The Federal Plan for Meteorological Services and Supporting Research

FISCAL YEAR 1991

OFCM

OFFICE OF THE FEDERAL COORDINATOR
FOR METEOROLOGICAL SERVICES
AND SUPPORTING RESEARCH

FCM P1-1990

U.S. DEPARTMENT OF COMMERCE/National Oceanic and Atmospheric Administration

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U.S. DEPARTMENT OF COMMERCE
Robert A. Mosbacher, Secretary

National Oceanic and Atmospheric Administration
John A. Knauss, Under Secretary

APRIL 1990
WASHINGTON, D.C.

PREFACE

This Federal Plan, the 26th in the series that began in 1965, provides a useful summary of the meteorological services and and supporting research activities of all agencies of the Federal Government. As in the past, the Plan provides the Congress and the Executive Branch with a coordinated, overall plan for Government meteorological services and for those research and development programs that directly support and improve meteorological services. The Plan covers the meteorological programs of all agencies for FY 1990 and FY 1991.

The first section of the Plan provides an overview and general summary of the entire document. Essential budget information is provided in graphic formats which summarize the significant aspects of the budget tables included in Section 3. The second section highlights interagency cooperation that is essential to meet the needs for meteorological services. Section 3 contains a discussion of resources requested in the President's budget for FY 1991 as compared to planned resources for FY 1990. The emphasis is on changes in resources and the related changes in programs. Fiscal data are current as of the end of February 1990. Section 4 provides a review and status report on the Next Generation Weather Radar (NEXRAD). The appendices contain descriptions of agencies' weather activities, a description of the World Weather Program, and a list of acronyms.

This Plan does not include information on basic research in the atmospheric sciences. By long-standing agreement, the longer term, more fundamental research activities have been coordinated and reported by the Subcommittee on Atmospheric Research (SAR), of the Committee on Earth Sciences under the Federal Coordinating Council for Science, Engineering and Technology. This division of responsibilities explains the absence in this report of any substantial references to large basic research programs, such as global climate change.

The most recent SAR report, National Atmospheric Sciences Program, covered the Fiscal Years 1984-1987. A new report, SAR-4 FY 1987-1990, is now being prepared. The SAR report is retrospective and serves a very different purpose from that of this Federal Plan, but there are similarities. Representatives of the OFCM and the SAR have coordinated approaches to these two reports; however, the distinctions between "supporting" research and "basic" research are sometimes debatable. Some duplications, some omissions, and some double reporting of funding are therefore possible, in spite of efforts to minimize these occurrences.

The principal task of coordinating weather activities is accomplished by the interagency committees shown on the inside front cover. These committees and the organizations shown on the inside of the back cover conduct systematic and continuous reviews of requirements for basic and specialized meteorological services and for supporting research according to guidelines set forth in the Office of Management and Budget Circular A-62.

Robert L. Carnahan
Federal Coordinator for Meteorological
Services and Supporting Research

THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH, FISCAL YEAR 1991

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EXECUTIVE SUMMARY

The President's Budget for FY 1991 requests over $2.3 billion for meteorological services and supporting research. This is 12.3 percent more than the $2.1 billion planned for FY 1990. As in previous years, nearly 90 percent of the total is requested for three Departments: Commerce, Defense and Transportation. Major programs initiated in previous years continue, with every indication that the decade of the 1990's will see dramatic evidence of the progress of meteorological science and technology. This progress will be evident in both observing systems and forecasting techniques.

Major Programs

A major program with continuing funding in FY 1991 is the Next Generation Weather Radar (NEXRAD). This tri-agency program, supported by the Department of Commerce (DOC), the Department of Defense (DOD), and the Department of Transportation (DOT), is well underway. A prototype radar was installed at Norman, Oklahoma, and was extensively tested in 1989. The full production phase was initiated in FY 1990. A Program Council, chaired by the Federal Coordinator, provides policy guidance and oversight to procure and install a system that will meet the common needs of the three agencies. The NEXRAD program is described in the feature article in Section 4.

Support for another major program, the Automated Surface Weather Observation Program under the guidance of a Program Council chaired by the Federal Coordinator, continues in the FY 1991 budget request for the Departments of Commerce and Transportation. This program will automate the surface weather observation network. The Department of Defense is monitoring the program; the U.S. Navy has an agreement with NWS to purchase 85 Automated Surface Observing Systems (ASOS) units.

Programs for automated weather information systems have been initiated in several agencies in response to their own unique requirements. These systems are being developed to reduce labor intensive functions and reduce the time for collecting, processing, and interpreting weather data. These automated systems will reduce the time to produce weather forecasts and warnings, and will assist in the production of tailored products for specific Federal users. Rapid distribution of the products to users is yet another goal. A Program Council, a committee, and several working groups within the OFCM structure provide coordination for various aspects of the agencies' programs. Funding for the DOC, DOT and DOD programs is in the FY 1991 budget request.

In response to a request from the Federal Committee for Meteorological Services and Supporting Research, a National Aviation Weather Program Council was established in late 1989. The Program Council will provide policy guidance to a working group established to prepare a National Aviation Weather Program Plan.

The OFCM is also playing a role in establishing weather data collection and reporting standards by overseeing the revision and subsequent publication of the Federal Meteorological Handbook series. The preparation of these handbooks is being performed by various OFCM committees and working groups. There are currently ten handbooks in use by Federal agencies and the meteorological community in the U.S. The revised FMH-10, Meteorological Rocket Observations, and a revised FMH-2, Surface Synoptic Codes, were published in 1989. Another handbook, FMH-1, Surface Observations, is expected to be published in 1991.

Resources

The FY 1991 resources requested for Federal meteorological operations and supporting research are $2.354 billion, representing a 12.3 percent increase from the $2.096 billion in FY 1990. Of this amount, about $1.932 billion will be for operations and $423 million for supporting research. The budget, by agency, is shown in Table 1.1.

A graphical illustration of the total requests is shown in Figure 1.1. The agencies' proposed spending for meteorological operations is shown in Figure 1.2. As in previous years, the Departments of Commerce, Defense, and Transportation account for approximately 99 percent of the Federal budget for meteorological operations. Proposed spending for supporting research is shown in Figure 1.3.

The total Federal budgets for the 12 year period 1980-1991 are shown in Figure 1.4; the budgets are presented in terms of actual and constant dollars (i.e., adjusted for the Consumer Price Index).

The agencies expect that 17,681 people will be engaged in meteorological operations in FY 1991, which is about the same as for FY 1990.

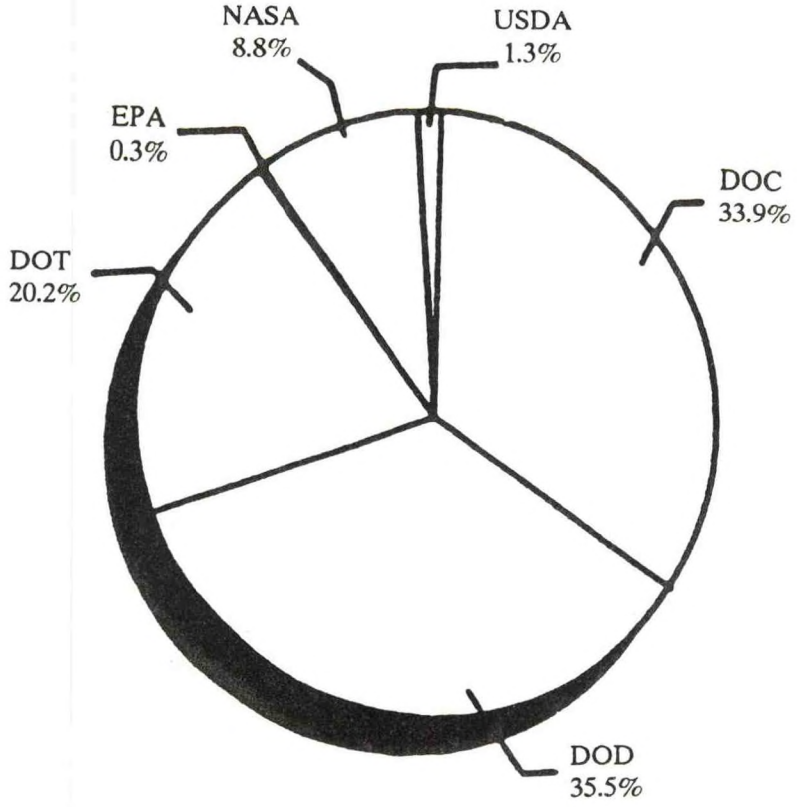

Figure 1.1 Total Federal Budget for Meteorological Operations and Supporting Research, FY 1991

Table 1.1. Federal Budget for Meteorological Services and Supporting Research, Fiscal Year 1991 (in thousands of dollars)

Agency	Operations	% of TOTAL	Supporting Research	% of TOTAL	Total	% of TOTAL
Agriculture	9,824	0.5	21,336	5.0	31,160	1.3
Commerce	749,778	38.8	48,935	11.6	798,713	33.9
Defense	697,685	36.1	138,250	32.7	835,935	35.5
Interior	870	0.0	0	0.0	870	0.0
Transportation	466,832	24.2	8,059	1.9	474,891	20.2
Envir. Prot. Agency	0	0.0	6,560	1.6	6,560	0.3
NASA	6,660	0.4	199,600	47.2	206,260	8.8
Nuclear Reg. Comm.	195	0.0	40	0.0	235	0.0
TOTAL	1,931,844	100.0	422,780	100.0	2,354,624	100.0

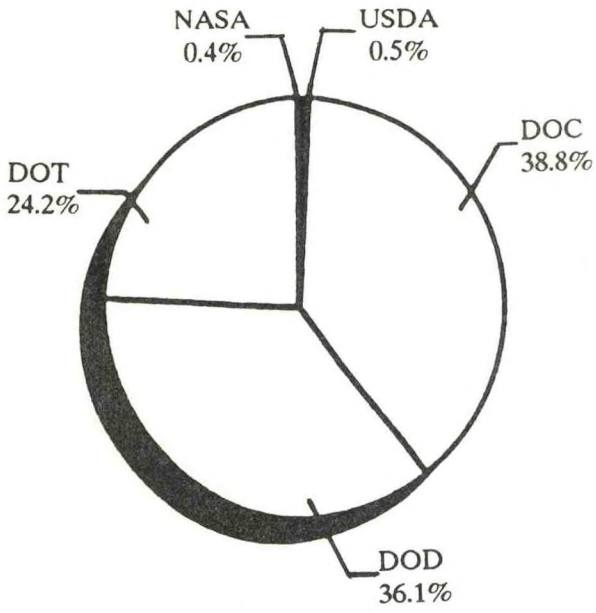

Figure 1.2 Federal Budget for Meteorological Operations, FY 1991 (Percent of Operations budget)

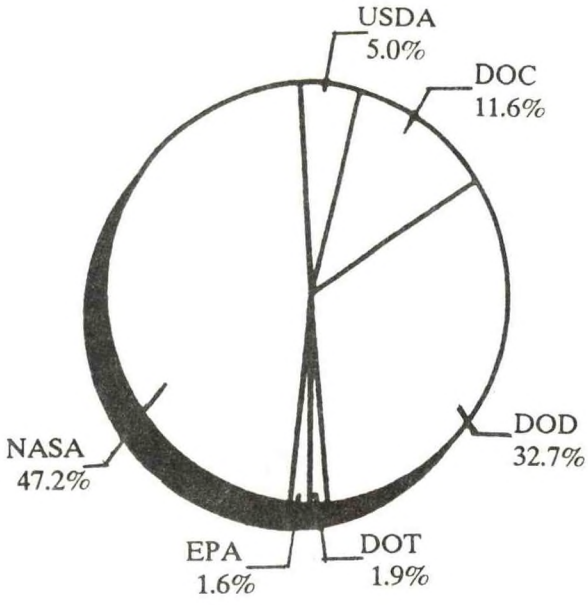

Figure 1.3 Federal Budget for Supporting Research, FY 1991 (Percent of Supporting Research budget)

