	900	2,300	2,705	2,907	402	500	
Industry (Profit)	350	210	250	3,280	4,140	4,340	904	1,450	
University				980	1,112	1,078	2,989	3,800	
Other (Non-Profit Labs)							470	750	

NATIONAL ATMOSPHERIC SCIENCES PROGRAM SUMMARY
by Research Areas
(in thousands of dollars)

Note: For definition of Research Areas see Classification System p. 75.

Table 3

OT			Army			Navy			Air Force			ARPA		
FY 1970	FY 1971	FY 1972	FY 1970	FY 1971	FY 1972	FY 1970	FY 1971	FY 1972	FY 1970	FY 1971	FY 1972	FY 1970	FY 1971	FY 1972
106	240	280	100	100	200	856	992	900	1,078	1,030	991			
			815	772	886				299	331	356			
			3,284	2,553	2,641	570	585	625	1,063	655	525			
			1,355	1,411	1,291		450	450				2,000	1,300	2,600
			498	520	502	865	300	300	727	455	395			
			793	650	700	850	585	615	205	250	200			
			222	223	522									
			360	350	556				1,136	2,390	6,015			
—	—	—	4,271	4,000	3,900	—	—	—	2,808	3,309	4,154	—	300	400
106	240	280	11,698	10,579	11,198	3,141	2,912	2,890	7,316	8,420	12,636	2,000	1,600	3,000
									151	125	100	750	880	900
534	430	420	282	405	312				1,106	1,120	1,046	1,363	2,150	2,100
									846	830	924	4,310	1,890	1,750
			261	340	355	50	179	150	2,416	2,280	2,389	1,780	815	660
									916	881	974	50		100
									1,165	703	724			200
						737	619	650	415	400	350			
									3,721	2,438	2,882			
			870	500	375							280	160	160
												150	450	
—	—	—	—	—	—	—	—	—	6,640	6,620	5,550	—	—	—
534	430	420	1,413	1,245	1,042	787	798	800	17,376	15,397	14,939	8,683	6,345	5,870
640	670	700	13,111	11,824	12,240	3,928	3,710	3,690	24,692	23,817	27,575	10,683	7,945	8,870
640	670	700	11,209	10,164	10,317	3,249	2,799	2,857	14,820	13,560	13,600	1,689	1,345	1,240
			323	281	579	328	276	253	3,460	4,478	8,080	7,869	4,385	5,380
			1,359	1,145	1,178	351	635	580	5,690	5,225	5,245	1,125	2,215	2,250
			220	234	166				722	554	650			

AEC			FAA			NASA			NSF			Totals		
FY 1970	FY 1971	FY 1972	FY 1970	FY 1971	FY 1972	FY 1970	FY 1971	FY 1972	FY 1970	FY 1971	FY 1972	FY 1970	FY 1971	FY 1972
1,692	1,724	2,008				746	660	760	4,480	5,200	6,700	15,584	17,314	19,247
2,637	2,434	2,358				450	375	650	4,620	6,800	8,100	12,824	16,394	21,470
1,536	1,501	1,510	135	973	779	40,789	49,848	48,816	3,820	4,300	4,900	55,355	64,728	64,899
433	348	302							60	100	500	7,517	8,951	10,175
108	87	76	286	47	255				50	100	900	4,464	3,823	4,607
				606	1,770	195	135	95	3,220	4,100	5,400	12,019	15,220	20,260
			85	57	542				90	100	300	504	487	1,578
			490	526	1,654	270	1,260	1,325	360	500	600	3,267	6,364	12,317
—	—	—	359	436	109	—	—	—	2,420	2,800	3,100	9,858	11,070	11,883
6,406	6,094	6,254	1,355	2,645	5,109	42,450	52,278	51,646	19,120	24,000	30,500	121,392	144,341	166,436
285	321	316							990	1,200	1,600	3,222	3,065	3,255
90	90	80				2,025	2,364	1,865	1,310	1,900	2,400	8,279	10,068	9,902
322	60	87				1,547	1,657	1,960	260	400	700	8,573	6,160	6,900
142	141	215							1,040	1,100	1,400	6,089	5,176	5,190
215	155	150							720	900	1,200	2,337	1,979	2,467
1,187	1,160	1,045							810	900	1,200	3,344	2,899	3,305
150	150	134							1,910	2,600	3,000	4,113	4,603	4,994
									580	800	800	4,301	3,238	3,682
									60	100	100	146	235	235
97	228	264				1,189	1,575		960	500	800	4,055	3,032	1,668
						1,069	950		10	-	-	1,335	1,510	110
—	—	—	—	—	—	—	—	—	690	700	700	7,684	7,599	6,529
2,488	2,305	2,291				5,830	6,546	3,825	9,340	11,100	13,900	53,478	49,564	48,237
						125,881	121,474	261,723	1,730	1,900	2,100	127,667	123,454	263,917
8,894	8,399	8,545	1,355	2,645	5,109	174,161	180,298	317,194	30,190	37,000	46,500	302,537	317,359	478,590
2,197	2,425	2,579	555	955	1,214	24,581	24,816	35,220	630	900	1,200	82,760	84,576	101,371
250	99	106	800	1,690	3,895				50	100	400	161,913	166,879	303,403
903	815	881							13,050	14,400	19,100	34,210	37,427	40,786
5,544	5,060	4,979							16,460	21,600	25,800	23,654	28,477	33,030

DEPARTMENT OF AGRICULTURE

The research program of the Department of Agriculture in the Atmospheric Sciences is aimed toward a fuller description and a more complete understanding of those atmospheric features and phenomena which significantly affect agriculture, forestry, and the products of these activities. Ultimately, of course, this understanding must be applied in either adaptation or modification to lessen the influence of adverse atmospheric effects or to exploit more fully the favorable weather conditions.

The level of funding of the atmospheric sciences program remains virtually unchanged in FY 1972.

Physical Meteorology. The principal research programs in physical meteorology involve measurement and analysis of atmospheric electrical fields associated with thunderstorms. The work is for the purpose of achieving a satisfactory theory of charge generation and an explanation of the mechanism of lightning discharge.

Forest fire meteorology research is seeking to obtain precise, quantitative relationships between forest fuel moisture and the weather variations with emphasis on the microclimate of forest fuels and vegetation.

The transport spreading and distribution of fine particles under environmental turbulence is being continued. This research is germane to both pesticide distribution and air pollution studies.

Agriculture Research Service continues a program in the partitioning and exchange paths of both heat and moisture at the crop-air-earth interface.

Dynamic Meteorology. In the area of dynamic meteorology the focus is on boundary layer wind flow. The definition of the interaction between local geography and large-scale force fields to determine local winds remains the principal objective of this work.

Observation. Work in the area of observations involves experimentation with several types of remote automatic weather stations. A completely suitable system for application in forest meteorology has not yet been developed. Testing and modification of existing systems continues.

Description. The efficient production of agriculture crops is a continuing aim of the Cooperative State Research Service. The wider adaptability of high yield crops is being sought through regional studies of climatic variables of agriculture import. These studies must recognize the impact on and tolerance of biological species to single weather events such as frost, maximum temperature and peak winds. Work in this area is beginning to consider the application of remote sensing and satellite observations to crop-weather problems.

Descriptions of fire climates and local weather events of fire importance are studied as aids in fire planning and fire control.

Weather Modification. The weather modification research in the Department of Agriculture is presently limited to work on the modification of lightning storms in the Northern Rocky Mountain area. This work undertaken within the Skyfire project involves development and experimentation in cloud seeding technology, electric field sensors, cloud microphysics and cumulus dynamics. This work is aimed at reduction in the number of lightning-caused forest fires.

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Meteorology			
Physical Meteorology	293	290	305
Dynamic Meteorology	50	50	50
Observation	30	30	30
Description	457	491	513
Modification	290	330	330
TOTAL	1,120	1,191	1,228

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House	790	861	898
Industry (Profit)	20	20	20
University	310	310	310

DEPARTMENT OF COMMERCE

National Bureau of Standards

The National Bureau of Standards is a principal focal point in the Federal Government for assuring maximum applications of the physical and engineering sciences to the advancement of technology in industry and commerce. In carrying out this mission, NBS conducts a research and development program which includes some aspects of atmospheric science.

Meteorology

NBS has the responsibility for basic measurements and standards, and many of these are of direct interest in meteorology. Some examples are development of improved instrumentation for the measurement of humidity; enhancement factor studies; research designed to increase our knowledge in fluid flow meter theory; improvement in the accuracy of air-speed measurements; investigations of the statistical properties of turbulence; improvements in radiometric standards, especially the standard of total irradiance; the development of reflectivity and emissivity standards in the 0.2 to 40μm region necessary for remote infra-red sensing of the atmosphere; thermodynamic studies of water vapor, CO_2, the rarer atmospheric gases (PVT relations); development of improved pressure measurement standards in the 0-760 mg of Hg range.

Aeronomy

JILA. The Joint Institute for Laboratory Astrophysics is located at Boulder, Colorado, and is a collaborative effort of the National Bureau of Standards and the University of Colorado, but also receives support from other government agencies. The purpose of the Institute is to provide a center for advanced research and training in physics related to the properties of very hot gases. Its primary mission is the furtherance of the national capability for measurement of properties of hot gases using the emergent radiant spectrum with particular concern for the requirements of astronomy, plasma physics and engineering applications.

Approximately 40 percent of JILA's work is considered to be in the field of atmospheric sciences as part of the overall program in laboratory astrophysics devoted to the gathering and analysis of essential data, and the development of diagnostic methods for the study of hot gases in general. The program is a relatively level effort consisting largely of laboratory measurements of cross sections for collision processes involving atoms and molecules of atmospheric gases, in neutral and ionic forms. Related ultraviolet and spectroscopic

measurements are also carried out. Theoretical techniques are being developed for solving jointly the problems of radiation transfer and statistical equilibrium of all the microscopic rate processes occurring in a high temperature gas.

In addition to the JILA, many other units of NBS contribute to aeronomy. Electronic, infrared and microwave spectroscopy studies of atmosphere molecules are being conducted, transition probability measurements of atoms and ions, plasma physics and plasma diagnostic research, experimental work on ion-molecule reactions involving atmospheric species, photoionization studies of small molecules, energy transfer studies and measurement of lifetimes of excited states of small molecules and radicals, compilation of kinetic rate constants for reaction of atmospheric species, theoretical evaluation of the energy states and structures of atmospheric molecules.

Planetary Atmospheres

Specific efforts include a spectroscopic study of the importance of hydrogen bonding among the constituents of the atmospheres of Jupiter, Saturn, Uranus, and Neptune and a collaborative effort with groups designing and analyzing results of planetary probes.

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Meteorology			
Physical Meteorology	189	194	197
Dynamic Meteorology	125	140	147
Observation	395	449	469
Description	25	25	25
Total	734	808	838
Aeronomy			
Ionospheric Physics	640	723	793
Atmospheric Chemistry	94	99	105
Solar Terrestrial Studies	499	481	507
Total	1,233	1,303	1,405
Planetary Atmospheres	56	80	94
PROGRAM TOTAL	2,023	2,191	2,337

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House (Including Other Agencies)	1,998	2,166	2,312
University	25	25	25

DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA) was established within the Department of Commerce on October 3, 1970 under the President's Reorganization Plan No. 4. The formation of NOAA brought together the functions of the Environmental Science Services Administration (Department of Commerce); the Bureau of Commercial Fisheries, the Marine Sport Fisheries Laboratories and the Marine Minerals Technology Center (Department of Interior); the National Oceanographic Data Center and the National Oceanographic Instrumentation Center (Department of the Navy); the National Data Buoy Development Project (Department of Transportation); the National Sea Grant Program (National Science Foundation); and elements of the U. S. Lake Survey (Department of the Army). In addition, on September 20, 1970 the Institute for Telecommunication Sciences (ITS) was transferred from ESSA to the Office of Telecommunications (OT) within the Department of Commerce and the atmospheric sciences program of ITS formerly reported by ESSA is now reported as a separate program of the Department of Commerce.

The National Oceanic and Atmospheric Administration in support of its environmental services and research missions conducts a program of research which includes nearly all aspects of the atmospheric sciences. The research is conducted primarily through NOAA's Environmental Data Service, Environmental Research Laboratories, National Weather Service and National Environmental Satellite Service.

The World Weather Program research and development activities planned by NOAA for FY 1972 focus on systems design and technological developments for both the Global Atmospheric Research Program and the World Weather Watch. The Global Atmospheric Research Program (GARP) is an international effort designed to further the understanding of atmospheric processes necessary to develop capability in long-range weather prediction. GARP consists of two major parts--theoretical research on atmospheric physical processes and supporting field experiments to gather the data required for the research. The processing of the data gathered in the first GARP interagency field experiment--the Barbados Oceanographic and Meteorological Experiment--is nearing completion and the research with the data will be accelerated in FY 1972. The principal purpose of this research is to provide the necessary understanding of how energy is exchanged between the atmosphere and oceans at the air-sea interface. The understanding of how small-scale processes can be incorporated in the terms of large-scale measurements of the atmosphere is essential in the development of the capability for long-range weather prediction.

A new major GARP field experiment to be conducted in FY 1974 is the highly important international tropical experiment, the GARP Atlantic Tropical Experiment (GATE), which is being designed to provide an understanding of convective mechanisms and the role they play in the transfer of energy between the atmosphere and the oceans. A lizeable international fleet of ships and aircraft will be deployed in the tropical Atlantic for collecting atmospheric

and oceanographic data. To conduct this experiment and ensure its implementation by FY 1974, the design construction and testing of prototype data acquisition systems and procurement of major items of equipment for installation on NOAA ships and aircraft will be started in FY 1972.

The Geophysical Fluid Dynamics Laboratory is conducting research in theoretical modeling of atmospheric and oceanic processes and dynamics, and in computational simulation of their characteristic behavior and phenomena. Significant advances in the physical understanding of the oceanic and atmospheric circulations and interrelationships have been made. The most sophisticated models have succeeded in simulating the broad features of these fluid systems. Many of the important details of weather changes for periods of the order of a week have been duplicated. The increased sophistication of the models and their growing fidelity and similitude to the actual atmosphere and oceans, have suggested a number of potential application areas bearing upon problems important to man. Among these are long-range weather and oceanic prediction, the large-scale, long-term dispersion of pollutants in the atmosphere and the oceans, and an assessment of the feasibility of intentional modification of climate and its inadvertent modification due to human activity.

Both the fundamental research and the exploratory application potentialities require vast amounts of computation which cannot be met with the size and speed of existing computers. It is therefore necessary to take advantage of new advances by the computer industry. An expansion of the activities of the laboratory is planned in FY 1972 in anticipation of the installation of a fifth generation computer system the last month of the fiscal year. Plans call for computer software conversion and further development and evaluation of more comprehensive models of the ocean-atmosphere system. The dynamics of particular ocean basins and the response of the atmosphere to seasonal changes in solar radiation will be studied. The consequences of alternative configuration of global observation practices on the predictability of the atmosphere will be assessed. The range of predictability of mid-latitude, large-scale storms beyond one week will be extended, and global prediction experiments to study the coupling between the hemispheric circulations and the role of the tropics will be performed. The nature and extent of the interaction between the lower and upper atmosphere will be studied as will the dynamics of meso-scale phenomena, e.g., tropical disturbances, convective elements, orographic disturbances.

High priority is being given to an expansion of the weather modification program and related research efforts in FY 1972. Specific goals will be the development and evaluation of the technology of hurricane modification, the modification of tropical cumulus clouds to control their growth and precipitation characteristics, and modification of cloud and precipitation over the Great Lakes. In addition, increased efforts will be directed toward improving NOAA's capabilities for monitoring secular changes in atmospheric constituents which may affect weather and climate. Additional information on NOAA's weather modification program is provided in the special section of this report devoted to weather modification.

Research on hurricanes and other tropical circulations, and severe local storms, such as thunderstorms, tornadoes, and associated phenomena, is conducted to acquire greater knowledge of these storms for developing techniques of detection, forecasting, and modification. In hurricane research specially instrumented research aircraft, weather satellites, and conventional surface and upper-air networks will continue to be used for obtaining data to study the structure, dynamics, and high energy processes of tropical cyclones. These data will be used also to study interactions between the tropical cyclone and its environment and to determine what factors are involved in hurricane formation, intensification, dissipation and movement. Studies of tropical cyclone genesis and maintenance will be accelerated through development of improved dynamical-numerical models of tropical circulations and hurricanes.

The physical and dynamic processes of severe local storms will be examined with enhanced field measurements and numerical models. Coordinated observations of the three-dimensional structure of thunderstorms and other severe local storm phenomena will be continued, utilizing specially designed networks of surface, upper-air and airborne meteorological instruments. Digital data from conventional and doppler weather radars and from an instrumented tower supplement these networks. The extremely complicated processes of condensation and precipitation and their interaction with the horizontal and vertical wind fields in tornadoes and severe storms will be treated in physical-mathematical models now under development. Experimental simulation of the vortices associated with vertical motion in storms will be complemented by theoretical studies and doppler radar measurements of actual wind fields. Research on the applications of measurements of electromagnetic emissions to severe storm detection and analysis, and the use of multi-station doppler radar for remote detection of the three-dimensional wind field will be continued and expanded.

Integrated field experiments employing a number of newly developed remote sensing techniques will receive increasing attention during FY 1972. The International Field Year of the Great Lakes (IFYGL) will provide an excellent opportunity to intercompare atmospheric data taken by various remote sensing and standard in situ techniques. Four new radar-type probing systems (microwave Doppler radar, FM-CW radar, optical radar and acoustic echo-sounder) will be tested and evaluated, in preparation for mesoscale research programs and GATE. Considerable new insight into the fine-scale structure and processes of the lower atmosphere is expected to result from these first attempts to use several different remote sensing techniques simultaneously in a carefully coordinated series of observations. The composite system will provide totally new capabilities for the remote measurement of vertical profiles of wind, turbulence and humidity, and for monitoring the internal structure of the boundary layer, using the naturally occurring temperature and humidity fluctuations as atmospheric tracers. In addition to the field programs, new theoretical and experimental studies will be undertaken to develop fuller understanding of the basic interactions of electromagnetic waves at all frequencies and of acoustic waves with the atmosphere.

In 1967 the U. S. Army Corps of Engineers was designated as the United States lead agency in the research program, the International Field Year on the Great Lakes (IFYGL) with responsibilities for cooperating with other agencies in meeting the objectives of the program, providing technical leadership and coordination with cooperating agencies, and managing the funds for planning, equipping, and conducting the U. S. portion of the program, including the analyses and preparation of results. The lead agency responsibilities were assumed by NOAA concurrent with the recent transfer of the Lake Survey to NOAA from the Corps of Engineers. The IFYGL which is a joint Canadian-U.S. program for increasing our understanding of the water problems of Lake Ontario and its basin, includes atmospheric studies involving lake meteorology and the energy balance between the lake and the atmosphere. A period of intensive data collection is scheduled to take place between January 1 and December 31, 1972, with data processing, analysis and research being undertaken as the data are obtained.

In the environmental satellite program emphasis will continue on deriving and using quantitative information from data obtained by satellites. Operational procedures for deriving winds from time-lapse cloud motion observations will be further developed and tested in preparation for the Geostationary Operational Environmental Satellite (GOES) system to be established late in FY 1972. Continued study and evaluation of methods for incorporating satellite sounding data in numerical weather prediction will receive high priority. Development of improved sounders is continuing, with introduced of an advanced sounder into the operational satellite system planned for 1975. Techniques to apply observations from the scanning radiometer to environmental services, including mapping of cloud tops and sea surface temperature, are being steadily refined. New projects to be undertaken in 1972 will emphasize the application of satellite technology to improved services and support of marine, hydrology and space distrubances programs. An increased effort is planned for 1972 in the development of satellite sensors needed to support geophysical monitoring for climate change, and sensors to obtain measurements required in the marine environmental prediction programs.

NOAA conducts a program in systems design and development aimed at improving its weather services. Included are the development of plans for specialized weather services and the design of the various subsystems to support these services. The program is also concerned with the improvement of forecasting techniques and the analysis and optimization of meteorological networks. An equipment development program includes the development of many specialized sensors. Testing and evaluation is a continuing effort on such devices as radar ancillary equipment, upper-air instrumentation, automatic weather stations, and other observing equipment. Emphasis is planned in FY 1972 on the following areas: development of automated equipment systems to improve the effectiveness of National Weather Service field station operations; development of operational prototypes of land-based, next generation upper-air systems; development of automatic weather stations with emphasis on simple, rugged equipment for use in remote geographic areas, field experimentation on the digitization of radar data; and the design and development of a data handling and display system for the National Hurricane Center.

The hydrologic research program is primarily directed toward the improvement of river forecasting, including development of data acquisition systems. The evaluation of the use of real time quantitative precipitation estimates from radar observations in operational hydrologic forecasting will continue in FY 1972. Current data acquisition studies of the use of a passive airborne gamma radiation system to measure the water equivalent of snowpack, improvement of techniques for gage measurement of solid and liquid precipitation, and the development of improved methods for computing evaporation, including an evaluation of the X-3 experimental insulated pan, will also continue in FY 1972.

Research and development at the National Meteorological Center are primarily directed toward improving the short, extended and long-range forecast products. The two main activities concern numerical weather prediction (NWP), which is a deterministic approach through physical realism of mathematical models, and long-range prediction, which is a systematic application of physical and statistical methods and models. The emphasis in NWP will be placed on objective analysis and numerical modeling for global forecasts, fine meshed grid models for limited area short-range forecasts, spectral model techniques. and improvements in the simulation of the important physical effects. Improvements will also be sought in methods of producing five-day forecasts of the day-by-day weather. Attempts to develop methods of long-range prediction will emphasize objective-numerical forecasts of the state of the ocean and its interaction with the atmosphere.

The Climatological Research Program in FY 1972 will continue the development of an Environmental Data Index (ENDEX) to facilitate ready access to available climatic and other data. Long-term changes in national and world climate will continue under study, using any newly acquired measurements from global benchmark stations. Satellite-based weather observations will be related to ground truth data in an effort to optimize eventual applications of earth resources satellite information. Types of weather data needed to aid food production, control natural pests and conserve environmental resources will be determined and uses of these data will be studied. Engineering applications of weather data will be extended to further define effects of wind, radiation, humidity and heat on structures and industrial processes.

NOAA conducts a research program in aeronomy to increase the understanding of the solar-terrestrial environment, and to develop techniques for the forecasting of solar disturbances and their subsequent effects on the earth environment. This research includes theoretical and analytic studies, laboratory experiments, and field observations utilizing satellite, rocket and ground station platforms.