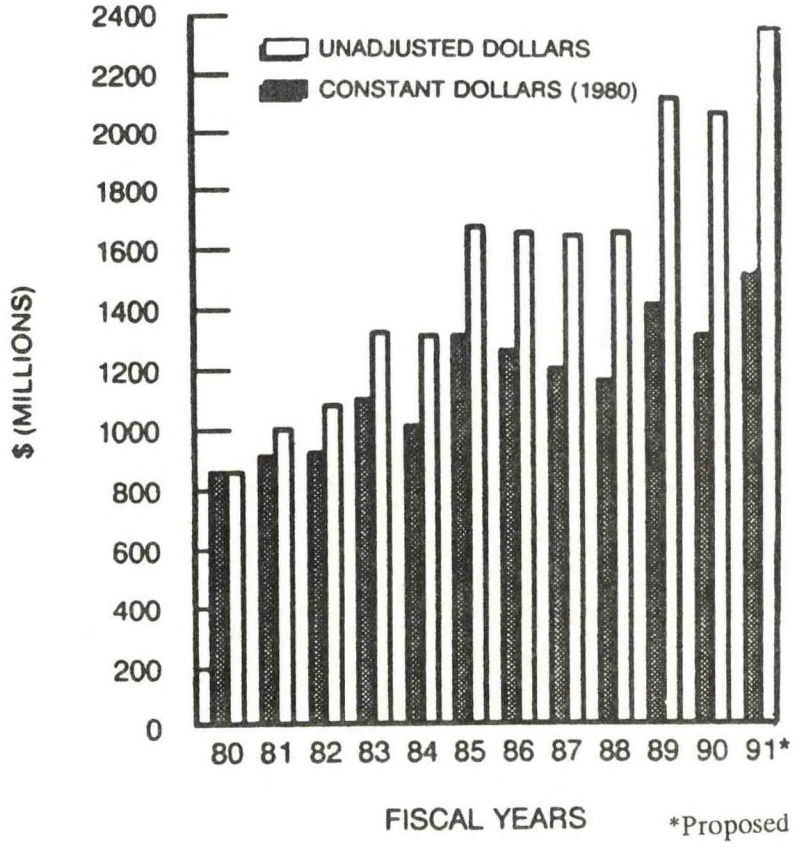

Figure 1.4 Total Federal Budgets for Meteorological Operations and Supporting Research, FY 1980-1991

SECTION 2

FEDERAL COORDINATION AND PLANNING

In 1963, activities in meteorology gave rise to concern in Congress and the Executive Office of the President as to whether Federal meteorological activities were being coordinated adequately. This concern was given expression by the Congress in Section 304 of Public Law 87-843, the Appropriations Act for State, Justice, Commerce, and Related Agencies. Congress directed that the Bureau of the Budget prepare an annual horizontal budget for all meteorological programs in the Federal agencies.

The Bureau of the Budget (now Office of Management and Budget) issued a report entitled "Survey of Federal Meteorological Activities" (1963). It described each agency's program in some detail, particularly its operational services, and spelled out the relationship between the programs of the various agencies. The report revealed close cooperation but little evidence of systematic coordination. As a result of this study and the concern of Congress, the Director of the Bureau of the Budget issued Circular A-62. The Circular provided the ground rules to be followed in the coordination process. It established a general philosophy for assignment and assessment of agency roles in the field of meteorology and set certain goals to be achieved by the coordination process. The Circular left the task of establishing the coordinating mechanism to the Department of Commerce (DOC), in concert with the other Federal agencies. The Circular reaffirmed the concept of having a central agency, the Department of Commerce, responsible for providing common meteorological facilities and services and clarified the responsibilities of other agencies for providing meteorological services specific to their own needs.

The implementation of Circular A-62 by the Department of Commerce led to creation of the Office of the Federal Coordinator for Meteorological Services and Supporting Research. The office operates with policy guidance from the Federal Committee for Meteorological Services and Supporting Research. The principal work in the coordination of meteorological activities and in the preparation and maintenance of federal plans is done by the staff of the Federal Coordinator with the advice and assistance of the Interdepartmental Committee for Meteorological Services and Supporting Research, several special purpose councils, committees, and working groups. The organizational relationships are shown on the inside of the back cover of this document.

MISSION AND STAFFING OF THE OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGY (OFCM)

The mission of the OFCM is to promote coordination and cooperation among those Federal agencies having weather related activities so that the most effective and best possible weather information and user services are provided for the funds made available by the Government. To discharge its mission, the OFCM objectives are meshed with the objectives of those agencies which provide the services and perform the research. The objectives are to:

- Review Federal weather programs and total Federal requirements for 13 Government agencies. This review may suggest additions or revisions to current or proposed programs or identify opportunities for improved efficiency, reliability, or cost avoidance through coordinated actions or integrated programs.

- Document agency programs and activities in a series of national plans and reports that enable agencies to revise or adjust their individual ongoing programs and provide a means for communicating new ideas and approaches to the satisfaction of requirements.

- Perform analyses, summaries, or evaluations of agency meteorological programs and plans that provide a factual basis for the Executive and Legislative branches to make appropriate decisions related to the allocation of funds.
- Provide a structure and program to promote continuity in the development and coordination of plans and procedures for interagency meteorological service operations and supporting research activities.

In 1979, a General Accounting Office (GAO) report, "The Federal Weather Program Must Have Stronger Central Direction," LCD-80-10, recommended stronger centralized planning and direction for Federal weather activities. Pursuant to GAO's recommendation, the DOC increased the permanent professional staff from one to seven and assigned an additional professional as agency representative; DOC also provides administrative support to the Office of the Federal Coordinator. The Department of Defense normally provides two staff officers (one Air Force colonel, and one Navy commander) and contributes approximately $300,000 per year to the operation of the OFCM. From mid 1988 to the present, the DOD has also provided a second Air Force Colonel to assist in OFCM coordination efforts; that position will be withdrawn in mid 1990. DOT/FAA provides one professional staff member and contributes approximately $300,000 per year. The four regularly assigned agency representatives act as assistant federal coordinators for liaison to their respective agencies. Based on current staffing, there are 10 professionals and 3 full time administrative support personnel within the OFCM. Approximately one-half of these resources is required for the direct support of the Committee structure and preparation of recurring plans (national operations plans and the annual Federal Plan). The remaining staff time is required for responding to special inquiries, investigations and studies.

COORDINATION OF MULTIAGENCY PROGRAMS

The Federal Committee for Meteorological Services and Supporting Research was established in 1964 with high-level agency representation to provide policy guidance to the Federal Coordinator and to resolve agency differences that arise during the coordination of meteorological activities and the preparation of Federal plans in general. The Committee is chaired by the Under Secretary of Commerce for Oceans and Atmosphere, who is also the Administrator of the National Oceanic and Atmospheric Administration.

Thirteen Governmental agencies that are engaged in meteorological activities, or that have a need for meteorological services, are represented on the committee. These include the Departments of Commerce, Agriculture, Defense, Energy, Interior, State, and Transportation as well as the Environmental Protection Agency, Federal Emergency Management Agency, National Aeronautics and Space Administration, National Science Foundation, National Transportation Safety Board and the U.S. Nuclear Regulatory Commission. In addition, the Office of Management and Budget is represented.

The Office of Management and Budget (OMB) and the Federal Committee provide guidance at the policy level to the Federal Coordinator. Guidance from the agencies is provided at the program management level by the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR). Under ICMSSR there are six standing committees: Basic Services, Operational Processing Centers, Automated Weather Information Systems, Aviation Services, Operational Environmental Satellites, and Space Environment Forecasting.

Six Program Councils have been established within the OFCM structure to coordinate specific interagency cooperative programs. These are: Joint Automated Weather Observations, Automated Weather Information Systems, Aircraft Icing, Aviation Weather, Next Generation

Weather Radar, and Improved Weather Reconnaissance. Each of the Councils is comprised of decision-level representatives of the agencies directly concerned with the specific program area.

Automated Surface Weather Observations

The Departments of Commerce, Defense, and Transportation (DOC, DOD, DOT) maintain approximately 950 surface weather observing sites requiring an estimated 1,000 staff-years annually to conduct surface observations. Most surface observations are taken manually and consume a significant amount of personnel time. In addition, sensor maintainability and reliability are presenting significant problems. Equipment maintenance alone at a typical observing station now costs over $25,000 per year, and this cost is projected to increase about 10 percent per year because of the increasing difficulty of obtaining replacement parts. Consequently, selective replacement of obsolete sensors is now taking place just to retain the current capability.

Historically, each agency has independently developed an operational weather system capability in pursuit of its mission; supporting research was frequently carried out jointly. In 1983, in order to coordinate these efforts and in response to OFCM's recommendation, the Joint Automated Weather Observing Program (JAWOP) was established. The JAWOP Council, chaired by the Federal Coordinator, provides policy and oversight for the three Departments' automated surface observation program development efforts.

In FY 1986, a Government-wide audit of the development of automated weather systems was performed by the President's Council on Integrity and Efficiency (PCIE). It was a joint effort of the Inspectors General from DOC, DOD, and DOT to determine if overlap and duplication existed in the development of automated weather systems. During this same period, the Departments took actions to greatly improve coordination and lessen duplication and overlap in the Federal weather community. Specifically, NWS and FAA sought convergence of their programs by closely examining system commonality and revalidating system requirements. This resulted in an agreement in 1987 by the JAWOP Council to use the NWS's Automated Surface Observing System (ASOS) at the FAA's towered airport locations.

The PCIE audit supported this action; it concluded that NWS and FAA could achieve substantial cost savings by consolidating development and acquisition actions. Subsequently, the Administrators of NOAA and FAA expanded this application and agreed that NOAA will procure, install, operate, and maintain the ASOS to meet FAA requirements for both the towered and most of the nontowered airports. Towered airports are the large airports that have a control tower and FAA personnel to control airplane traffic. The NWS and FAA application of ASOS will make this system the primary federal surface observing system. Immediate needs of the FAA for limited weather observations at small non-towered airports will be satisfied by procuring 160 off-the-shelf automated weather observing systems (AWOS) as an initial capability system until ASOS is fielded.

Earlier NWS completed operation of prototype ASOS as part of its demonstration phase. The demonstration involved six systems at operational NWS offices in the State of Kansas, as well as a system for FAA control tower evaluation. In addition, other systems were placed in different climates for further evaluation and development of key sensors and algorithms. The demonstration modeled the future observing operation and provided very useful information on system, sensor, and algorithm performance. The experience has supported key sensor development as well. Overall, the demonstration showed ASOS to be suitable for large-scale deployment.

The NWS demonstration contributed to significant improvements in laser ceilometer technology, a critical component of automated observing efforts. These technical improvements were factored into the NWS's next generation laser ceilometer procurement. Production delivery has begun with field installation underway at primary NWS observing locations. The new ceilometer will be used as part of the ASOS sensor suite at most locations. Both the Air Force and FAA have decided to use the NWS-developed Next Generation Ceilometer for replacement purposes. The Air Force is presently acquiring 287 ceilometers and FAA is acquiring 115 ceilometers through the NWS. The Air Force is also considering use of the NWS developed ASOS for general Air Force application.