In FY 1972 aurora and airglow observations will be made with an auroral radar in Alaska and a resonant locked dye laser tuned to the emitting frequency of atmospheric sodium. Auroral rockets will be flown in conjunction with the radar observations. Obervational techniques having greater speed and resolution will be applied to studies of stable red arcs and of sodium day glow and twilight glow.

Investigations into ionospheric physics will use new approaches and exploit recent significant results. The recently developed non-linear theoretical analysis of the structure of plasma turbulence, which has successfully explained the observed characteristics of various ionospheric irregularities, will be applied to non-linear problems in neutral turbulence and to shock processes in interplanetary space and in the solar atmosphere. Equipment has been contructed which is capable of producing modeled ionospheric irregularities in the laboratory. The growth and decay of these irregularities will be studied by diagnostic equipment. The heating of the ionosphere by a powerful radar, such as the one recently constructed in Platteville, Colorado, will be modeled in the laboratory so the observed ionospheric reactions to the heating can be more easily interpreted. A theoretical study will be initiated to understand the behavior of plasma sheaths around probes in the transition region of the atmosphere near 80 kilometers where molecular collisions begin to assume importance.

A portable station has been developed which will measure the Doppler spectra of ionospheric irregularities which have been illuminated by powerful radars. This equipment will be used both at Jicamarca, Peru, and in the Arctic regions to more fully define the extent and variation of the equatorial and auroral electrojets. The study of ionospheric and magnetic storms will be increased to anticipate better the occurrence and severity of the disturbances of the ionosphere. Studies will be made of the nature of ionospheric disturbances created by solar X-rays. This research will be directly supported by solar X-ray measurements from the GOES satellite beginning in 1973.

The measurement in the laboratory of rate constants for important ionospheric reactions will continue and be extended to reactions important in the atmosphere of other planets. A large volume of data from rockets launched during Polar Cap Absorption (PCA) events will be integrated into a D-region model of these events. One facet of the coupling between the upper and lower atmosphere will be analyzed by an investigation of the influence of water vapor on the ionosphere. The very recent first successful rocket measurement of the height profile of atomic oxygen in the mesosphere will be followed by a number of further rocket measurements to understand the variations of atomic oxygen with season, latitude, altitude and time.

In geomagnetism a study will be initiated of the atmospheric current systems resulting from tidal effects on the atmosphere in the presence of the geomagnetic field. Using a year of ATS-1 magnetometer data, an investigation will be made of the association between the magnetic field at satellite altitudes and observed surface magnetic anomalies, in preparation for the analysis of magnetometer data to be received from the GOES satellite in 1973.

Expanding on a recent discovery, the relationship of the magnetic characteristics of active solar regions and flare activity will be explored in detail, using optical observations of solar magnetic fields, and radio observations with a three-centimeter polarimeter. These relationships show promise for much greater accuracies in predicting the time and location of major solar flares. The observational studies will be complemented by the development of theoretical magnetohydrodynamic models of solar active regions.

Theoretical and experimental studies will continue concerning the transport of energy released by the sun, and propagated through the interplanetary medium to the vicinity of the earth. Theoretical models of energy transport will be tested with data obtained from experiments on board various NASA and NOAA spacecraft. Experimental data from the satellites will be used to compare with theoretical models of interplanetary shock waves. These models will be extended to include the region between the shock wave and the sun. The interaction of the solar wind and shock waves with the moon and with comets will also be investigated. Earlier work on ground observed radio source scintillation, due to electron density irregularities in the solar wind, will be extended to investigate solar flare effects and from this to estimations of the expected duration of subsequent magnetic storms. These studies will be complemented by the development of general stellar wind models and models of the enhanced mass loss from binary star systems.

Data from ITOS and other NOAA spacecraft and rocket experiments will be used to study the transfer of energy from the interplanetary medium into the magnetosphere, its subsequent transfer throughout the magnetosphere, and on into the upper atmosphere. The emphasis will be on the analysis of the time variation of the trapped particle boundary, proton events, and the comparison of the data with ionospheric models. Electron, proton, and alpha particle intensities and spectra will be directly available throughout the magnetosphere and near-earth interplanetary regions for these investigations.

Instrumentation development will begin on the design of ground equipment for recording Faraday rotation and differential phase in readiness for the launching of radio beacons on board the ATS-F satellite. The thin film technique for detection of atomic oxygen will be applied to the measurement of the water vapor profile in the mesosphere.

DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Meteorology			
Physical Meteorology	1,244	1,545	1,506
Dynamic Meteorology	3,828	5,492	8,923
Observation	3,093	3,294	3,817
Description	2,157	2,798	2,406
Prediction	1,840	2,264	2,129
Modification	1,701	2,064	4,450
Dissemination	107	107	214
Systems	651	1,333	2,167
Support	-	220	220
Total	14,621	19,117	25,832
Aeronomy			
Aurora and Airglow	246	239	239
Ionospheric Physics	929	886	886
Atmospheric Chemistry	294	324	324
Atmospheric Structure	-	21	21
Energetic Particles	236	43	43
Atmospheric Geomagnetism	182	136	136
Solar Terrestrial Studies	402	353	353
Instrumentation, General	86	135	135
Instrumentation, Rockets	29	69	69
Instrumentation, Satellites	106	110	110
Support	354	279	279
Total	2,864	2,595	2,595
PROGRAM TOTAL	17,485	21,712	28,427

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House	15,120	19,420	24,927
Industry (Profit)	800	826	1,344
Universities and Colleges	1,327	1,187	1,671
Other (Non-profit or not for-profit organizations)	238	279	485

DEPARTMENT OF COMMERCE
Office of Telecommunications
Institute for Telecommunication Sciences

For more than two decades the Institute for Telecommunication Sciences of the Office of Telecommunications, or its predecessors, has fulfilled a central Federal need in telecommunications by providing research and services to describe and predict electromagnetic wave transmissions in the atmosphere, over the surface of the earth, and in space. The Institute's atmospheric sciences program includes studies in physical meteorology relative to wave propagation in the higher electromagnetic frequencies including infrared and optical frequencies. These studies are aimed at extending the utility of the electromagnetic spectrum for telecommunication purposes. Studies in aeronomy are undertaken principally in ionospheric physics. Emphasis is placed on increasing knowledge of propagation characteristics in the frequency range below 2 MHz up to 50 MHz.

During FY 1972 increased emphasis will be placed on EM wave propagation at millimeter and optical frequencies. For example, precise measurements of the absolute intensity distribution of the 60 GHz oxygen line complex will be made. Dispersion at several frequencies will be studied to measure integrated atmospheric water vapor.

In ionospheric physics, studies continue in the production and observation of ionospheric modification using the high power transmitter located near Platteville, Colorado. The studies are leading to important new understandings of ionization processes in the upper atmosphere and of ionospheric disturbances affecting telecommunications. Backscatter studies using this transmitter are planned to determine the influence of Sporadic-E on long distance propagation.

Studies will continue at frequencies below about 2 MHz where emphasis is placed on determining D-region electron density profiles by means of experimental partial reflections, cross modulation, and LF pulse soundings. This work will contribute, for example, to advanced radio navigation for maritime and aeronautical uses.

ALLOCATION OF FUNDING

	FY 1970	FY 1971	FY 1972
Meteorology			
Physical Meteorology	106	240	280
Aeronomy			
Ionospheric Physics	534	430	420
TOTAL	640	670	700

Note: All funds are In-House.

Atmospheric processes have a significant impact on Army operations. Inadequate knowledge in small-scale meteorology, atmospheric modification, meteorology and climatology of extreme regions, physics and chemistry of the atmosphere, dynamic processes of the atmosphere, atmospheric sensing and probing techniques, and the ionosphere, confronts the Army with many critical operational problems. The atmospheric sciences program of the Army is oriented toward solving these problems. The following general areas are emphasized: Lower Atmospheric Research, Upper Atmospheric Research, Remote Atmospheric Sensing, Atmospheric Modification, Exploratory and Engineering Development and Meteorological Support Activities.

Lower Atmospheric Research: Investigations are conducted to determine the specific effects of meteorological conditions, especially as influenced and modified by terrain, on the processes of atmospheric transport, diffusion and trajectory of aerosols and particulates. Theoretical and experimental studies of micro- and mesoscale systems will continue. Numerical models to describe atmospheric motion over various terrain will be developed and tested. This research provides information required for the solution of problems involving the atmospheric effects on the tactical deployment of weapons, material, target acquisition, detection, and tracking systems. Data and information obtained are being used in connection with the Army's planned demilitarization and detoxification program (destruction of CB munitions) and have direct application to problems associated with air pollution abatement.

Upper Atmospheric Research: Research in this area is intended to acquire new knowledge of the properties and dynamic processes of the atmosphere that affect the propagation of electromagnetic energy and the design and operation of missiles and rockets. Major efforts include development of special instruments for conducting high-altitude observations. These instruments are used to make in-situ measurements in the ionosphere, especially in and above the D-region to determine total electron content, electron density and the earth's magnetic field. Studies continue in investigating methods of measuring the electrical and chemical properties of the ionosphere, measuring ionospheric reaction rate constants in laboratory experiments and incorporating reactions into computer codes to produce models of the ionosphere. The ultimate goal of this research is to provide a better prediction of the duration of electromagnetic blackout in the upper atmosphere following a natural or man-made distrubance. Research also is being conducted to establish a climatology of high altitude regions, especially wind and density profiles.

Remote Atmospheric Sensing: This research seeks new knowledge and advanced methods for use in the development of improved sensors and probing devices to obtain observations of importance to Army operations. Experiments on cross-beam wind finding techniques will be carried out and the effects of high powered lasers on a turbulent medium will be determined. Studies of atmospheric transmissivity in controlled atmospheres will be performed at laser wavelengths with

the introduction of trace constituents. Studies will continue using the experimental 80 km laser propagation path at 1.2 km above the surface established during 1970. Investigations will continue on the use of lidar to determine the occurrence, distribution, size, and composition of atmospheric particulates.

Atmospheric Modification: Studies will continue to acquire a better understanding of the physical processes of the atmosphere which cause the formation, growth and dissipation of clouds, fog, and rain. In addition, investigations of atmospheric electrical structure near cumulus clouds and related modification possibilities will continue using specialized equipment installed in 1970. The first phase of data acquisition shows evidence of higher than expected charging currents during thunderstorm activity. Physical models of these atmospheric phenomena will be derived and verified experimentally. Development of numerical models describing the life cycle of natural radiation fog and describing various methods of modification of radiation and advective fog will be initiated. Research will continue to determine the population of artificial nuclei in a warm fog and to determine the growth behaviors and crystallization of selected condensation nuclei in an atmospheric control chamber. Field studies will concentrate on the modification of warm fog and will be conducted jointly with the Navy, Air Force and NOAA. The Army will continue to participate in the National Hail Research Experiment.

Exploratory and Engineering Development: This program is designed to provide techniques and equipment essential to meteorological support of combat operations, real time missile impact predictions and other Army activities. Effort will continue on the design and development of the rocket components to fulfill the Army's requirements for obtaining atmospheric meteorological data up to 30 km. The final component development of the Meteorological RDT&E Rocket will be completed and rocket subsystem flight tests will be conducted to evaluate performance against requirements. Development of this rocket, intended to obtain data up to 70 km, is jointly shared by the US (Army and NASA) and Canada.