Initial FAA and NWS tests of precipitation identification sensors and freezing rain sensors were conducted during the 1986-87 and 1987-88 winter seasons, with continued testing of sensor refinements during the 1988-1989 winter season. This testing is part of a JAWOP plan to conduct comparative testing of these sensors. These tests of precipitation identification sensors were conducted at both the Air Force Geophysics Laboratory's Weather Test Facility at Otis Air National Guard Base, Massachusetts, and the NWS's Systems Research and Development Center at Sterling, Virginia. Freezing rain sensors were tested at Worcester, Massachusetts, Municipal Airport, and at Newfoundland, Canada, both of which experience frequent icing events.

A JAWOP Visibility Sensor Development Test Program was established in FY 1987 to support sensor development in industry; this program has recently been completed. The purpose of the test program was to minimize risk with this key sensor. The Working Group for Surface Observation's Task Group for Surface Instrumentation Standards has completed development of a standard for siting meteorological sensors of automated systems at airports. Development of the initial Federal standard algorithms was completed in FY 1988.

The Air Force activity in automated sensor development is principally focused on the war fighting environment. The Air Force Tactical Weather Observing System (TWOS) will include surface, airborne, and satellite-based observations. Air Force sensor development is the responsibility of the Geophysics Laboratory (GL) (Air Force Systems Command). They will develop tactical sensors while continuing to monitor ASOS. A fixed-base automated observing system based on the tactical sensors and ASOS will be developed in the late 1990s.

The Navy is planning to replace obsolete equipment with the ASOS at Navy and Marine Corps air stations. The Navy will not use ASOS as a fully automated station except at remote sites where surface observations are not presently taken due to manpower limitations, such as bombing ranges. The Navy requires 85 ASOS units at 82 shore sites both in the continental U.S. and overseas. In order to satisfy the requirement for automated shipboard observations, the Navy is developing the Shipboard Meteorological and Oceanographic Observing System (SMOOS).

The U.S. Army's Atmospheric Sciences Laboratory (ASL) has developed and installed the Surface Automated Meteorological System (SAMS) for automated collection and processing of surface weather parameters for supporting the Army's Research, Development, Test, and Evaluation sites. Standard measured parameters are solar radiation, air temperature, humidity, wind speed and direction, barometric pressure, and soil temperature at each data collection platform (DCP). The central site, called the Acquisition Control Unit (ACU), directs the DCPs to acquire and transmit data, calculates a variety of derived parameters, and maintains a listing of the acquired data including reports and plots.

Planned activities for FY 1990 and FY 1991 include:

- Completion of two NWS contracts for the competitive design, development, fabrication and testing of four preproduction prototype ASOS from each contractor. The ASOS development being conducted under the guidelines of OMB Circular A-109 will conclude with the awarding of the production contract to one contractor, scheduled for August 1990. Critical design and in-plant testing will be completed in FY 1990 with field testing beginning mid-1990.
- NWS, FAA, and DOD (under the auspices of the JAWOP) will continue an evaluation of various precipitation identification sensors, with final reports scheduled for 1990.
- Under the auspices of the JAWOP, the NWS, DOT's Transportation Systems Center, and DOD (GL), with support from FAA and Canada's Atmospheric Environment Service, will evaluate visibility sensors in support of the ASOS production system acquisition.
- NWS will continue installation of Next Generation Ceilometers at its primary observing sites.
- OFCM will revise the Federal Meteorological Handbook No. 1 to reflect automated observing procedures.
- USAF and FAA will continue selective replacement of aging sensors, including the purchase of new laser ceilometers by means of an add-on to the NWS procurement.
- U.S. Navy will plan for the replacement of the AN/GMQ-29 semi-automated observing systems ashore with ASOS.
- U.S. Navy will test the Shipboard Meteorological and Oceanographic Observing System (SMOOS) at sea during 1990.

Automated Weather Information Systems (AWIS)

Automated Weather Information Systems (AWIS) are required by a number of Federal agencies. The AWIS are being procured to reduce labor intensive functions; to reduce the time required to collect, process and interpret weather data; to reduce the time to produce forecasts, warnings and special tailored products; and to distribute these products to users expeditiously. Major agency systems classified as AWISs are the Department of Commerce's Advanced Weather Interactive Processing System (AWIPS), the Federal Aviation Administration's Central Weather Processor (CWP), the U.S. Air Force's Automated Weather Distribution System (AWDS), and the Naval Oceanographic Data Distribution and Expansion System (NODDES). The systems include communications to collect and distribute raw data, information, and processed products. Excluded from AWIS are the observation subsystems and the supercomputers at the major centers.

The AWIS Program Council, which consists of high level representatives from the Departments of Commerce, Defense and Transportation, was established during February 1986 as part of the Federal coordination mechanism for meteorology. This was in response to a 1985 recommendation by the Inspectors General of these agencies. The Council decided to identify major items that needed coordination in both the short and long term; to determine if there was redundancy among the systems and, if so, whether it should be eliminated; to determine what commonalities existed among the systems; and to produce a Federal Plan for the Coordination of AWIS Programs.

In order to further its agenda, the AWIS Program Council uses the Committee for Automated Weather Information Systems (CAWIS) and its Working Group for Communications Interfaces and Data Exchange (WG/CIDE) and Working Group for AWIS Meteorological Applications (WG/AMA). CAWIS published the Federal Plan for the Coordination of AWIS

Programs in May 1988. WG/CIDE publishes standards documents relating to formats and telecommunications procedures. Its most recent Standard Formats for Weather Data Exchange Among Automated Weather Information Systems was published in December 1986. Its most recent Standard Telecommunication Procedures for Weather Data Exchange was published in July 1989. This latter standard is based upon the Federal Information Processing Standard 100 which is compatible with a similar document produced by the International Standards Organization. The thrust of the Working Group's effort is to adopt Federal, American and international standards and, where necessary, to develop standards, procedures and guidelines that are unique to weather information systems. WG/AMA is preparing an inventory of meteorological applications programs and techniques and provides a forum for coordination of developments in new or improved meteorological applications. In addition, WG/CIDE designed the Interdepartmental Meteorological Data Exchange system (IMDES). The first progress report on the implementation of IMDES was published in July 1989

National Aircraft Icing Program

In late 1983, a subgroup of the Federal Committee for Meteorological Services and Supporting Research and other high-level officials in DOD, FAA, and NASA agreed to promote greater coordination in aircraft icing and to form a National Aircraft Icing Program Council. The Council was established in 1984.

The Council is responsible for developing and maintaining a technology plan and for providing policy guidance for its execution. The Council's Working Group for Aircraft Icing prepared the initial National Aircraft Icing Technology Plan, published in 1986. The planned program has dual objectives: 1) improving aircraft icing technologies for the current generation of aircraft, and 2) promoting advances in aircraft icing technology that will be needed by 1995 to meet national aeronautical goals for new generations of aircraft. This plan presents a comprehensive list of aircraft icing research needs and objectives, describes the efforts now underway, and proposes the areas of need. It recognizes that the scope, definitions, and priorities may change as the National Aircraft Icing Technology Plan is implemented and the need to update to reflect accomplishments and changes in agency missions and goals.

One section of the technology plan, "Detecting, Monitoring and Forecasting" is addressed in detail in the National Plan to Improve Aircraft Icing Forecasts, prepared by an ad hoc group for the Committee for Aviation Services, and published in 1986.

In 1989 the FAA established a 6-year funding schedule, beginning in FY 1990, to achieve the goals set forth in the icing forecasting plan. In FY 1990, funding was provided by the FAA to the National Center for Atmospheric Research (NCAR) to develop and conduct an extensive icing research program. The objectives of this program are to develop and evaluate an icing severity index, and an operational icing forecast for aviation. A third objective is to evaluate sensors appropriate for the detection of icing conditions. NCAR will conduct field data collection exercises during four sucessive winters: two in the Denver area and two in the central U.S. This effort commenced in January 1990 with a combined ground-based and airborne data collection in the Colorado area.

National Aviation Weather Program Council

A new program council was formed in late 1989 to address aviation weather issues and provide guidance in the preparation of a national aviation weather program plan. It held its first meeting in January 1990 -- the membership consists of the Departments of Agriculture, Commerce, Defense, and Transportation, the National Aeronautics and Space Administration, and the National Transportation Safety Board. The principal activity of this program council is, through a joint

action group, preparation of a National Aviation Weather Program Plan by March 1991. This plan will establish user needs and agency responses in the area of aviation weather services.

Next Generation Weather Radar (NEXRAD)

This year's Federal Plan has a special section on the NEXRAD program (See Section 4.) As a result, the usual report on NEXRAD in this section has been omitted.

PLANNING ACTIVITIES, COMMITTEE CHANGES, AND METEOROLOGICAL PUBLICATIONS

Meteorological Information Management

The development of new, higher-resolution atmospheric observational systems, the operational deployment of large-scale graphic and alphanumeric communications and display systems, and the transition from traditional paper and film displays for graphical and satellite imagery to automated digital displays, mean that a virtual explosion of meteorological information is occurring and will continue for the foreseeable future. The tremendous volume and complexity of new information threatens to overwhelm present-day archival systems and lead to confusion and serious inefficiencies in the application of retrospective data to scientific and operational needs.

At the same time, the explosion of data is coupled to a growing demand for retrospective meteorological data to support research initiatives, such as analysis of global change, and operational uses such as military planning and environmental and engineering studies. These factors have led to a proliferation of retrospective databases and the real possibility of significant duplication of effort and development of incompatible databases by Federal agencies, other producers, and users.

Recognition of this growing problem led ICMSSR to establish the Working Group for Meteorological Information Management. The aims of the Group are to review current agency plans and requirements, develop guidelines for new data systems, develop a national reference system for retrospective databases, and devise a coordination mechanism to ensure, (1) that user needs are considered, and (2) that duplication of effort is eliminated to the extent possible. The Group arranged for a contractor to prepare a draft Federal Plan for Meteorological Information Management. The contract was awarded in May 1989 and the plan will be published in 1990. In a complementary effort, the Working Group is beginning a review of data archival media, in order to provide some guidance to agencies with significant archival responsibilities.

Federal Meteorological Handbooks

At the direction of the ICMSSR, the OFCM has undertaken a revitalization of the Federal Meteorological Handbooks (FMH) using the existing interdepartmental coordination infrastructure of committees and working groups. The FMH series includes observing and reporting practices for surface, upper air, radar, and meteorological rocket observations. The titles of ten existing handbooks are: Surface Observations, Surface Synoptic Codes, Radiosonde Observations, Radiosonde Code, Winds-Aloft Observations, Upper Wind Code, Weather Radar Observations, Manual on Barometry, Aviation Weather Observations, and Meteorological Rocket Observations. Another, Doppler Radar Meteorological Observations, is under development. The OFCM is reevaluating the status of the FMH series and revising each handbook, as required, to:

- highlight the responsibility for preparation and maintenance;
- develop a mechanism to make sure the FMHs remain current and complete;
- assure the merging of information from new or automated technology;

- meet requirements for utility of the primary users;
- reinforce the status of each handbook as the Federal standard for observing and reporting the meteorological phenomena and parameters by which the atmosphere is usually described.

Many OFCM working groups of the Committee for Basic Services are participating in this task. To date revisions have been completed for the Surface Synoptic Codes (FMH-2) and Meteorological Rocket Observations (FMH-10) handbooks. When completed, the new handbooks will be available to private sector users through the National Climatic Data Center in Asheville, NC.

National Program for Lightning Detection Systems

In 1983 the Office of the Inspector General, Department of Commerce, issued a management audit report that indicated the significance of the threat of lightning to life and property and the need to improve severe weather forecasting. It stated that a number of agencies were active in programs directed toward lightning detection and encouraged the Department of Commerce (NOAA) to determine the action necessary to improve the Nation's lightning detection program.

The Department of Commerce member of the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) requested that the Office of the Federal Coordinator for Meteorology (OFCM) undertake a study to document the Federal agencies' interest in lightning detection and existing and planned programs of the agencies. The study, completed in early 1985, revealed that extensive systems exist for the detection and tracking of cloud-to-ground lightning. These systems are organized in networks operated by various Federal agencies, universities and private industry.

In December 1984, ICMSSR agreed that there was a need for a National Plan for Lightning Detection Systems. The National Plan should make maximum interagency use of existing systems and coordinate the ongoing lightning programs of the Federal agencies. Preceding the plan, however, a study of the status of the various agency, university and industry lightning programs was conducted. The study revealed agencies were operating with different levels of experience in lightning detection and at different stages in formulating operational requirements. A report entitled "The Status of National Programs for Lightning Detection Systems", published in 1986, identified issues and problems that needed to be resolved in developing a national plan for lightning detection systems. A field testing program evaluating available lightning detection systems was conducted by the National Severe Storms Laboratory (NSSL). A report by NSSL entitled "An Evaluation of Two Lightning Ground Strike Locating Systems" was published in 1988.

The Working Group for Lightning Detection Systems (WG/LDS) determined that development in several areas had not progressed sufficiently to prepare a final National plan but, to further the many efforts in progress, including an interagency experiment in using National Lightning Data, a Preliminary National Plan for Lightning Detection Systems was published by the OFCM in 1988 to provide a framework for further development. The Working Group has now completed a compilation of agency requirements for lightning detection and developed a set of standards for lightning detection systems. These documents will form the foundation for a National Weather Service procurement of operational lightning data from a commercial source and will be published in 1990. This action will complete the national plan.

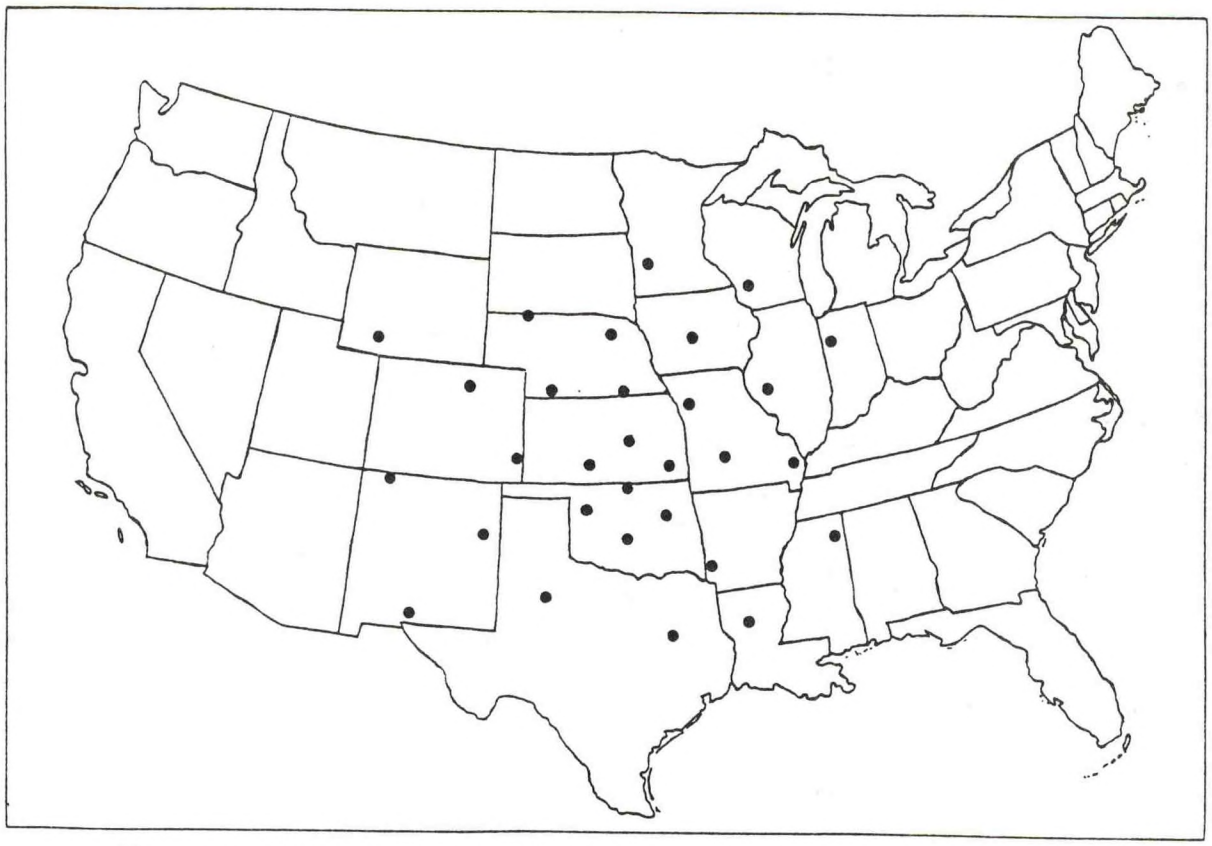

Figure 2.1 Planned Wind Profiler Demonstration Network in Central U.S.
(Dots show locations of wind profilers.)

Profiler System

The Profiler program was formally initiated in NOAA in 1980 to explore the development of ground-based systems that would supplement, and in some cases provide an alternative to, the radiosondes used for the past 50 years to obtain upper-air meteorological data. The profiler concept involves some combination of remote sensors to monitor upper-air winds, temperature, and moisture automatically and continuously. Work on instruments that can measure each of these three parameters has progressed somewhat independently and at different rates. Wind profiler development, for example, has reached the stage where instruments are now being produced by industry and a demonstration network will be implemented during the 1989-1991 time frame. Development of thermodynamic profilers to measure temperature and moisture, while promising, has not reached this stage.

Wind Profilers. The NOAA wind profiler demonstration network will consist of 30 stations located across the central U.S. (See Figure 2.1.) This network is scheduled to operate from 1990 through 1992 providing data for assessing the impact of this new information and the new instruments on NWS operations, and on a range of atmospheric research problems.

Data from the network will be collected at the Environmental Research Laboratories in Boulder, CO, and redistributed in both real-time and retrospectively to the NWS and several research groups. These data will form the basis of an assessment activity designed to determine the value of a national network and to make decisions concerning the implementation of such a network.

Other agencies have also recognized the potential value of wind profilers. Research groups in both the U.S. Army and U.S. Air Force have procured profilers for use in their research and to assess the role of such instruments as a military weather support tool. NASA has installed one system at Kennedy Space Center and is in the process of examining the role of profilers in test range weather support. The OFCM Working Group for Profiler Systems is coordinating interagency activities in this field.

Thermodynamic Profiling. Within the past year, several promising advances have occurred in remote sensing of temperature and moisture. These advances include the Radio Acoustic Sounding System (RASS), the High-resolution Interferometric Sounder (HIS), the correlation radiometer (CORRAD), and the Raman and Differential Absorption Lidar (DIAL). The six-channel microwave radiometer has continued to operate at Stapleton International Airport, Denver, CO, alongside the NWS radiosonde launch site. Several experiments have been conducted to compare and to combine data from these new techniques:

(1) Comparisons of temperature soundings from NWS radiosondes, from RASS, and from the microwave radiometer have been made for 22 cases. RASS profiles had excellent vertical resolution over a limited portion of the atmosphere (from 1 to 3 km above ground level); a combination of RASS data with those of the microwave radiometer yielded temperature profiles with rms accuracies of better than 1°K up to 8 km.

(2) An experiment at Stapleton Airport was conducted from October 29 to November 4, 1988. Instruments used included HIS, RASS, and the microwave radiometer. Analysis of the data is continuing; preliminary results of deriving both temperature and humidity profiles are encouraging.

(3) Limited experimentation with RASS resulted from using radars that operated at 915, 405, and 50 MHz. The upper height range of soundings depends strongly on wavelength; soundings at 50 MHz were obtained to about 10 km above ground level.

As a result of the successful tests completed in 1989, NOAA has officially accepted the Unisys-produced Wind Profiler and authorized production of the remaining 30 wind profilers for the NOAA demonstration network as depicted in Figure 2.1. above. All of the profiler sites have been acquired with 20 sites fully prepared to date. The contract for input communications has been awarded to CONTEL. In case of CONTEL satellite failure, GOES DCS would be used as a backup.

The profiler Hub (at ERL in Boulder, CO) is operational, receiving data from the Platteville, CO, wind profiler and sending test data sets to NMC. Installation of the 30 wind profilers has commenced with completion scheduled by April 1991. NWS will conduct an assessment of the NOAA wind profiler demonstration network starting late 1990 and run through 1992. The assessment will include looking at the meteorological uses and engineering aspects of the network.

Space Environment Services and Supporting Research

The National Space Environment Forecast and Warning Program provides Federal agencies and public users real-time space environment data, forecasts of the time of terrestrial impact of significant solar output variations, and warnings of solar events threatening human life or effective and economic operation of modern technical systems. The common needs of the participating agencies have led to a program of shared resources and responsibilities that extend to observations and to operation of forecast centers which provide standard services to meet those needs.

Observations of solar activity with optical and radio telescopes are provided by the Department of Defense (DOD). Solar and near-earth space environment observations are provided by complementary sensors on DOD and Department of Commerce (DOC) environmental satellites. DOD provides ionospheric and geomagnetic field data from terrestrial networks. Research data, also useful for the forecast and warning services, are obtained from other agencies and shared through real-time communication networks and jointly operated data bases. Research data from the National Science Foundation (NSF) experiments have been made available through these data sharing arrangements. Provision for real-time access to data from National Aeronautics and Space Administration satellites has been made for missions where the data are shown to have operational use and where logistical arrangements for data reception can be worked out. The Departments of Energy (DOE) and Interior (DOI) make space-based and ground-based data available though similar arrangements. The Department of Transportation (DOT) operates radio navigation systems that also provide information on the state of solar-terrestrial disturbances. Universities and private foundations engaged in solar-terrestrial research contribute to the pool of observations. Finally, real-time exchange of data with other countries through the International Ursigram and World Days Service fills gaps in the U.S. observing system. Most of the data gathered in this program are archived in data centers for use in future studies.

The data gathered in the space environmental monitoring program needs to be reduced to a set of standardized indices and warnings and used to make forecasts of future levels of activity. A Space Environment Services Center to provide the forecasts and warnings and data bases to the agencies is operated jointly by DOD and DOC to meet common needs. Some agencies, such as DOD, also operate dedicated centers to meet specific agency needs beyond those provided by the common service. Most of the data gathered in the operational portion of the space environment program are archived in the National Geophysical Data Center.

The role and responsibilities of agencies participating in the space environment program are detailed in the National Plan for Space Environment Services and Supporting Research: 1988-1993 (FCM-P10-1988), which was prepared by the OFCM Committee on Space Environment Forecasting and published in 1988.

Monitoring the Stratosphere

There is considerable public concern and political debate about the possible man-made effects and influences on the ozone layer. Similarly, there are concerns about possible changes in the earth's global climate. To measure these effects and changes, if any, long-term monitoring of the ozone and other stratospheric trace gases and temperatures is necessary.