Development of new and improved techniques and equipment for application to existing Army problems will be pursued. These include determination of improved ballistic meteorological data, studies of wind flow in and over forest areas for application to personnel detection problems, investigation of tropical raindrop size distributions and liquid water content; development of a portable weather radar for field wind measurements; initiation of tests on a new portable automatic weather observing station (PAWOS); evaluation of a new technique for fabricating streamline meteorological balloons and develop new balloon coatings to improve ascent rates. Studies of wind conditions in mountainous terrain will be initiated and a study of a laser ceilometer will be completed.

Meteorological Support Activities: This program provides meteorological support to Army RDT&E activities and other organizations and to users of the White Sands Missile Range. Detailed meteorological data are obtained from the surface to 300,000 feet using standard and special purpose meteorological instrumentation. To illustrate the extent of this program, in 1970 meteorological support was provided for 607 programs of 69 Army RDT&E activities at nine permanent sites

and for 26 programs at temporary sites. Meteorological support was provided for 120 RDT&E programs at White Sands Missile Range (Army, Navy, Air Force and NASA) involving approximately 4,500 range missions. This program includes the Army's participation in the Cooperative Meteorological Rocket Network. Support also is provided to the Army's demilitarization and detoxification activities as well as to the National Hail Research Experiment and to the International Field Year of the Great Lakes.

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Meteorology			
Physical Meteorology	100	100	200
Dynamic Meteorology	815	772	886
Observation	3,284	2,553	2,641
Description	1,355	1,411	1,291
Prediction	498	520	502
Modification	793	650	700
Dissemination	222	223	522
Systems	360	350	556
Meteorological Team Support	4,271	4,000	3,900
Total	11,698	10,579	11,198
Aeronomy			
Ionospheric Physics	282	405	312
Atmospheric Structure	261	340	355
Instrumentation, Rockets	870	500	375
Total	1,413	1,245	1,042
PROGRAM TOTAL	13,111	11,824	12,240

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House	11,209	10,164	10,317
Industry (Profit)	1,359	1,145	1,178
University	323	281	579
Other	220	234	166

DEPARTMENT OF DEFENSE
Navy

The Navy atmospheric sciences research program continues to diminish as a result of general Navy Research and Development budget reductions. No new areas of study have been initiated or are planned but changes in research emphasis and funding have occurred in response to Navy requirements.

Physical meteorology efforts will be in the general areas of cloud physics, atmospheric optics and atmospheric electricity. Basic studies in cloud physics will continue on the nucleation processes, source characteristics of cloud condensation nuclei and droplet growth, with particular emphasis on maritime type phenomena such as trade wind cumulus clouds and marine fog.

Investigations in atmospheric optics are directed toward determination of optical transmissions in a marine atmosphere as affected by wave length, over water path, transmitter and receiver parameters and meteorological conditions.

Atmospheric electricity studies will include comprehensive investigations of the thunderstorm environment. Relationships between spherics emissions from clouds and precipitation occurrences and between lightning emission mechanisms and cloud thermodynamics will be investigated. Detailed work will be conducted on the physics of lightning and the discharge and breakdown process. In addition to thunderstorm investigations fair weather electrical field and current measurements will be made to study the charge transfer mechanisms in the atmosphere and to correlate these with other atmospheric phenomena.

The program for developing improved sensors and associated telemetry systems for atmospheric and oceanic variables will continue. It is planned to continue development of equipment, including deficiency correction and on-going testing, of humidity measuring devices, back-scatter visibility instruments, solid-state sensors for buoys, automatic weather station sensors capable of tolerating low temperatures, sub-surface transducers, and instruments that will reliably measure the ozone and water-vapor content in the stratosphere.

Efforts in the area of analysis and prediction are directed toward the development of new and improved techniques for predicting meteorological parameters and those oceanographic parameters which directly affect the lower atmosphere. These investigations include extraction of useful information from satellite data for input into numerical and conventional forecasting methods, improvement of numerical prediction techniques through incorporation of these and other previously excluded observational data, continued efforts to interpret meteorological predictions in terms of effect on naval operations, and the relationship of stratospheric anomalies to the troposphere.

Warm fog and tropical storms continue to be the primary targets of the Navy's weather modification research effort. Emphasis will continue on

laboratory and field tests of nucleating materials, and methods of dispersal. Computer models of fog and convective processes will be updated and improved through the incorporation of laboratory and field experimental data, and new empirical and theoretical results. Development efforts will continue on instruments and methods for studying natural cloud processes and for evaluating experiments.

Two major projects continue which involve solar reaction. The first involves investigations of solar emissions in the extreme ultraviolet portion of the spectrum. One goal of this project is to resolve the source in time and space of solar emissions with sufficient accuracy to be able to correlate highly specific solar events with reactions in the ionoshpere and the earth's atmosphere. The second project is directed toward determining how the ionosphere is created, maintained and neutralized.

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Meteorology			
Physical Meteorology	856	992	900
Observation	570	585	625
Description	-	450	450
Prediction	865	300	300
Modification	850	585	615
Total	3,141	2,912	2,890
Aeronomy			
Atmospheric Structure	50	179	150
Solar Terrestrial	737	619	650
Total	787	798	800
PROGRAM TOTAL	3,928	3,710	3,690

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House	3,249	2,799	2,857
Industry (Profit)	328	276	253
University	351	635	580

DEPARTMENT OF DEFENSE
Air Force

The Air Force program in atmospheric sciences explores those areas which are of direct interest to military operations and planning. Funding levels for FY 72 are essentially the same as for FY 71 with the exception of some additional funds for hardware development programs.

Meteorology

The primary of objective in these areas of effort is to gain sufficient understanding of atmospheric processes to assist with Air Force operations, through more effective observing, forecasting, or modification. Emphasis will be placed upon the operation and data gathering from the mesoscale observing network constructed in the Bedford, Massachusetts area. The objective of this net and its associated research is to derive quanitatively better forecast procedures for short period terminal forecasting. Tropical meteorology will continue to receive attention with emphasis on Southeast Asia forecasting techniques. Projects involved with the radar detection of CAT and severe storms phenomena will continue on a joint basis with NASA and independently. General meteorological instrumentation development will continue, and two types of laser CAT detectors will be tested on board aircraft. Final testing of an expendable automatic weather station will be started with drop tests from aircraft and subsequent 7-10 day remote operation. Results of the warm fog modification experiments conducted in California during January 1971 will be evaluated with an eye toward a larger, joint test to be conducted the following year. This test would evaluate promising warm fog modification techniques identified during 1971 as well as several new approaches toward the problem of dispersing this operationally restrictive condition.

Two significant hardware programs are being undertaken. The first, the Airborne Weather Reconnaissance Program (AWRS), will develop a sensor and data handling system for the Air Weather Service's WC-130 aircraft fleet. The development has been approached from a system standpoint to provide a highly accurate data sampling and processing equipment which will fulfill the requirements for worldwide synoptic and hurricane-typhoon data. Prototype completion is scheduled for June 1972 with production units following. The other program, The Expendable Remote Operating Weather Station, is significant since this has the potential for use by several agencies. The Station will be capable of being dropped from an aircraft and, in an automatic mode, will respond to interrogation each hour for over 10 days. Parameters to be measured will be temperature, pressure, humidity, wind speed and direction, rainfall rate and amount and cloud cover. If retrieved, the units will be reusable. Development is scheduled for completion late in CY 72.

Aeronomy

The thrust of Air Force efforts in aeronomy is to understand ionospheric and space environments, their interactions and effects upon Air Force systems

and operations. Of continuing interest is a definition of the effects of solar radiation upon the ionosphere including its density, ion and neutral composition and the physical and chemical characteristics of the dynamics of the disturbed and normal ionosphere. Studies of the density and density changes in the 90-300 km range will continue with the launch of the CANNONBALL II satellite. This satellite will determine density effects on its orbit and thereby density variations over its 50-day life. A variety of tasks will be accomplished to support forecasting of ionospheric and polar cap changes and subsequent effects on Air Force communications. These will include direct probing of the polar ionosphere by means of sounding rockets to measure parameters associated with the disturbed D region and Sudden Ionospheric Disturbances. Probe rockets will be used to continue studies of background and target radiation using a variety of backgrounds, targets and frequencies. The Sacramento Peak Observatory will continue optical coverage of the sun to support solar forecasts as well as continuing research into solar flares, their parameters and precursors.

Allocation of Funding

	FY 1970	FY 1971	FY 1970
Meteorology			
Physical Meteorology	1,078	1,030	991
Dynamic Meteorology	299	331	356
Observation	1,063	655	525
Prediction	727	455	395
Modification	205	250	200
Systems	1,136	2,390	6,015
Support	2,808	3,309	4,154
Total	7,316	8,420	12,636
Aeronomy			
Aurora and Airglow	151	125	100
Ionospheric Physics	1,106	1,120	1,046
Atmospheric Chemistry	846	830	924
Atmospheric Structure	2,416	2,280	2,389
Energetic Particles	916	881	974
Atmospheric Geomagnetism	1,165	703	724
Solar Terrestrial	415	400	350
Dynamic Aeronomy	3,721	2,438	2,882
Support	6,640	6,620	5,550
Total	17,376	15,397	14,939
PROGRAM TOTAL	24,692	23,817	27,575

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House	14,820	13,560	13,600
Industry (Profit)	3,460	4,478	8,080
University	5,690	5,225	5,245
Other	722	554	650

DEPARTMENT OF DEFENSE
Advanced Research Projects Agency (ARPA)

The broad objectives of the ARPA atmospheric research program are being pursued under three major program divisions: Nuclear Monitoring Research, Strategic Technology and Distributed Information Systems.

Nuclear Monitoring Research seeks to improve, through research and development, the U. S. capability to detect underground, atmospheric and space tests of nuclear weapons.

Strategic Technology research seeks to develop a background of scientific and technical knowledge and techniques for the improvement of strategic systems, both offensive and defensive; to investigate the effects of nuclear perturbations of the atmosphere on strategic systems, both offensive and defensive.

Under Distributed Information Systems a global atmospheric climatic modelling program has been initiated organizing computer resources to interconnect researchers and large computer facilities. Numerical experiments will be developed and supported to examine the large scale effects of perturbations on climatic trends. The stability of long term climatic modelling will be investigated. Air-sea interaction and energy balance investigations will be pursued to improve the global atmospheric model for long term stability.

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Meteorology			
Description	2,000	1,300	2,600
Support	-	300	400
Total	2,000	1,600	3,000
Aeronomy			
Aurora and Airglow	750	880	900
Ionospheric Physics	1,363	2,150	2,100
Atmospheric Chemistry	4,310	1,890	1,750
Atmospheric Structure	1,780	815	660
Atmospheric Geomagnetism	-	-	200
Energetic Particles	50	-	100
Instrumentation, Rockets	280	160	160
Instrumentation, Satellites	150	450	-
Total	8,683	6,345	5,870
PROGRAM TOTAL	10,683	7,945	8,870

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House (Including Other Agencies)	1,689	1,345	1,240
Industry (Profit)	7,869	4,385	5,380
University	1,125	2,215	2,250

DEPARTMENT OF DEFENSE

Defense Atomic Support Agency (DASA)

DASA's research effort in the atmospheric sciences area will continue to be directed toward understanding the behavior of the upper atmosphere under the influence of ionizing radiation resulting from high altitude nuclear detonations. The program will consist primarily of laboratory, rocket borne and field measurements during naturally disturbed conditions such as aurora and polar cap events.

Most of this activity continues to be conducted through the Air Force Cambridge Research Laboratories and the U. S. Army Ballistic Laboratories.