In 1982, OFCM published The National Plan for Stratospheric Ozone Monitoring and Early Detection of Change, 1981-1986. The plan developed a program of transition from a reliance on a ground-based network to a combined satellite and ground-based program providing global coverage of ozone and temperature.

The more recent National Plan for Stratospheric Monitoring, 1988-1997 (FCM-P17-88) published in 1988 builds on the previous effort and, in particular, stresses that the problem is not simply one of detecting ozone change. The complex interactions of chemistry, radiation, and dynamics require that meteorological parameters and many chemical species be monitored. Moreover, experience has shown that monitoring, per se, is not a simple engineering problem of taking observations at a station. The stratospheric changes being sought are relatively small, thus monitoring should be considered as a combination of theory, laboratory measurements, field

measurements, and interpretation. Sections in the plan give detailed attention to monitoring ozone, meteorology (temperature and winds), solar irradiance, source gases, and trace gases. The agencies' programs and plans for monitoring are described.

The plan has three themes:

(1) The monitoring system cannot rely on data from a single instrument because systematic errors in individual instruments can lead to erroneous trend detection. Intercomparison of data from different instruments is necessary;

(2) Monitoring requires a combination of a high quality/low spatial resolution ground-based system and a high spatial resolution satellite system;

(3) Changes in the stratosphere can result from natural and man-made perturbations. It is, therefore, essential that the agency research programs be complementary with the monitoring program.

From the viewpoint of sensors and sensor platforms, the overall timeframe of 1988-1997 can be subdivided into three general periods. From the present to the early 1990s, the emphasis is on the development of the Network for Detection of Stratospheric Change (NDSC) sponsored by NASA, NOAA, the World Meteorological Organization (WMO), and the Chemical Manufacturers Association (CMA). This is to be a high-technology ground-based program designed to supplement the current ground-based systems and provide, from at least six sites, information on many species and parameters. This Network will serve both to validate/calibrate the available satellite systems and provide information on possible causes of ozone change. Starting in the early 1990s, the NASA Upper Atmosphere Research Satellite (UARS) will make measurements of many of the parameters of interest in this Plan. UARS, which is planned to be launched in late 1991, is a unique instrument of opportunity that will be included within the monitoring program for as long as this satellite lasts. Finally, for the late 1900s, consideration is given to the next-generation NOAA operational satellite systems and the Earth Observing System.

Federal Meteorological Requirements for the Year 2000

A contract for a study of Federal requirements for meteorological services and supporting research for the year 2000 was awarded in August, 1989. The study was requested by the former chairman of the Federal Committee for Meteorological Services and Supporting Research. The study will be completed in one year, and is expected to reveal new opportunities for interdepartmental cooperation.

Improved Weather Reconnaissance System (IWRS)

The United States Air Force (USAF) and the National Oceanic and Atmospheric Administration (NOAA) require high quality and a large quantity of weather data from USAF WC-130 weather reconnaissance aircraft. These data are needed to improve the forecasts and warnings of tropical cyclones and East Coast winter storms. To provide improved data in support of the National Hurricane Center (NHC) and the National Meteorological Center, eight aircraft of the 53rd Weather Reconnaissance Squadron and four from the 815th Weather Flight (USAFR) at Keesler Air Force Base have now been configured to fly IWRS, a newly developed, fully automated, meteorological data gathering system. The OFCM managed the production contract, and all deliveries occurred on schedule, in advance of the June 1990 hurricane season. Although all twelve aircraft will not be available for the entire hurricane season due to scheduled navigational upgrades, there will be a sufficient level of IWRS capability throughout the season. The OFCM

also arranged for IWRS system maintenance during this season to assure a smooth transition of these systems into the USAF inventory and logistical support network.

Based on demonstrated capability, the IWRS will improve hurricane and tropical cyclone reconnaissance through:

- Continuous, high-density data acquisition at all flight levels;
- Enhanced dropsonde density and work-up capability;
- Real-time data communication with the National Hurricane Center via USAF satellite network;
- Automated forms generation and observation documentation;
- New graphical data products and capabilities;
- Elimination of inadvertent data entry and transmission errors.

Committee and Working Group Changes

A schematic of the Federal Committee structure for meteorological coordination is found on the back inside cover of this Plan. In the past year, the following changes were made in the coordinating structure:

- The National Aviation Weather Program Council was established, as described above.

- An Ad Hoc Group for Tropical Cyclone Research was established to review recent tropical cyclone research, assess developing sensors and other technology, and publish -- and periodically update -- a national plan to guide research in tropical cyclone meteorology.

- A Working Group for Marine Environmental Services (WG/MES) was formed by combining the Working Group for Drifting Data Buoys and the Working Group for Marine Environmental Predictions. The latter two groups were disestablished.

- The Ad Hoc Group for NOAAPort Liaison (AHG/NPL) was transferred from ICMSSR to the Committee for Automated Weather Information Systems (CAWIS).

- The Task Group for Tropical Cyclone Studies submitted the report they were tasked to prepare and they were disestablished.

Meteorological Publications of OFCM

The preparation of Federal plans is a major responsibility of the Federal Coordinator and requires extensive planning and coordination. Generally, Federal plans are prepared for each of the specialized meteorological services and for meteorological programs common to two or more agencies. In most cases, the preparation of Federal plans is facilitated by the existence of individual agency plans for the service or program involved. The Federal Coordinator compiles information from the involved agencies and proposes a unified plan for consideration. Current publications of the Federal Coordinator for Meteorology are listed in Table 2.1. In general, single copies are available upon request to OFCM.

Table 2.1 Current Publications of OFCM

Title	Date	Number
Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 1991	April 1990	FCM-P1-1990
National Plan for Space Environment Services and Supporting Research: 1988-1993	October 1988	FCM-P10-1988
National Severe Local Storms Operations Plan	April 1989	FCM-P11-1989
National Hurricane Operations Plan	April 1990	FCM-P12-1990
National Winter Storms Operations Plan Change 1	October 1987 October 1988	FCM-P13-1987
Federal Plans for Mutual Support and Cooperative Backup Among Operational Processing Centers	March 1985	FCM-P14-1985
National Plan for Stratospheric Monitoring, 1988-1997	September 1988	FCM-P17-1988
National Aircraft Icing Technology Plan	April 1986	FCM-P20-1986
National Plan to Improve Aircraft Icing Forecasts	July 1986	FCM-P21-1986
Preliminary National Plan for Lightning Detection Systems	June 1988	FCM-P22-1988
Federal Plan for the Coordination of Automated Weather Information System Programs	May 1988	FCM-P23-1988
Federal Plan for Meteorological Information Management	July 1990 (Estimated)	FCM-P24-1990
Federal Meteorological Handbook No. 1 - Surface Observations	April 1988	FCM-H1-1988
Federal Meteorological Handbook No. 2 - Surface Synoptic Codes	December 1988	FCM-H2-1988
Federal Meteorological Handbook No. 10 - Rocketsonde Observations	December 1988	FCM-H10-1988
Tropical Cyclone Studies Tropical Cyclone Studies Supplement	December 1988 August 1989	FCM-R11-1988 FCM-R11-1988 S
Interdepartmental Meteorological Data Exchange System Report	July 1989	FCM-R12-1989
Standard Formats for Weather Data Exchange Among Automated Weather Information Systems	December 1986	FCM-S2-1986
Standard Telecommunication Procedures for Weather Data Exchange	July 1989	FCM-S3-1989
Federal Standard for Siting Meteorological Sensors at Airports	May 1987	FCM-S4-1987

RELATED FEDERAL METEOROLOGICAL COORDINATION

The focus of OFCM and of this report is on Federal operational meteorological programs and directly supporting research. While not specifically a part of OFCM activities, brief descriptions are given below of Federal coordination activities that relate to other aspects of meteorology.

Subcommittee for Atmospheric Research

The Subcommittee for Atmospheric Research (SAR) was originally the Interdepartmental Committee for Atmospheric Sciences (ICAS). It was established in 1959 by the Federal Council for Science and Technology (FCST) and was the principal mechanism for coordination of research in atmospheric sciences within the Federal Government until 1977. At that time, FCST and its subordinate organizations were abolished and replaced by the Federal Coordinating Council for Science, Engineering and Technology (FCCSET). SAR succeeded ICAS and became a Subcommittee of the FCCSET Committee on Atmosphere and Oceans (CAO). In 1987 the CAO was disestablished and replaced by the Committee on Earth and Environmental Sciences (CEES). The SAR is now a standing subcommittee under CEES.

The primary goal of SAR is to improve the planning and coordination of atmospheric research activities among the agencies involved. Agencies represented on SAR are the U.S. Departments of Agriculture, Commerce, Defense (Army, Navy, Air Force), Energy, Interior, and Transportation. The Environmental Protection Agency, National Aeronautics and Space Administration, and National Science Foundation are also represented. Observers from several other agencies such as the Office of the Federal Coordinator for Meteorological Services and Supporting Research, the National Climate Program Office, the Office of Science and Technology Policy, and the National Academy of Sciences/National Research Council complete the SAR.

SAR publishes a biennial report on the National Atmospheric Sciences Program that is distributed widely. The 1984-87 report highlighted those years for budget purposes and focused on FY 1986 for the narrative involvement by agencies in atmospheric sciences and major field programs. The report includes retrospective budget data. The next SAR report is being prepared now and will highlight 1987-1990 activities and budgets.

National Climate Program

The National Climate Program (NCP) was established in 1978 by Public Law 95-367 to help "understand and respond to natural and man-induced climate processes and their implications." This interagency program of research and applications is managed by the National Climate Program Office (NCPO) for the Secretary of Commerce. The Act also mandates the development of an Intergovernmental Climate Program aimed at supporting "Federal and State cooperative activities in climate studies and advisory services" at state and regional levels, and the augmentation of climate research activities by the establishment of Experimental Climate Forecast Centers.

In 1986, the Act was amended by Public Law 99-272. An interagency Climate Program Policy Board is now responsible for coordinated planning and program review for the Program, review of all agency and department budget requests related to climate, submittal of a report to the Office of Management and Budget concerning such budgets, and consultation with users and producers of climate data, information and services. The amended Act provides that the NCPO be headed by a Director who represents the Board and is the spokesperson for the Program. The NCPO also serves as staff for the Board, reviews each agency budget request, coordinates interagency

participation in international climate-related activities, and works with the National Academy of Sciences and other private, academic, state and local groups in preparing and implementing the 5-year plan and the Program.

Activities of the NCP are reported each year in an Annual Report to Congress, copies of which can be obtained from the National Climate Program Office, NOAA, [Telephone: (202) 673-5360]. Copies of the Program's 5-year Plan are also available.

World Weather Program

International activities relating to meteorological services and data exchange are carried out under the World Weather Program of the World Meteorological Organization which is a specialized agency of the United Nations. The World Weather Program is described in Appendix E.

SECTION 3

RESOURCE INFORMATION AND ANALYSES

Resources included in the Federal Government requested budget for FY 1991 for meteorological services and supporting research total $2.354 billion. This is an increase of 12.3 percent from the amount appropriated for FY 1990. Of the total, the Department of Defense budget represents 35.5 percent, Department of Commerce about 34 percent, and Federal Aviation Administration about 20 percent with the remaining 10.5 percent for other agencies.

The tables in this section summarize fiscal information of the Federal Government for the fiscal years 1990 and 1991. The funds shown are those used to provide meteorological services and supporting research which has as its immediate objective the improvement of these services. Fiscal data are current as of the end of February 1990 and are subject to later changes. The data for FY 1991 do not have legislative approval and do not constitute a commitment by the U.S. Government. The budget data is prepared in compliance with Section 304 of Public Law 87-843, in which Congress directed that an annual horizontal budget for meteorological programs in the Federal agencies be prepared.

AGENCY OBLIGATIONS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

The fiscal information in Table 3.1 is presented by agency for meteorological operations and supporting research and shows the planned (appropriated) funding level for FY 1990, the budget request for FY 1991, the percent change, and the individual agencies' percent of the total Federal funding for FY 1990 and FY 1991.

DEPARTMENT OF AGRICULTURE (USDA)

The USDA budget request for FY 1991 is $31.16 million for operations and supporting research. This is an increase of 30.4 percent from the planned funding level of $23.89 million for FY 1990. The FY 1991 funding for meteorological operations ($9.82 million) permits USDA to assist the Department of Commerce in determining farmers' needs for weather information and in disseminating such information to them. Major USDA activities related to weather observations include the incremental modernization of the snow telemetry (SNOTEL) system operated by the Soil Conservation Service and the replacement of manual fire rating stations with remote automated weather stations (RAWS) by the Forest Service. The SNOTEL and RAWS networks provide cooperative data for NOAA's river forecast work, the irrigation water supply estimates, and Bureau of Land Management operations. The Digital Weather Image Processing System (DWIPS) has enhanced global monitoring capabilities through integration of satellite data with ground observations for global monitoring of crop conditions by the Joint Agricultural Weather Facility.

The supporting research component of the USDA request ($21.33 million) focuses on understanding the interactions of weather and climate with plant and animal production and water resources management. The mission of the supporting research is to develop and disseminate information and techniques to ensure an abundance of high-quality agricultural commodities and products while minimizing adverse effects of agriculture on the environment. The increase reflects an enhanced effort on plant response to ultraviolet band (UVB) radiation and has been coordinated with the Environmental Protection Agency's UVB program. The Forest Service initiated in FY 1988 a priority research program to establish a long-term monitoring network to assess potential effects of global climate change and variability on forest health and productivity.

TABLE 3.1 METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH COSTS, BY AGENCY
(Thousands of Dollars)

AGENCY	Operations			% of FY91	Supporting Research			% of FY91	Total			% of FY90	% of FY91
	FY90	FY91	%CHG	TOTAL	FY90	FY91	%CHG	TOTAL	FY90	FY91	%CHG	TOTAL	TOTAL
Agriculture	9004	9824	9.1	0.5	14889	21336	43.3	5.0	23893	31160	30.4	1.1	1.3
Commerce/NOAA	639817	749778	17.2	38.8	50596	48935	-3.3	11.6	690413	798713	15.7	32.9	33.9
Defense(Subtot)	674744	697685	3.4	36.1	132719	138250	4.2	32.7	807463	835935	3.5	38.5	35.5
Army	11961	15520	29.8	0.8	37591	40779	8.5	9.6	49552	56299	13.6	2.4	2.4
Navy	92119	96177	4.4	5.0	33890	33890	0.0	8.0	126009	130067	3.2	6.0	5.5
Air Force	570664	585988	2.7	30.3	61238	63581	3.8	15.0	631902	649569	2.8	30.1	27.6
Interior/BLM	870	870	0.0	0.0	0	0	0.0	0.0	870	870	0.0	0.0	0.0
Transp/CG	1990	1990	0.0	0.1	0	0	0.0	0.0	1990	1990	0.0	0.1	0.1
Transp/FAA	355501	464842	30.8	24.1	13411	8059	-39.9	1.9	368912	472901	28.2	17.6	20.1
EPA	0	0	0.0	0.0	6560	6560	0.0	1.6	6560	6560	0.0	0.3	0.3
NASA	6167	6660	8.0	0.4	190100	199600	5.0	47.2	196267	206260	5.1	9.4	8.8
NRC	195	195	0.0	0.0	40	40	0.0	0.0	235	235	0.0	0.0	0.0
TOTAL	1688288	1931844	14.4	100.0	408315	422780	3.5	100.0	2096603	2354624	12.3	100.0	100.0
% of FY TOTAL	80.5	82.0			19.5	18.0			100.0	100.0			

DEPARTMENT OF COMMERCE (DOC)

All reported DOC meteorological activities are within the National Oceanic and Atmospheric Administration (NOAA). The NOAA FY 1991 total congressional request of $798.7 million for meteorological programs is 15.7 percent more than the FY 1990 appropriated funds.

Changes in NOAA's operations and supporting research for FY 1991 are presented below, subdivided by activities. NOAA proposes to streamline NWS management by consolidating six of the National Weather Service (NWS) regions into four, saving a net of $1.2 million and eliminating 30 positions (NWS savings $852,000 and 18 positions). Additional items that affect the budget are discussed under Weather Services, Environmental Satellite, Data, and Information Services; and Weather Research.

Weather Services. Increases in the subactivity for FY 1991 include the following: NWS requests an increase of $11.0 million and 38 positions for the Modernization and Associated Restructuring Demonstration and Implementation (MARDI) program. Funding is necessary to prepare for the multi-site operational demonstration as well as implementing the modernization program nationwide. NWS also requests an increase of $43.3 million to fund its share of the tri-agency NEXRAD program. The increase is necessary to augment funding the production phase and initiate logistics support activities. $5.4 million is needed for the Automated Surface Observation Systems (ASOS) to proceed with the full-scale production phase. Plans also include an increase of $28.4 million for the AWIPS/NOAAPORT program. The requested level will allow completion of the Definition Phase efforts; initiation of the Development Phase; and provision for remapping of GOES data at NESDIS.

Proposed FY 1991 decreases include the following: NWS requests a decrease of $500,000 for maintenance costs associated with the first Class VII computer to be installed in the second quarter of FY 1990. Reduce staff forecast services at eight WSFO's for a savings of $787,000 and 35 positions. Consolidate the Pacific and Alaska region headquarters for a savings of $383,000 and 11 positions. Eliminate contractual data buoy system engineering and tests for $540,000. Discontinue maintenance of four moored buoys surrounding Hawaii for $565,000. Eliminate agriculture weather services for $2.4 million and 37 positions. Reduce fire weather services for $470,000 and 8 positions. Discontinue the operation support for the Susquehanna and the Colorado River Basin Flood Warning System for a total of $1.0 million. Savings of $200 thousand will be achieved by canceling contract observations at Stampede Pass, Washington; Sexton Summit, Oregon; and Blue Canyon, California. A decrease of $1.1 million is requested for equipment maintenance.

Environmental Satellite, Data, and Information Services. Proposed funding for FY 1991 includes an increase in the polar-orbiting satellite program of $49.4 million and a decrease in the geostationary satellite program of $26.8 million. These changes will allow for continuation of procurements to provide the spacecraft and instruments, launch services, and ground systems necessary to assure continuity of environmental satellite coverage. The FY 1991 budget request will maintain a system of polar-orbiting satellites that obtains global data and a system of geostationary satellites that provides near continuous observations of the Earth's western hemisphere.

Funds are also included to provide basic mission services including maintenance and operation of satellite ground facilities; provision of satellite-derived products; conduct of research

to improve the use of satellite data; and the archiving and dissemination of climatic, oceanographic and geophysical data.

Weather Research. Under the Weather Research line item, including Solar Environmental Research, there will be a net decrease of $1.5 million. Major elements are decreases of $2.2 million in Cooperative Federal/State weather research, a program that supports studies of the physical mechanisms of cloud and precipitation formation, and $1.8 million for development and evaluation of electronic forecaster workstations for use in weather warning offices of the 1990's. These decreases are partly offset by an increase of $1 million for a Class VII supercomputer upgrade at the ERL/Geophysical Fluid Dynamics Laboratory.

Solar environmental research will increase by $1.5 million to improve forecasts of solar-terrestrial conditions through the integration and application of new data sources, by data technique development, and research to better understand the solar-terrestrial system. This increase will allow for the analysis and use of data from numerous sources that will soon be available. These sources include interplanetary scintillation data, improved energetic particle flux data from GOES-I, and solar x-ray images from the GOES Solar X-ray Imager.

The FY 1991 request also includes $1.3 million for upgrades to NOAA's P-3 aircraft.

DEPARTMENT OF DEFENSE (DOD)

The DOD total budget request for FY 1991 is $835.9 million which is 3.5 percent more than the total funding level for FY 1990. Details are given below.

U.S. Army

Army spends approximately $12 million per year on operational support for its artillery meteorological sections and on support costs associated with USAF weather detachments and personnel assigned to the Army. The Field Artillery School will lose ten instructors in FY 1991, but will expend between $1 to $3 million for Meteorological Measuring Sets, as they become available, to support the training programs. Forces Command will spend approximately $0.5 million in FY 1991 to upgrade the GOLDWING tactical weather communication system. Cost associated with the peacetime garrison support and tactical training support by the USAF Weather Teams is expected to remain about the same in FY 1991. Atmospheric Sciences Laboratory (ASL) will spend approximately $33.5 million in FY 1990, which is about 90 percent of the Army RDT&E funds for meteorological research. Over 50 percent of the ASL funding is for the Meteorological Teams at test facilities and ranges for program support. In FY 1991 another Meteorological Team will be added at the U.S. Army Cold Regions Research and Engineering Laboratory, and ASL will increase exploratory development on Global Positioning System (GPS) radiosondes and atmospheric effects on acoustics. Total increase in the ASL budget is about $3 million in FY 1991. The other meteorological R&D efforts are expected to remain constant.

U.S. Navy

Operations Support. Operations Support for Navy includes the day-to-day provision of meteorological products and services, as it does for other agencies. Navy also provides specific and unique services such as acoustic propagation models and products, environmentally-sensitive tactical decision aids, and global ice analysis and forecast products. Communication costs are significant for an organization with global responsibilities, and the uniqueness of forces at sea drives requirements for specific products and communications capabilities.

Systems Acquisition. Major systems undergoing procurement in FY-1991 are identified below (see Appendix B for more detail):

- Tactical Environmental Support System (TESS)
- Primary Oceanographic Prediction System
- SMQ-ll Environmental Satellite Receiver/Recorder
- Automated Observation System
- Shipboard Meteorological and Oceanographic Observation System
- NEXRAD Principal User Processors (PUPs)

Systems Development Supporting Research. This category equates to Research and Development efforts focused on the development of a specific system. Navy's tabulation of these data includes R&D funding for Advanced Development initiatives. An office has been established within the Commander, Naval Oceanography Command to define the environmental needs and develop, integrate and implement R&D programs to meet the requirements of emerging systems. This Emerging Systems Program Office ensures that research efforts sponsored by Naval Oceanography are keyed to the systems and equipment which will be in use.

Research and Development. This equates to basic or exploratory research, usually conducted by a government or university laboratory. This research is not generally system-specific, but may have applications to one or more meteorological, oceanographic or tactical systems. Navy's tabulation of these data includes R&D funding for Exploratory Development initiatives.

U.S. Air Force

Operations. The operations budget request for FY 1991 is $586 million, of which the Defense Meteorological Satellite Program (DMSP) comprises $275 million. Excluding DMSP, since last year's Federal Plan submission, the operations budget was reduced $12 million in FY 1990 and another $8 million in FY 1991. The $20 million reduction impacts programs requiring operations and maintenance (O&M) funding and reduces weather systems procurement efforts. Operations and maintenance funding reductions were primarily applied to Air Force Global Weather Central computer hardware and software maintenance efforts. Consequently, the Automated Computer Flight Plan, a computer system which provides improved flight planning information to aircrews may be delayed; and work on the Air Force Global Weather Central Software Improvement Program (ASIP) will be decreased. Additionally, technology transition/weather computer software models for improved cloud analysis and forecasting and space environment specification may be delayed.