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Aeronomy			
Aurora and Airglow	800	300	100
Atmospheric Chemistry	900	900	1,050
Atmospheric Structure	400	300	-
Energetic Particles	200	-	-
Instr., Rockets	630	-	-
TOTAL	2,930	1,500	1,150

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House (Including Other Agencies)	2,580	1,290	900
Industry (Profit)	350	210	250

ENVIRONMENTAL PROTECTION AGENCY
Air Pollution Control Office

The Environmental Protection Agency's research efforts in the atmospheric sciences are directed to an assessment of meteorological factors of importance to the solution of air pollution problems. Through a research program conducted and supported by the Air Pollution Control Office, both theoretical and experimental studies are carried out to improve the understanding of chemical-physical processes affecting the transport, diffusion, and ultimate disposition of air pollutants from the atmosphere.

Research areas that are being emphasized include studies of the planetary boundary layer, with efforts to describe and improve techniques to forecast and determine air pollution potential, mixing depth, vertical profiles of wind and temperature, and the spatial and temporal distribution of meteorological and geophysical parameters in urban areas. In the Los Angeles Basin an in situ study, including meteorological observations, has been undertaken to determine the photochemistry and kinetics involved in atmospheric reactions. The results will be integrated into atmospheric diffusion models to permit estimation of photochemical air pollution concentrations. Other attempts to imporve urban diffusion models include sensitivity analysis studies, adaptation of boundary layer models, and efforts to develop second generation diffusion models that take into account non-steady state conditions and reactive pollutants.

In the area of developing indirect (remote) sensing techniques for measuring meteorological parameters in urban areas, the following studies are planned: the demonstrated use of lidar (laser-radar) for measuring mixing depth; the development of acoustical radar and cross-beam techniques for wind and turbulence profile measurements; and the completion of performance testing of a millimeter radiometer used to obtain vertical temperature profiles. A fouth year of field studies, to evaluate the rise, transport, dispersion, and precipitation washout of plumes originating from tall stacks at large power generation facilities will be carried out in western Pennsylvania.

The long term geophysical effects of air pollution are being studied. Measurements of atmospheric turbidity are being made in this country and in selected parts of the world to assess the possible impact of suspended particulates on global air quality; the feasibility of using satellites as platforms for monitoring global air pollution is being investigated. A critical review of the long term geophysical effects of global air pollution is in progress.

ENVIRONMENTAL PROTECTION AGENCY
Air Pollution Control Office

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Meteorology			
Physical Meteorology	4,800	5,339	5,400
Observation	640	540	787
Description	1,030	2,028	2,088
Prediction	90	50	50
TOTAL	6,560	7,957	8,325

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House (Including Other Agencies)	2,300	2,705	2,907
Industry (Profit)	3,280	4,140	4,340
University	980	1,112	1,078

DEPARTMENT OF THE INTERIOR

Bureau of Reclamation

The Bureau of Reclamation, through its Division of Atmospheric Water Resources Management, will continue development and adaptation of cloud seeding technology for early use in critical water areas. The objective of the Bureau's program is to manage precipitation to increase the available water supplies to meet the Nation's growing water needs. Average increases in precipitation of 10 to 20 percent would add millions of acre-feet annually to national water resources. Preliminary planning for operational application of existing techniques on Interior water resources projects will begin in FY 1972.

Development of limited, but feasible and practical, techniques for increasing snowfall from orographic clouds is expected by about 1975 in Western areas. Augmented streamflow to Federal and non-Federal reservoirs will provide needed water for expanding cities, increased power production, better recreation opportunities, and increased agricultural production.

The proposed program in FY 1972 will continue the 3 Reclamation pilot projects and 10 experimental field projects, and will continue planning for 1 new pilot project and 2 new field experiments. Major new development efforts include establishment of an interconnected computer system between field projects for joint utilization of cloud models and data presentation programs; comprehensive statewide investigations of the potential benefits and environmental effects of cloud seeding; and weather modification legal research with emphasis on water law and river compact questions. Planning studies will begin FY 1972 for incorporating operational cloud seeding for increased water yield into Western water resource planning and existing water developments.

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Meteorology			
Weather Modification	4,765	6,500	6,700

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House	402	500	500
Industry (Profit)	904	1,450	1,450
University	2,989	3,800	3,800
Other	470	750	950

The Atomic Energy Commission atmospheric sciences research program consists of field experiments, laboratory studies, and development of theory for prediction of the local and global disposition of radioactive material introduced to the atmosphere. Because those atmospheric processes determining the transport and fate of radioactive materials affect other materials as well, the AEC program contributes a great deal of knowledge directly applicable to the national air pollution problem.

Research in physical meteorology is concerned with the origin, characteristics, and behavior of radioactive gases and particles, their interaction with each other, with precipitation, and with the surface of the earth. Specific objectives include: (a) to develop and test quantitative models for prediction of deposition through wet or dry atmospheric processes, (b) to define the properties of atmospheric aerosols adequately for the design of air sampling devices, (c) to determine the importance of the interactions between aerosols and rain and snow, to place these interactions in usable wet deposition models, (d) to measure the concentrations of radionuclides and other trace substances in airborne particles and precipitation, and (e) to provide input data needed to assess the hazards to man from radioactivity.

The objectives of the research in dynamic meteorology are (a) to investigate the driving forces and atmospheric motions which are related to transport and diffusion on scales up to and including global, and (b) to develop and test quantitative models for prediction of the motion and distribution of atmospheric contaminants. A feature which makes this program increasingly effective is the extensive development and use of natural and artificial tracers. To supplement the field studies involving the release and tracking of a tracer material, a modest but significant program exists in the use of wind tunnels to model atmospheric turbulence and diffusion. The wind tunnel is useful for extending the range of outdoor experiments and in observing under controlled, steady conditions the basic physics of air motions.

Observation of nuclear debris at high altitudes from aerospace power units and from foreign atmospheric tests is being continued with both aircraft and balloon-borne filters. The data are used to develop and test prediction models for global stratospheric transport of radioactivity and other pollutants such as introduced by aircraft. The data are routinely used to predict radioactive dose to mankind from nuclear activities.

A strong effort continues at the nuclear test sites, consisting of (a) characterization of the types and patterns of air flow over varieties of terrain and structures under various atmospheric conditions, (b) studies of the smaller scale motions which determine the changing width and concentration of material clouds at low elevations, (c) experiments and theoretical studies of the deposition of gaseous and particulate pollutants onto water, ground, and vegetation surfaces,

(d) theoretical studies of the gamma energy doses received at the ground from hypothetical radioactive clouds passing overhead, and (e) placing all of this knowledge into use on an operational prediction basis.

The AEC also supports a program in aeronomy in order (a) to gain information applicable to observing and understanding the effects of nuclear explosions in and above the atmosphere, and (b) to study high energy cosmic radiation propagation for application to accelerator and space shielding.

In jointly funded projects with the Environmental Protection Agency, AEC laboratories are studying the transport, dispersion and modification and removal of sulfur dioxide in urban atmospheres.

Portions of the AEC atmospheric sciences program have shifted attention from processes in environments typical of low populations to those of urban and city environments, and to research in the "meso" or intermediate scales. This is in response both to future radioactive potential source locations, and to national needs in the air pollution problem.

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Meteorology			
Physical Meteorology	1,692	1,724	2,008
Dynamic Meteorology	2,637	2,434	2,358
Observation	1,536	1,501	1,510
Description	433	348	302
Prediction	108	87	76
Total	6,406	6,094	6,254
Aeronomy			
Aurora and Airglow	285	321	316
Ionospheric Physics	90	90	80
Atmospheric Chemistry	322	60	87
Atmospheric Structure	142	141	215
Energetic Particles	215	155	150
Atmospheric Geomagnetism	1,187	1,160	1,045
Solar Terrestrial	150	150	134
Instrumentation, Rockets	97	228	264
Total	2,488	2,305	2,291
PROGRAM TOTAL	8,894	8,399	8,545

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House (Govt. Labs)	2,197	2,425	2,579
Industry (Profit)	250	99	106
University	903	815	881
Other (AEC Contractor Labs)	5,544	5,060	4,979

DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration

The FAA Aviation Weather Program is designed to provide the technical and operational developments required to improve the performance and utilization of existing components of weather acquisition, transfer, processing, and display equipment to relieve immediate problems and to modify specific components for integration into the modernized configuration of the National Airspace System.

This program is expected to:

(1) Provide more extensive, accurate, and timely weather observation and forecast information to the aviation community to ensure safety and efficiency in the use of the airspace.

(2) Achieve optimum use of new and existing kinds of aviation weather services by more effectively informing pilots and traffic controller personnel about the availability of such services.

(3) Continue research and development, in cooperation with other Government agencies and industry, to achieve operational weather modification systems for cold and warm fog dispersal in terminal areas, and to evaluate their environmental/ecological effects.

(4) Continue development of improved hazardous weather and turbulence detection techniques utilizing Doppler radar and other detection devices.

(5) Conduct research to evaluate techniques and equipment for detecting and predicting clear air turbulence.

(6) Formulate a research program to determine inadvertent weather modification caused by SST exhaust particulates, contrails and photochemical reactions in the stratosphere and their effect on atmospheric heat balance and climate.

(7) Continue development of automated methods for producing aviation terminal forecasts with greater accuracy, timeliness, and reliability.

(8) Continue development of techniques for production of automated forecasts of meteorological elements for flight levels between 40,000 feet and 100,000 feet.

(9) Investigate possible methods of improving mass pilot briefings at Flight Service Stations and investigate the feasibility of using automatic data processing methods to prepare flight profiles for use in briefing pilots.

(10) Investigate the feasibility of producing forecasts of clear air turbulence probability out to twelve hours in advance as a by-product of the automated upper wind and temperature forecasts currently being produced by the National Meteorological Center (NMC).

(11) Incorporating within the FAA air navigation and communications subsystem new methods and equipment including use of miscellaneous facility developments for weather transmission and display devices.

(12) Conduct research on aircraft wake turbulence and develop techniques and systems to sense and suppress its effect on other aircraft.

The FAA Aviation Weather Program is planned to provide pilots and air traffice controllers the best service possible within the state-of-the-art through in-service improvements, system modernization, and research and development in anticipation of future aviation weather requirements to increase the airport and airway system capacity.

To realize the maximum return for effort expended, and in order to assure a coordinated integrated National Weather System, this Department is closely associated with, and time-phased to, other agencies' weather research programs.

Major increased efforts are underway or planned in the observation and dissemination of significant aviation meteorological parameters. These include: An increase in the research program for improvement in ceiling and visibility systems in order to present runway visual range (RVR), taxiway visual range (TVR), slant visual range (SVR), and ceiling height representative of existing airport conditions to air traffic controllers and pilots. A more accurate system for measuring shorter distances than our present RVR will be sought for particular application to Category II and Category III visibility conditions. Low cost weather data acquisition and display systems will be developed for terminals to provide air traffic controllers with current terminal aviation weather in digital form. Additionally, techniques to display hazardous flight weather on ATC radars will be developed in order to permit air traffic controllers to display contoured severe weather outlines on their radar scopes without compromising the aircraft target detection capability of their equipment. The development of techniques for handling the wake turbulence problem will get special emphasis.

In the weather modification area an effective program has been initiated and will be accelerated to develop warm and cold fog dispersal systems which are operationally efficient, meet aviation requirements, and are economically feasible.

In the Systems category increased funding will provide for:

(1) Analysis, sensing and suppression of aircraft wake turbulence through development of simulation environments, sensing devices

and airport physical modification to provide for detection, avoidance and/or suppression of hazardous wake vortices.

(2) Delineation of areas of aviation hazardous weather (turbulence, rain, snow, hail, icing conditions, etc.). Minimization of these adverse weather and environmental effects will improve air traffic flow management.

(3) Improvement in the Flight Service Station System to provide standards for better physical facilities and communications equipments for improved technical interface with the National Airspace System.

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Meteorology			
Observation	135	973	779
Prediction	286	47	255
Modification	-	606	1,770
Dissemination	85	57	542
Systems	490	526	1,654
Support	359	436	109
TOTAL	1,355	2,645	5,109

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House	555	955	1,214
Industry (Profit)	800	1,690	3,895

NASA conducts a broad program in the atmospheric sciences in support of space exploration. The work includes the analysis and interpretation of data from flight research experiments, the investigation and exploration in the laboratory of new concepts for flight experiments, the laboratory determination of physical constants necessary for interpretation of flight data, and theoretical studies explaining phenomena of planetary atmospheres.

Aeronomy

A rocket sounding program seeks to obtain measurements between maximum balloon altitudes and minimum satellite altitudes, obtain vertical profile measurements of the earth's upper atmosphere, and test instruments intended for satellite use. Rockets are launched from a number of locations in the U. S. and from sites in foreign countries to altitudes up to about one earth radius. Principal rocket types include Aerobee, Nike-Cajun, Nike-Apache, Javelin, Nike Tomahawk, Astrobee 1500, and Arcas.

The supporting research includes laboratory, field and flight experiments to explore and understand the physical and chemical processes occurring in the atmospheres of the earth and the planets. Studies and experiments are made in such areas as atmospheric dynamics, composition, photochemistry, energy sources and balance, aurora and airglow, and ionosphere properties. Models of the earth's atmosphere are developed from experimental data, and models of the atmospheres of other planets are developed for the engineering design purposes and the planning of other experiments.

The Explorer Satellite Program employs smaller satellites to carry a small group of experiments into orbits selected to meet the needs of the experiments. This type of satellite is employed in international cooperative programs. Their design is such that it enables their use by groups with limited experience and resources in space research. For these spacecraft the Scout and Delta class launch vehicles are used. Orbits can be circular or eccentric, and of a wide range of inclinations.

Planetary Atmospheres Flight Program

The 1971 mission to Mars consists of two Mariner class orbiters. The selected orbits will permit picture coverage from $+40^{\circ}$ to -50° latitude in a 90 day period. Data from the television and other experiments, including thermal mapping, and infrared and ultraviolet sounding of the atmosphere, should provide invaluable new information regarding the planet and its environment.

The Viking Program 1973 mission to Mars consists of two spacecraft to be landed on the planet supported by two planetary orbiters. The landers will determine atmospheric profiles of composition, temperature, and pressure during descent, and after landing will perform investigations of wind velocity and direction, pressure, temperature, humidity, and composition.

Three new major flight programs have been approved and are included here for the first time. The Pioneer Program will launch Pioneer F in 1972 and Pioneer G in 1973 into heliocentric orbits toward Jupiter. The objectives are to study the interplanetary medium, the nature of the asteroid belt, and Jupiter and its environment. And in 1973 Mariner J will be launched into a trajectory past Venus towards Mercury. The primary objective is the study of Mercury and its environment. Investigations of Venus will also be performed during the fly-by past the planet.

Meteorology

NASA conducts a broad program of applied research directed toward the improvement of meteorological satellite systems. This includes the development of improved, new, and advanced sensors, spacecraft components, electronic subsystems, long-life power, and control systems to provide global and quantitative measurements of atmospheric emission and transfer in various parts of the electromagnetic spectrum, of heat and momentum transfer, etc. which will permit the three dimensional description and prediction of the state of the atmosphere.

The supporting research program evaluates the latest advances in spacecraft technology and the performance of currently flown instruments and experiments for the development of advanced components for meteorological satellites, improved sensors for the acquisition of pictorial and quantitative atmospheric data, and advanced power and attitude control and stabilization systems which will be incorporated in meteorological satellite systems. The research includes the study of the effects of the atmosphere and its constituents upon the satellite measurements of emitted and reflected radiation from the earth's surface. In addition, the utilization and application of satellite meteorological data is under continual study for improving the interpretation and information content in order to extend the capability of the data and systems to meet requirements. This research draws heavily upon the results of the Nimbus, TIROS, and ITOS meteorological satellites and other research and development satellites.

The meteorological satellite research and development program, which, through flights of the TIROS and Nimbus satellites, has resulted in the flight of operational meteorological satellites for the National Oceanic and Atmospheric Administration (NOAA), continues its efforts to improve and increase the capability of the National Operational Meteorological Satellite System (NOMSS). The Improved TOS (ITOS) spacecraft series is directed toward the expansion of the operational capability of the basic TIROS Operational Satellite System for use in day-to-day, real-time weather analysis. The ITOS combines stored data and Automatic Picture Transmission (APT), both day and night, in a single, Earth-stabilized vehicle. TIROS-M, the operational prototype of this series of second generation operational satellites was launched successfully on January 23, 1970. The first three satellites in the ITOS series will carry two Advanced Vidicon Camera Systems (AVCS) for stored-data readout, two APT cameras for real-time readout, and a flat-plate radiometer similar to instrumentation of the TOS satellites. In addition, each will carry redundant two-channel scanning radiometers having one channel in the visible region and one in the thermal infrared band, and a solar proton monitor.

On the following four ITOS series spacecraft, redundant Vertical Temperature Profile Radiometers (VTPR) and Very High Resolution Radiometers (VHRR) will be substituted for the APT and AVCS cameras of the earlier ITOS spacecraft. The next major change will be TIROS-N which will be the forerunner of the advanced operational spacecraft required to provide the advanced technology needed for the GARP and NOMSS by the mid-1970 time frame. With TIROS-N, the emphasis will shift from the imaging of cloud cover to the quantitative measurement of the vertical structure of the atmosphere which is needed for the improvements in numerical weather prediction required for GARP and NOMSS. Attainment of the numerical weather prediction system's goal of accurate weather forecasts is absolutely dependent upon the availability of quantitative atmospheric data on a global scale.

A level-of-effort research and development program will be continued in FY-1971 and FY-1972 to improve the usefulness and/or effectiveness of the TOS/ITOS series spacecraft by developing and adapting advanced systems and sensors. Efforts will be continued on the following: developments leading to improved camera systems, radiometer development for higher resolution and for night-and-day coverage, a multichannel narrow-band radiometer for sounding the atmosphere, and other improvements which evolve from our developmental experience.

Experiments leading to the achievement of obtaining meteorological data continuously from synchronous altitude are being conducted with Applications Technology Satellites I and III. They include spin-scan cameras which provide daylight cloud cover of essentially the full disc of the Earth, weather data relay experiments (WEFAX) for rapid dissemination of weather data, and a data collection system (OPLE) for obtaining quantitative meteorological data from platforms immersed in the atmosphere. NASA is also programming funds for FY 1972 to include development for prototype operational synchronous meteorological satellite (SMS) spacecraft, the predecessor of the NOAA Geostationary Operational Environmental Satellite (GOES).

The Nimbus program continues to provide an earth observations observatory satellite. The program's purpose is to develop and flight test sensors and technology to obtain global quantitative measurements of the atmospheric structure and extend the knowledge and understanding of the atmospheric processes and other earth observations disciplines. The collection of such global data will permit the full exploitation of current developments in numerical forecasting aimed at long-range weather prediction. The Nimbus spacecraft are designed with a high degree of flexibility to accommodate many types of scientific and technological experiments for use in meteorological research and for testing prior to operational application. Nimbus 3, launched April 14, 1969, included seven experiments. These involved the measurement of the vertical temperature profile, cloud cover, solar radiation, and earth/atmosphere radiation. The use of radio-isotope power for space applications and a data collection and location system for <u>in situ</u> sensors was also demonstrated. On September 25, 1970, after more than 17 months of successful operation in orbit, the aft scanner failed, seriously degrading the spacecraft attitude control capability, and making most of the sensor data unusable. Nimbus 4 was successfully launched April 8, 1970. The nine experiments aboard

included those for obtaining measurements of temperature structure, cloud cover and composition (water or ice), emitted and reflected radiation from the ultraviolet to the infrared, the composition of the atmosphere, the solar energy variation and the measurement of wind velocities by tracking constant level balloons. With the exception of the Filter Wedge Spectrometer (for distinguishing between ice and water clouds and for obtaining a vertical water vapor profile) which failed June 7, the instruments continue to operate successfully. Nimbus E and F are under development with planned launches of advanced meteorological sensors in 1972 and 1973. These satellites will make the first exploratory use of the microwave region of the spectrum for atmospheric sounding. Passive microwave and infrared spectrometry experiments will provide a means for determining vertical profiles of temperature and water vapor through cloud cover to the surface. Advanced microwave and infrared radiometry will provide improved spatial and spectral resolution for day-and-night mapping of water vapor clouds, cloud heights, and surface features.

NASA will continue to provide support to the World Weather Watch and the Global Atmospheric Research Program (GARP). Operational satellites of the Improved TIROS series, developed and launched for the Department of Commerce by NASA, and the Synchronous Meteorological Satellite (SMS) predecessor of the Geostationary Observational Environmental Satellite (GOES), currently under development by NASA, will provide basic observations of global and local weather conditions essential to both the World Weather Watch and GARP. In addition, work is in progress on the development of an advanced meteorological satellite, TIROS-N, which will serve as the operational prototype for a third generation operational satellite system designed specifically to meet requirements of the GARP program as well as the requirements of our national weather services.

NASA is continuing its efforts to develop and improve sounding systems for measuring basic meteorological parameters in the altitude region from 30 to about 100 km over wide geographical regions and in an inter-hemispheric basis with a reliable, simplified, inexpensive sounding rocket system. Coordinated launchings are carried out from various geographical locations using one and two stage meteorological sounding rockets and in cooperative programs with other countries. The approach used is to improve rocket vehicles for use with newly developed sensors and data acquisition systems.

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Meteorology			
Physical Meteorology	746	660	760
Dynamic Meteorology	450	375	650
Observation	40,789	49,848	48,816
Modification	195	135	95
Systems	270	1,260	1,325
Total	42,450	52,278	51,646
Aeronomy			
Ionospheric Physics	2,025	2,364	1,865
Atmospheric Chemistry	1,547	1,657	1,960
Instrumentation Rockets	1,189	1,575	-
Instrumentation Satellites	1,069	950	-
Total	5,830	6,546	3,825
Planetary Atmospheres	125,881	121,474	261,723
PROGRAM TOTAL	174,161	180,298	317,194

Distribution of Funding

	FY 1970	FY 1971	FY 1972
In-House	24,581	24,816	35,220
Industry (Profit)	143,479	148,924	277,306
University	6,101	6,558	4,668

NATIONAL SCIENCE FOUNDATION

The National Science Foundation will continue to support a broad program in atmospheric sciences that includes specific programs in the areas of meteorology, aeronomy and solar terrestrial research. In addition, atmospheric sciences are contained in parts of the astronomy programs, the U.S. Antarctic Research Program, the Global Atmospheric Research Program (GARP), the Arctic Research Program, the International Decade of Ocean Explorations (IDOE), and the program of Research Applied to National Needs (RANN) including the entire Weather Modification Program. The procurement of specialized atmospheric science facilities for the nation's universities will be continued. A major continuing activity supported by the National Science Foundation is the National Center for Atmospheric Research (NCAR), located in Boulder, Colorado. It is operated for the National Science Foundation by the University Corporation for Atmospheric Research, a consortium of member universities.