DMSP FY 1991 funding increases are primarily associated with a $16 million increase for DMSP Mark IV-B tactical ground receiving/processing terminals and a $5 million increase in multi-year procurement of a satellite (S18). Weather systems FY 1991 procurements were decreased approximately $13 million resulting in a $6 million reduction to the Automated Weather Distribution System (AWDS) and a $7 million decrease in weather equipment spares funding. FY 1991 AWDS funding remains at the FY 1990 level which provides that installations will continue at the rate of five sites/month. Other FY 1991 programs include continuation of payments to the Department of Commerce towards the Next Generation Weather Radar full production, and continuation of the three year program to upgrade/replace unsupportable components of the Solar Electro-Optical Network.

Supporting Research. The FY 1991 budget for supporting research and development is $63.58 million which is a 3.8 percent increase over FY 1990. Again, the increase is almost totally comprised in the Defense Meteorological Satellite Program (DMSP). DMSP funds continue to provide for the continuation of the microwave imager/sounder design development, sensor calibration/validation studies, and most importantly, Block VI concept studies. Developmental funding for the DMSP Mark IV-B tactical ground terminals also continues from FY 1990 into FY 1991.

Research funds in the weather systems development area support efforts to refine NEXRAD algorithms, enhancements to the Automated Weather Distribution System through preplanned productivity enhancements, efforts to obtain weather sensors for employment on unmanned air reconnaissance vehicles, development of a new sensor for the Radio Solar Telescopes, and development of new weather computer models to improve space environment specification. The Air Force continues to monitor the Department of Commerce's Automated Surface Observing System prototype development and testing program.

DEPARTMENT OF THE INTERIOR (DOI)

The DOI funding request is for meteorological operations within the Bureau of Land Management (BLM). The FY 1991 request is for $870 thousand which is the same as for FY 1990. In the BLM, the total implementation of the Bureau-wide Initial Attack Management System (IAMS) and the Remote Automated Weather Station (RAWS) programs has been severely hampered over the years as a result of overall funding problems. In FY 1987, this trend changed as the funding and implementation for these programs were re-emphasized with a planned FY 1991 program completion. This established changes in the operational and maintenance (O&M) funding required and the procurement funding needed to complete the total system. Annual increases in program costs are attributed to the increased requirements of personnel, travel, and operations to cover the added stations and network expansion to full implementation. After full implementation is reached, procurement costs will be reduced to systems life cycle change-out and O&M costs will normally plateau.

DEPARTMENT OF TRANSPORTATION (DOT)

Within DOT, the U.S. Coast Guard and the Federal Aviation Administration have reported on meteorological programs in FY 1990 and FY 1991.

U.S. Coast Guard (USCG)

All of USCG's funding for meteorological programs is for operations support. In FY 1991, the requested funding level is $1.99 million. This is unchanged from the planned funding for FY 1990. Among the Coast Guard's activities is the collection and dissemination of meteorological information for the benefit of the marine community. The Coast Guard provides this information to NOAA's National Weather Service and provides use of facilities to the National Data Buoy Center.

Federal Aviation Administration (FAA)

The FAA total proposed funding for FY 1991 is $472.9 million which represents an increase of 28.2 percent over FY 1990. Significant changes in funding for operations include increases for ASOS, NEXRAD, Direct User Access Terminal, ground-to-air data links for weather data, the Weather Message Switching Center replacement, Flight Service Station Automation, FSS pilot briefings, and contracting for weather observations at Flight Service Stations; offset by decreases

in funding for the Automated Weather Observing System (AWOS), and Terminal Doppler Weather Radar (TDWR). Also the Terminal NEXRAD has been cancelled as a result of a decision to rely on the closely related TDWR. The FAA's role in operational meteorology is limited to observation taking and observation systems, pilot briefings, communications, equipment for the Center Weather Service Units, Flight Service Stations, and the Weather Message Switching Center, and the maintenance of this equipment. In this plan the FAA has, for the first time, included weather briefings to pilots and weather observations taken by Flight Service Station specialists as meteorological functions. For this reason, the FY 1990 base figures are about $124 million higher than the FY 1989 base used in last year's Federal Plan for FY 1990.

Supporting research generally follows the same functional areas as operations. Even though there is a proposed six percent decrease in funding for research, represented by decreases in the Low Level Wind Shear Alert System (LLWAS) and NEXRAD projects, there are offsetting increases in projects for aircraft icing forecasting and airborne windshear advanced technology.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

All of EPA funding of meteorological programs is for supporting research. The requested funding for FY 1991 is $6.56 million, which is equal to the planned funding in FY 1990. EPA is continuing development and validation of air quality dispersion models for pollutants on all temporal and spatial scales. The research will focus on indoor, urban, mesoscale and regional models, and will be used to develop pollution control and exposure assessment strategies. Increased emphasis will be placed on meteorological research into regional ozone transport, global climate change, and acid aerosol formation, while research into acid deposition model development and evaluation will be decreased.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Virtually all of NASA's funding in meteorology is for supporting research. Historically, this research has been reported as "supporting research" in the annual Federal Plan for Meteorological Services and Supporting Research because a significant fraction of the activity is applicable to meteorological problems. This year's report provides a more realistic estimate of the actual portion of each element in the program which directly supports meteorological objectives as opposed to the Earth science objectives of NASA. The result is a reduction in both the FY 1990 and FY 1991 budget estimates.

Under this revised accounting, the FY 1991 request for supporting research is $199.6 million, an increase of 5 percent from the FY 1990 level. This results from the transfer of the Earth Observing System (EOS) platforms to the Office of Space Science and Applications, a new start for Earth Probes, and the reductions in the Upper Atmospheric Research Satellite (UARS) and Scatterometer budgets as these programs progress toward completion of flight hardware.

NUCLEAR REGULATORY COMMISSION (NRC)

The total NRC requested funding for FY 1991 is $235,000. The FY 1991 request is essentially unchanged from the FY 1990 funding. The FY 1991 request includes $195,000 for operations and $40,000 for supporting research.

The meteorological support program in the U.S. Nuclear Regulatory Commission (NRC) is primarily focused on obtaining and analyzing meteorological data and information to be utilized in atmospheric dispersion models used in the determination of concentration and dose projections,

TABLE 3.2 AGENCY OPERATIONAL COSTS, BY BUDGET CATEGORY
(Thousands of Dollars)

AGENCY	Operations Support FY90	Operations Support FY91	Systems Acquisition FY90	Systems Acquisition FY91	Special Programs FY90	Special Programs FY91	Total FY90	Total FY91	%CHG	% of FY91 TOTAL
Agriculture	8520	9320	0	0	484	504	9004	9824	9.1	0.5
Commerce/NOAA	382597	393944	252606	351197	4614	4637	639817	749778	17.2	38.8
Defense(Subtot)	475169	474648	199575	223037	0	0	674744	697685	3.4	36.1
Army	11961	12010	0	3510	0	0	11961	15520	29.8	0.8
Navy	85856	92346	6263	3831	0	0	92119	96177	4.4	5.0
Air Force	377352	370292	193312	215696	0	0	570664	585988	2.7	30.3
Interior/BLM	870	870	0	0	0	0	870	870	0.0	0.0
Transp/CG	1990	1990	0	0	0	0	1990	1990	0.0	0.1
Transp/FAA	172722	213249	178783	247228	3996	4365	355501	464842	30.8	24.1
EPA	--------- Not Applicable ---------									
NASA	3408	4433	2002	1218	757	1009	6167	6660	8.0	0.3
NRC	195	195	0	0	0	0	195	195	0.0	0.0
TOTAL	1045471	1098649	632966	822680	9851	10515	1688288	1931844	14.4	100.0
% of FY TOTAL	61.9	56.9	37.5	42.6	0.6	0.5	100.0	100.0		

and plume pathway characterizations related to the safe operation of nuclear facilities and the protection of the health and safety of the public and the environment. Obtaining current, accurate, and relevant meteorological information on a real-time basis for use if needed during emergencies is a prime consideration. The NRC budget in this area reflects these priorities.

AGENCY FUNDING BY BUDGET CATEGORY

Table 3.2 shows how the agencies plan to obligate their funds for meteorological operations broken down by budget category. The funding levels for each agency were discussed above. Table 3.3 shows how the agencies plan to obligate their funds for meteorological supporting research according to the budget categories.

In previous years, the agencies' operational budget was subdivided into "functional" categories -- Observations, Analyses and Forecasts, Communications, Dissemination, and Management Support. Advancing technology and increasing integration of components have blurred the meaning of these functions and has made identification more difficult. The new categories were chosen to align more closely with agency budgets or, at least, to simplify the relationship between agency budgets and the new categories. As a result, the new categories are referred to as "budget categories". The two major new categories are "Operations Support" and "Systems Acquisition". To a large degree, these correspond to hardware costs (Systems Acquisition) and non-hardware costs (Operations Support). For agency convenience in identifying small components that do not fit into the above two major categories, a third category, is added, "Special Programs". The agencies supporting research budgets are subdivided along similar lines -- Systems Development (hardware), Research and Development (non-hardware), and again Special Programs for activities that do not easily fit into the first two categories.

AGENCY FUNDING BY SERVICE CATEGORY

Table 3.4 summarizes how the agencies plan to obligate operational funds for basic and specialized meteorological services; Table 3.5 indicates the corresponding data for supporting research. Table 3.4 shows that "Basic" services require approximately 52 percent of the total operational costs while Aviation Services require about 38 percent. The remaining 10 percent is used to support the other specialized services. The definitions of specialized and basic services are provided below.

Specialized Services

Aviation Meteorological Services. Those services and facilities established to meet the requirements of general, commercial and military aviation. Civil programs are included that are directly related to services in support of rotary wing aircraft and medium or long-range missile operations.

Marine Meteorological Services. Those services and facilities established to meet the requirements of Commerce and Defense on the high seas, coastal and inland waters, and for boating activities in coastal and inland waters. The civil programs which are directly related to services solely for marine uses and military programs supporting fleet, amphibious and sea-borne units (including carrier-based aviation and fleet missile systems) are included.

Agriculture and Forestry Meteorological Services. Those services and facilities established to meet the requirements of the agricultural industries and Federal, state and local agencies charged with the protection and maintenance of the Nation's forests.