Meteorology

The major objective of the Meteorology Program is to provide balance to the national effort in meteorology (1) by providing funds to scientific areas within the fields that are underdeveloped or need exploitation and (2) by offering encouragement to young investigators. For example, atmospheric chemistry is an area of underdevelopment but one that is related closely to air pollution problems and inadvertent modification of the weather. The Meteorology Program has been instrumental in suggesting that several universities include atmospheric chemistry as a part of their program in atmospheric sciences (1) so students can obtain the necessary training and (2) research can be undertaken in this important aspect of meteorology. Although other agencies have the responsibility for providing weather services, the Meteorology Program provides support for studies of atmospheric energetics not only of the general circulation but of local storms to provide the scientific basis on which better forecasting of storms must depend.

The effect that an urban environment causes on weather patterns is another area of increasing importance not only to meteorology itself, but to mankind. Consequently, the Meteorology Program is initiating a continuing urban pollution study in the St. Louis area. This project will determine the space-time variation of pollution within the urban environment and its effect upon clouds, precipitation, and frequency of unfavorable weather. Field experiments are expensive and it is anticipated that these studies will absorb the major fraction of the increased funds for meteorology. On a smaller scale, the meteorological environment of a small city, Columbia, Maryland, is being studied as the city grows from the fields of Howard County to produce a significant perturbation in the local environment.

The reduction of support for basic research by the Department of Defense has resulted in an increase of highly competent proposals to the Meteorology Program. An increase of proposals has also been noted which is the result

of physicists, chemists, and engineers applying their training to environmental problems. Consequently, the Meteorology Program will use a portion of any increased funding to support and encourage these interdisciplinary studies.

In FY 1972, continuing emphasis will be placed on the topics of atmospheric chemistry and the production, behavior, and fate of atmospheric constituents whether occurring naturally or added inadvertently. Support for numerical simulation of local storm systems and associated field measurement programs will continue to increase. Interactions between the lower and upper atmosphere and between global scale and medium scale - mesoscale - weather will form another area of increased attention. The Meteorology Program will continue to support research to provide interpretation of meteorological data, including satellite data and its use for short-range weather prediction, as well as for research directed to achieving a more complete understanding of atmospheric processes.

International Decade of Ocean Exploration

The National Science Foundation is the designated lead agency with responsibility for planning, funding and coordinating the International Decade of Ocean Exploration. Through IDOE, the Foundation funds programs of Federal agencies, universities, and other research organization.

Programs within the area of environmental studies with application to atmospheric science which IDOE intends to support during FY 71 are the following: Lagragian Measurement of Ocean Currents in the Caribbean, Development of Wave Forecasting Techniques, Tropical Storm Surge Forecasting, Open Ocean Tsunami Measurement and Shoreline Interaction, Marine Climatology, Near Surface Circulation Studies, Air/Sea Interaction and the Mixed Layer in the Ocean, Air/Sea Interaction Data Analysis, and World Ocean Numerical Modeling.

In 1972, IDOE will continue to support the numerical modeling program and is considering additional programs. Although a great many proposals relating to air/sea interaction and environmental forecasting in general have been received, no commitments have been made. A comprehensive study of large scale air/sea interaction in the North Pacific will probably be supported within the next few years, as will studies of upwelling phenomena and general ocean circulation.

Weather Modification

During FY 1972 the Foundation will continue to support research in weather modification at universities, the National Center for Atmospheric Research and nonprofit institutions. The primary effort of the weather modification program will be to provide support to the National Center for Atmospheric Research (NCAR) in establishing the support facilities, logistic planning, and scientific design for the National Hail Research Experiment which will begin field operations in the summer of 1972. In addition various academic and nonprofit groups will be supported to develop capabilities and techniques in support of the National Hail Research Experiment effort. This National Experiment will be based upon a plan prepared by NCAR and coordinated with ICAS. The plan calls for the establishment of a statistical study of hail suppression over a protected area of 600 square miles which will be continuously monitored and seeded on a randomized basis. In addition, an elaborate observational capability is being developed which includes six or more specially instrumented aircraft, one of which has been specially armoured to permit penetration of the storm in the hail forming zone. At least four of the observational aircraft will be tied into a central computer system by means of telemetry together with a number of special ground radar systems and a ground meteorological network. This will permit a real time display of the actual hail cell development at the control center and will provide input for the eventual development of a mathematical model which can be used for hail prediction and optimization of hail suppression techniques.

Cooperative observations and services will be provided by the Department of Commerce, Department of Interior, Department of Defense, Department of Transportation, Department of Agriculture, and Atomic Energy Commission.

In accordance with the ICAS plan for the acceleration of progress in weather modification, the Foundation plans in FY 1972 to support the efforts of other lead agencies in the conduct of their National Projects through sponsorship of observational and study projects at NCAR, universities, and nonprofit institutes as appropriate. In FY 1971, the Foundation initiated a contract with the Stanford Research Institute for a technology assessment of snowpack augmentation in the Upper Colorado River Basin at the request of ICAS.

Studies of the basic mechanisms of ice and condensation nucleation will continue to receive support as well as research in atmospheric electricity. Attention will be given to the need for a sound theory of cloud charging mechanisms that can be used to permit the construction of a mathematical model.

An attempt will be made to increase the participation of social scientists in the application of weather modification to problems of present day society. Present projects in the social and economic aspects of weather modification will be continued, and it is hoped that published reports will result in enlarging the circle of interest. The report of the Task Group

on the Legal Aspects of Weather Modification has now been published by the Cambridge Press under the title "Controlling the Weather; A Study of Law and Regulatory Processes" edited by Professor Howard J. Taubenfeld of Southern Methodist University.

Effort will also be made to increase the interest of physical scientists and meteorologists in studies of inadvertant modification of the weather produced by man's activities.

Interdisciplinary Research

The support of research directed toward meeting national needs is being continued by the Foundation under its program Research Applied to National Needs (RANN). This program exclusive of Weather Modification is directed toward exploring the application of advances in science and engineering toward the alleviation of societal problems, and embraces the cooperative application of the social, economic, legal, medical, and ecological sciences in the form of interdisciplinary researches or studies. In this research, atmospheric sciences plays a significant role. Focused programs dealing with a balanced interdisciplinary approach to national problems such as energy generation are now being conducted, and other programs related to trace contaminants of the atmosphere and the societal impacts of atmospheric pollution are under development.

Astronomy Programs

The Astronomy Programs of the Foundation support research on solar and planetary physics at a few universities and at the Kitt Peak National Observatory. Although the emphasis of the research is primarily astronomical, that is considering the sun as a star and planets as astronomical bodies, much of this research is relevant to atmospheric sciences and overlaps the activities of the Solar-Terrestrial Research Program.

Most of the optical investigations of the sun are carried out at the Kitt Peak National Observatory. Theoretical studies and rocket measurements of planetary atmospheres also are conducted there. Radio observations of the sun and planets are supported at several university-affilitated observatories such as those of the Universities of Maryland, Colorado, Florida, Texas and Michigan.

Global Atmospheric Research

Foundation support of GARP research in universities began in FY 1968 with support of numerical simulation of the general circulation of the atmosphere. In FY 1969, the Foundation provided $500,000 for university sponsored field programs and theoretical studies. In FY 1970, the Foundation supported the analytic and interpretive phases of the Barbados Oceanographic and Meteorological Experiment (BOMEX), an important preliminary program of the GARP. In 1971, support for university research in numerical simulation, predictability and the dynamics of global and mesoscale weather has continued.

The National Academy of Sciences' Committee for the Global Atmospheric Research Program published a report in July 1969 entitled Plan for U.S. Participation in the Global Atmospheric Research Program, which proposes a scientific program to be undertaken by the United States. The following programs are involved in the main: (1) mathematical modeling and observing simulation studies, (2) global observations and (3) field experiments.

To date, the National Science Foundation has supported the first area strongly. Numerous small groups with mathematical modeling expertise are working on integral parts of the overall general circulation problem. Two areas of fundamental importance are supported: the energetics of the general circulation including specific data on the partitioning and distribution of available energy and the interaction of the meso- and micro-scales with the synoptic- or macro-scales. NSF has been given responsibility for Observing Systems Simulation Experiments (OSSE) and NCAR will have the primary role for these activities. Numerical experiments using atmospheric general circulation models have already been performed in order to evaluate the design of atmospheric observing systems. These systems are needed to define the synoptic state of the global atmosphere for use in the longer period predictions.

In the second area recommended, global observation, NCAR will be involved deeply through the GHOST program and other observing systems. The third area, field experiments, will emphasize an international tropical study. This experiment will take place in mid 1974. The Foundation will be a major contributor via support for university investigators similar to the support provided for BOMEX.

NSF is anticipating considerable research efforts by universities during the GARP Atlantic Tropical Experiment (GATE) currently scheduled in 1974. Integrated proposals by several universities are being planned through the efforts of the UCAR GARP Council and the NCAR GARP Task Group. These two groups have recently been established to provide an effective communications channel in GARP activities and a quick response to identified research problems for the university community.

On the management side, the Tropical Experiment Council (TEC) and the Tropical Experiment Board will plan the international aspects of GATE which will be primarily concerned with problems related to the energy-exchange processes between various scales of atmospheric motions.

Office of Polar Programs

The U.S. Antarctic Research Program will include a continuation of meteorological and upper atmospheric physics programs on the Antarctic continent utilizing surface and upper air observations at the McMurdo, and South Pole Stations and the new Siple Station at 76.0°S, 84.0°W.

The studies are directed at a better understanding of the solar-terrestrial relationship. The probability of collecting meaningful low energy data is enhanced by the presence of the southern geomagnetic pole and the overhead proximity of aurora. Research will continue on the details of particle impacts that cause aurora, on the morphology of the ionosphere, and on monitoring cosmic rays with counters located at McMurdo and South Pole Stations. At McMurdo Station increased emphasis will be given to special high-level balloon observations of low energy cosmic ray particles.

A new station, Siple, situated at relatively low L value (L=4) will investigate wave-particle interactions by means of ground based and balloon based measurements of VLF, the geoelectric and geomagnetic fields and solar particles. Plans continue for the development of a remote Antarctic geophysical station in the interior of the continent. It is anticipated that a major part of the standard meteorological and upper atmospheric physics measurements can be carried out eventually at several completely automated and unmanned stations at key inland locations.

The Arctic Research Program which began in FY 71 will continue research in the following major problem areas specified in the Vice President's letter of November 7, 1969, designating the National Science Foundation as lead agency for extension of Arctic research:

1) the polar icepack and its role in transportation and in earth-atmosphere heat engine;

2) the polar magnetic field and its effects on communications and space electromagnetic phenomena;

3) geologic structures underlying the land and polar seas as both mineral sites and hazards for construction and resource development;

4) a delicately balanced ecological system;

5) the presence of permafrost;

6) slow degradation of liquid and solid waste; and

7) the behavior and physiology of man in this environment.

Research in the atmospheric sciences aspects of these specific problem areas will be coordinated closely with the total U. S. effort in atmospheric sciences.

National Center for Atmospheric Research (NCAR)

The National Center for Atmospheric Research (NCAR) conducts and fosters research on key atmospheric problems whose solutions may provide information or techniques useful in dealing more effectively with the urgent concerns of mankind. A fundamental research program is conducted which covers the full spectrum of phenomena which affect the earth's atmosphere, the totality of physical and chemical processes occuring at the dynamic interface between the atmosphere and the ocean, and the mechanisms which occur in various regions of the atmosphere and between the earth and the sun. NCAR also serves as a focus in planning and participation by the university community in national and international programs such as the Global Atmospheric Research Program (GARP), and the National Hail Research Experiment (NHRE). It provides the scientific community with research facilities too costly for a single university or research group to acquire and operate; supports a program of visiting senior scientists to increase the number of scientists entering the atmospheric sciences from the disciplines of Applied Mathematics, Physics and Chemistry and to foster an effective NCAR-University exchange of ideas, methodologies and results.

The Center will continue refinement of a six-layer global circulation model, incorporating the effects of convection and precipitation, interaction with a dynamically active ocean, orographic and soil effects in the boundary layer and an improved radiation calculation. The long range goal of this effort is to make the model sufficiently realistic to be useful in assessing various kinds of intentional and inadvertent large scale weather modification and of investigating the causes of long range climatic changes. In addition to models of the global circulation, NCAR scientists will be involved in developing models of convective clouds and severe convective storms, of fundamental turbulent processes of solar fluid dynamics processes, and conducting studies of radiative transport in the solar atmosphere.

Other major activities include: further development of the Global Horizontal Sounding Technique Balloon System (GHOST) and dropsondes over ocean areas through continuing flights of constant level balloons launched from New Zealand and Ascension Islands; continued analytical study of tropical and southern-hemisphere circulations; research on hailstorms associated with the National Hail Research Experiment under the field management of NCAR; further airborne and laboratory research into the relationship between electrical forces and the efficiency with which raindrops form through coalesence and accretion of smaller droplets; laboratory studies of cloud nucleation and ice crystal formation; use of an inertial platform and other airborne instrumentation to measure vertical motions in order to better understand both the behavior of clouds and their influence on larger scale circulation; research in solar physics; research in atmospheric chemistry, including the study of life cycles of trace gases and aerosols in the atmosphere, and how these elements can be

used as tracers of large-scale circulations. Planning is now under way for a field program in the St. Louis area to ascertain the long term effect of pollutants in the atmosphere, and instrumentation for a five station network is being planned to establish global monitoring of trace gases.

Solar-Terrestrial Research

The Solar-Terrestrial Research Program supports research on the space environment of the earth and on the reactions of this environment to solar influences. The goal of solar-terrestrial research is to trace and understand the long complex chain of events which starts with activity on the sun, propagates through interplanetary space, interacts with the earth's magnetosphere, and finally dissipates within the earth's atmosphere in the form of atmospheric heating, ionization, airglow and aurora.

The status of solar-terrestrial research at the end of this first decade of exploration and the directions and needs for the decade ahead have been the subject of a comprehensive series of studies by the National Academy of Sciences, which resulted in the following reports:

"Physics of the Earth in Space - A Program of Research 1968-1975"
"Physics of the Earth in Space - The Role of Ground-Based Research"
"Polar Research: A Survey"
"Sounding Rockets: Their Role in Space Research"

Consistent with some of the recommendations of these studies, increased emphasis in the support of research will be placed on the determination of solar magnetic fields by optical and radio techniques, on the modulation of cosmic rays at low energies, on wave-particle interactions in the magnetosphere, and on the coupling mechanisms between the magnetosphere and ionosphere and between the ionosphere and the stratosphere.

Many of these programs will involve coordinated measurements by a variety of ground-based and space techniques. Such experiments will be closely coordinated between NSF and other federal agencies such as NASA, NOAA AEC and DOD.

"A "1970 Solar Eclipse" symposium will be held in conjunction with the 1971 COSPAR meeting in Seattle, Washington at which time the major scientific results from the eclipse will be presented and eventually published.

Aeronomy

Aeronomical studies seek to understand how solar energy, having penetrated the earth's magnetosphere in the form of charged and neutral particles, light, and plasma waves, can be transferred to the upper atmosphere. In this height range of 50 to 200 km the dominant processes include energetic collisions, photochemistry, radiative transfer, and electromagnetic waves. An effective approach through observation, theory, and experiment is supported by the Aeronomy Program and carried out largely by university research groups. This program, too, serves as a balance in the overall Federal funding in this area by supporting young academic investigators and the academic university in general.

Patterns of aeronomy research are indicated in the representative reports of the Inter-Union Commission on Solar Terrestrial Physics (IUCSTP) and the recent reports of the National Academy of Sciences referred to in the following section. How the ionosphere responds to varying energy inputs will be probed by sensitive methods of measuring returned electromagnetic waves. In particular, the incoherent Thompson scattering technique affords many simultaneous determinations of atmospheric parameters, and the interaction of two frequencies give information on D region ionization. Neutral and ionized winds in the ionosphere, electric and magnetic fields, mass distributions, and reactions of neutral components will be studied by rocket borne as well as ground based instruments. Optical emissions from aurora and airglow will give sensitive measures of the energy input processes. Emphasis will be placed on detailed laboratory measurements of corresponding collisional excitation processes and reaction rates. Development of basic theory in all these areas is basic to their understanding and use and will be undertaken concurrently.

Coordination of associated measurements, either at one site by diverse methods or by repetitive measures at a wide mesh of locations provided by satellites or ground stations, will be exploited for new insights. The increasing power of instrumentation and analysis, together with the multiple advantages of the coordinated attack, will be exploited to continue the high momentum of success of recent aeronomical research.

NATIONAL SCIENCE FOUNDATION

Allocation of Funding

	FY 1970	FY 1971	FY 1972
Meteorology			
Physical Meteorology	4,480	5,200	6,700
Dynamic Meteorology	4,620	6,800	8,100
Observation	3,820	4,300	4,900
Description	60	100	500
Prediction	50	100	900
Dissemination	90	100	300
Modification	3,220	4,100	5,400
Systems	360	500	600
Support	2,420	2,800	3,100
Total	19,120	24,000	30,500
Aeronomy			
Aurora and Airglow	990	1,200	1,600
Ionospheric Physics	1,310	1,900	2,400
Atmospheric Chemistry	260	400	700
Atmospheric Structure	1,040	1,100	1,400
Energetic Particles	720	900	1,200
Atmospheric Geomagnetism	810	900	1,200
Solar Terrestrial Studies	1,910	2,600	3,000
Dynamic Aeronomy	580	800	800
Instrumentation, General	60	100	100
Instrumentation, Rockets	960	500	800
Instrumentation, Satellites	10	-	-
Support	690	700	700
Total	9,340	11,100	13,900
Planetary Atmospheres	1,730	1,900	2,100
PROGRAM TOTAL	30,190	37,000	46,500

Distribution of Funding

	FY 1970	FY 1971	FY 1972
Industry (Profit)	50	100	400
University	13,050	14,400	19,100
Transfer to other Government Agencies	630	900	1,200
National Centers, NAS, nonprofit and others	16,460	21,600	25,800

CLASSIFICATION SYSTEM

The following definitions are those prescribed in the ICAS/ICAMR* Common Reporting System and apply to all program descriptions:

Atmospheric Sciences: The sciences concerned with the physical and chemical properties, the composition, behavior and processes of the planetary atmospheres of the solar system.

Meteorology: The portion of the atmospheric sciences concerned with the physics and chemistry of the earth's atmosphere as a continuum. This includes problems of the troposphere, the stratosphere, and the mesosphere, and studies of such phenomena as the general circulation, weather systems, precipitation processes, turbulence, diffusion, and atmosphere/surface interactions. Meteorology areas of interest extend from the surface of the earth to approximately 100 km.

Aeronomy: The portion of the atmospheric sciences concerned with the physics and chemistry of the earth's upper atmosphere. This includes problems of the mesosphere and thermosphere including the ionosphere, and studies of such phenomena as airglow, aurorae, magnetic fields, radiation belts and solar terrestrial relationships. Aeronomy areas of interest extend from outer space to approximately 50 km above the earth's surface.

Planetary Atmospheres: The portion of the atmospheric sciences concerned with the studies of extra-terrestrial atmospheres.

Meteorology

Physical Meteorology: The study of the optical, electrical, acoustical, and thermodynamic phenomena of the atmosphere; its chemical composition, the laws of radiation; and the explanation of clouds and precipitation.

Dynamic Meteorology: The study of atmospheric motions as solutions of the fundamental equations of hydrodynamics or other systems or equations appropriate to special situations, as in the statistical theory of turbulence.

Observation: The functions of sensing, measuring or otherwise determining the state of the atmosphere and the magnitude of its phenomena. Computations, recordings, interfacing with communications systems and observations directly associated with these actions are part of this category.

* The Interdepartmental Committee for Applied Meteorological Research, a committee of the Federal Coordinator for Meteorological Services and Supporting Research.

Description: The functions of analyzing meteorological variables and describing the existing state of the atmosphere whether done by manual or automated methods and including related operations such as data plotting, forecast verification, interfacing with communications systems and further including climatology as related to the study of long-term manifestations of weather and the application of climatic data analysis to the solution of specific design or operational problems.

Prediction: The function of preparing forecasts of meteorological variables and phenomena whether done by manual or automated methods and including related operations such as interfacing with communications systems.

Dissemination: The functions of communicating meteorological information, displaying it and disseminating required service products to users, including message composition, handling, relaying and editing, preparation of local area meteorological charts, and presentation of briefing and forecasts to users.

Modification: The functions (1) intended to modify the atmosphere through artificial means including, but not limited to, seeding of clouds and fog to influence the natural development cycle, intentional initiation of large heat sources or fires to influence convective circulation or evaporate fog, intentional modification of solar radiation exchange of the earth or clouds through the release of gases, dusts, liquids or aerosols in the atmosphere, intentional modification of the energy transfer characteristics of the earth's land or water surface by dusting with powders, liquid sprays or dyes, etc., (2) of research which does not directly involve intentional modification but is carried on with the primary intent to apply its results to such activities, and (3) of research in inadvertent modification such as the monitoring of atmospheric constituents and studies of their modifying influences on the weather.

Systems: The integration of efforts in the various functional categories of meteorology into a coherent research pattern or organized set of development procedures.

Support: The provision of support to research, development, test and evaluation activities.

Aeronomy

Aurora and Airglow: All phenomena associated directly with luminescence in the high atmosphere, including the size, shape, structure, geographical distribution, and composition of the elements or agents comprising or causing these phenomena.

Ionospheric Physics: Ionization and related phenomena, including electromagnetic propagation and ionospheric motions.

Atmospheric Chemistry: The chemical composition, chemical reactions and their distribution.

Atmospheric Structure: Temperature, pressure, density, winds, turbulence and other dynamic and kinetic properties of the upper atmosphere.

Energetic Particles: Trapped radiation, cosmic rays and their interaction with the atmosphere.

Atmospheric Geomagnetism: Magnetic fields and their variations as influenced by the earth's and solar atmospheres.

Solar-Terrestrial Studies: Solar activities as they affect the atmosphere of the earth.

Dynamic Aeronomy: The study of upper atmospheric motions as solutions of the fundamental equations of hydrodynamics or other systems of equations appropriate to special situations.

Instrumentation, General: Research and development of upper atmosphere sensors (including indirect or balloon-borne systems) and directly associated telemetering and control systems.

Instrumentation, Rockets: Research and development of upper atmosphere sensors and directly associated rocket guidance, telemetering and booster systems.

Instrumentation, Satellites: Research and development of upper atmosphere sensors and directly associated satellite guidance, telemetering and booster systems.

Support: The provision of support to research development, test, and evaluation activities.

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