TABLE 3.3 AGENCY SUPPORTING RESEARCH COSTS, BY BUDGET CATEGORY
(Thousands of Dollars)

AGENCY	Research & Development		Systems Development		Special Programs		Total			% of FY91
	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	%CHG	TOTAL
Agriculture	14889	21336	0	0	0	0	14889	21336	43.3	5.0
Commerce/NOAA	38911	41346	3776	1893	7909	5696	50596	48935	-3.3	11.6
Defense(Subtot)	128716	134865	4003	3385	0	0	132719	138250	4.2	32.7
Army	33588	37394	4003	3385	0	0	37591	40779	8.5	9.6
Navy	33890	33890	0	0	0	0	33890	33890	0.0	8.0
Air Force	61238	63581	0	0	0	0	61238	63581	3.8	15.0
Interior/BLM	--------- Not Applicable ---------									
Transp/CG	--------- Not Applicable ---------									
Transp/FAA	1980	2923	11131	4816	300	320	13411	8059	-39.9	1.9
EPA	6560	6560	0	0	0	0	6560	6560	0.0	1.6
NASA	85600	93600	104500	106000	0	0	190100	199600	5.0	47.2
NRC	40	40	0	0	0	0	40	40	0.0	0.0
TOTAL	276696	300670	123410	116094	8209	6016	408315	422780	3.5	100.0
% of FY TOTAL	67.8	71.1	30.2	27.5	2.0	1.4	100.0	100.0		

TABLE 3.4 AGENCY OPERATIONAL COSTS, BY SERVICE
(Thousands of Dollars)

AGENCY	Basic		Aviation		Marine		Agriculture & Forestry		General Military		Other		Total	
	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91
Agriculture	0	0	0	0	0	0	9004	9824	0	0	0	0	9004	9824
Commerce/NOAA	586252	694185	29583	34521	18165	17060	2917	1112	0	0	2900	2900	639817	749778
Defense(Subtot)	287508	305814	237117	236228	26552	27702	0	0	79186	83292	44381	44649	674744	697685
Army	0	0	0	0	0	0	0	0	11961	15520	0	0	11961	15520
Navy	15997	16463	26820	28447	26552	27702	0	0	17859	18406	4891	5159	92119	96177
Air Force	271511	289351	210297	207781	0	0	0	0	49366	49366	39490	39490	570664	585988
Interior/BLM	0	0	0	0	0	0	0	0	0	0	870	870	870	870
Transp/CG	1374	1374	0	0	616	616	0	0	0	0	0	0	1990	1990
Transp/FAA	0	0	355501	464842	0	0	0	0	0	0	0	0	355501	464842
EPA	---------- Not Applicable ----------													
NASA	0	0	0	0	0	0	0	0	0	0	6167	6660	6167	6660
NRC	75	75	0	0	0	0	0	0	0	0	120	120	195	195
TOTAL	875209	1001448	622201	735591	45333	45378	11921	10936	79186	83292	54438	55199	1688288	1931844
% of FY TOTAL	51.8	51.8	36.9	38.1	2.7	2.3	0.7	0.6	4.7	4.3	3.2	2.9	100.0	100.0

TABLE 3.5 AGENCY SUPPORTING RESEARCH COSTS, BY SERVICE
(Thousands of Dollars)

AGENCY	Basic		Aviation		Marine		Agriculture & Forestry		General Military		Other		Total	
	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91	FY90	FY91
Agriculture	0	0	0	0	0	0	14889	21336	0	0	0	0	14889	21336
Commerce/NOAA	47345	44186	1767	1767	0	0	0	0	0	0	1484	2982	50596	48935
Defense(Subtot)	6650	6890	0	0	33890	33890	0	0	91467	97470	712	0	132719	138250
Army	1695	1695	0	0	0	0	0	0	35896	39084	0	0	37591	40779
Navy	0	0	0	0	33890	33890	0	0	0	0	0	0	33890	33890
Air Force	4955	5195	0	0	0	0	0	0	55571	58386	712	0	61238	63581
Interior/BLM	--------- Not Applicable ---------													
Transp/CG	--------- Not Applicable ---------													
Transp/FAA	0	0	13411	8059	0	0	0	0	0	0	0	0	13411	8059
EPA	0	0	0	0	0	0	0	0	0	0	6560	6560	6560	6560
NASA	190100	199600	0	0	0	0	0	0	0	0	0	0	190100	199600
NRC	40	40	0	0	0	0	0	0	0	0	0	0	40	40
TOTAL	244135	250716	15178	9826	33890	33890	14889	21336	91467	97470	8756	9542	408315	422780
% of FY TOTAL	59.8	59.3	3.7	2.3	8.3	8.0	3.6	5.0	22.4	23.1	2.1	2.3	100.0	100.0

General Military Meteorological Services. Those services and facilities established to meet the requirements of military user commands and their component elements. Programs and services which are part of Basic, Aviation, Marine, or Other Specialized Services are not included here.

Other Specialized Meteorological Services. Those services and facilities established to meet requirements of user agencies or groups not included in the preceding categories, such as support to civil and military programs involving space operations and support to Federal, state and local governmental agencies responsible for dealing with urban air pollution.

Basic Services

"Basic" services include the programs and activities that do not fall under one of the specialized services identified above. Basic services provide products that meet the common needs of all users and include the products needed by the general public in their every day activities and for the protection of lives and property.

PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS

Table 3.6 shows agency staff resources in meteorological operations. Overall, agency staff resources for FY 1991 total 17,681, which is about the same as for FY 1990.

TABLE 3.6 PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS
(Units are Full Time Equivalent Staff Years)*

	Total			%of FY91
AGENCY	FY 90	FY91	%CHG	TOTAL
Agriculture	96	98	2.1	0.6
Commerce/NOAA	4656	4592	-1.4	26.0
Reimbursed**	777	777	0.0	4.4
Defense (Subtotal)	9268	9308	0.4	52.6
Army	350	340	-2.9	1.9
Navy	1705	1736	1.8	9.8
Air Force	7213	7232	0.3	40.9
Interior/BLM	14	16	14.3	0.1
Reimbursed**	3	4	33.3	0.0
Transp/CG	79	79	0.09	0.4
Transp/FAA	2898	2805	-3.2	15.9
EPA	0	0	0.0	0.0
NASA	0	0	0.0	0.0
NRC	2	2	0.0	0.0
TOTAL	17793	17681	-0.6	100.0

* Numbers of personnel are rounded to nearest whole number.
** Reimbursed are personnel funded by other agencies.

INTERAGENCY FUND TRANSFERS

Table 3.7 summarizes interagency fund transfers for FY 1990 to other agencies to pay for services that the receiving agencies can perform more efficiently and effectively. While specific amounts may vary from year-to-year, depending upon agency needs, the pattern shown in this table is essentially stable and reflects a significant level of interagency cooperation.

Department of Commerce (DOC). The FAA will be reimbursed $486,000 for facilities support; the USCG $687,000 for support to the Data Buoy Center; NASA $131,000 for support at Wallop's Island; and DOI's Minerals Management Service $150,000 for continued operation of moored buoys off the California coast.

Department of Defense (DOD). The Army reimbursements include: DOC $670,000 for supporting research relating to Lidar development, horizontal path profilers, UHF wind profiler, radio acoustic sounder, radar support, icing model evaluation, mini Sodar, expendables, and coordination of supporting research; and DOE $208,000 for diffusion modeling and MACH software. The Navy will reimburse DOC a total of $740,000 of which $700,000 is for climatological analysis and forecasting and $40,000 for training in satellite applications. The Air Force will reimburse DOC a total of $1.425 million--for climate data ($668,000), NOAA's satellite relay to AFGWC ($263,000), ionospheric data ($280,000), GOES agreement ($58,000), general support ($130,000) and miscellaneous support items ($26,000). The Air Force will transfer $214,000 to DOT to support a contract for development of an observation system and $108,000 to USGS for magnetometer data.

Department of Transportation. The FAA will reimburse DOC/NOAA a total of about $18.72 million -- $6.31 million for meteorological support at Center Weather Service Units (located with most Air Route Traffic Control Centers and the National Aviation Weather Unit in Kansas City); $12.16 million for contract weather observations; and $250,000 for high altitude facsimile charts. NASA will be reimbursed $7.667 million for having the Jet Propulsion Laboratory develop the Real-time Weather Processor prototype, and for airborne windshear work at NASA Langley. The National Science Foundation will be provided $4.505 million to have the National Center for Atmospheric Research run TDWR/LLWAS field tests, and related work. The Air Force will be reimbursed $1.470 million for Lincoln Laboratory's Orlando TDWR prototype field work.

National Aeronautics and Space Administration. The Air Force will be reimbursed $435,000 for data acquisition; NOAA will be reimbursed $840,000 principally for meteorological support to the space-shuttle operations; NOAA/ERL $100,000 for wind analysis; and NOAA/NCC, $100,000 for climatological data.

Environmental Protection Agency. NOAA's Air Resources Laboratory will be reimbursed $3.5 million for research related to air quality dispersion models, and guidance for EPA policy development.

Department of Energy. The NOAA/NWS will be reimbursed $2.246 million to support the Weather Service Support Office at the Nevada Nuclear Test Site.

Nuclear Regulatory Commission. NOAA's Air Resources Laboratory will be reimbursed $50,000 for technical assistance; and DOE's PNL will be reimbursed $40,000 for technical assistance.

Department of Agriculture. NOAA's National Climate Program Office will be reimbursed $30,000 to support a study by the National Academy of Sciences.

LOCATIONS BY TYPE OF OBSERVATION

Table 3.8 indicates the number of locations or platforms at which the Federal agencies carry out (or supervise) the various types of weather observations. Both the type and the number of platforms tend to be fairly stable from year to year.

TABLE 3.7 INTERAGENCY FUND TRANSFERS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

Agency Funds Transferred from:	Agency Funds Transferred to:	FY 1990 Funds ($K) Estimated or Planned	
		Operations	Supporting Research
Commerce/NOAA	DOT/FAA	486	
	DOT/USCG	687	
	NASA	131	
	DOI/MMS	150	
Defense: Army	DOC/NOAA		670
Army	DOE		208
Navy	DOC	740	
Air Force	DOC	1,425	
Air Force	DOT		214
Air Force	USGS	108	
Transportation/FAA	DOC/NOAA	18,727	300
	NASA		7,667
	NSF		4,505
	DOD/USAF		1,470
NASA	DOD/USAF	435	
	DOC/NOAA/NWS	840	
	DOC/NOAA/ERL	100	
	DOC/NOAA/NCC	100	
EPA	DOC/NOAA/ARL		3,500
DOE	DOC/NOAA/NWS	2,246	
NRC	DOC/NOAA/ARL	50	
	DOE/PNL		40
USDA	DOC/NOAA/NCPO	30	

TABLE 3.8 LOCATIONS BY TYPE OF OBSERVATION

Type of Observation	Agency	No. of Locations (FY 1990)
Surface, land	Commerce (WSO, WSFO, WSMO)	233
	Commerce (WSCMO)	21
	Commerce (Marine Reporting/CG Station)	171
	Commerce (AMOS, RAMOS, AUTOB, DARDC)	129
	Commerce (Supplem. Aviation Wea. Reportg Station)	450
	Defense (U.S.)	173
	Defense (Overseas)	92
	Transportation (Flight Service Station)	210
	Transportation (Limited Aviation Wea. Rprtg Station)	146
	Transportation (FAA Contract Wea. Obs. Station)	19
	Transportation (USCG Coastal)	100
	Interior	214
	Agriculture	840
	NASA	2
Surface, marine	Commerce (Merchant Ship Coop Program)	1,500
	Commerce (Merch Ship Coop - Foreign Assisted)	314
	Commerce (SEAS-equipped ships)	120
	Commerce (Coastal-Marine Automated Network)	36
	Commerce (Moored Buoy)	50
	Commerce (Large Navigation Buoy)	9
	Defense (Ships with met personnel)	39
	Defense (Ships without met personnel; based on record archivals during CY 1989)	283
	Transportation (Coast Guard Ships)	77
Upper air, balloon	Commerce (U.S.)	98
	Commerce (Coop. foreign)	33
	Defense Fixed (U.S. & Overseas)	69
	Defense (Ships)	33
	Defense Mobile (U.S. & Overseas)	70
	NASA (U.S.)	2
Upper air, rocket	NASA	1
	Defense	2
Weather radar	Commerce (NWS)	129
	Commerce (At FAA Sites)	27
	Defense (U.S. & Overseas)	125
	Defense (Remote displays)	49
	NASA	1
Weather reconn. (No. of aircraft)	Commerce (NOAA)	2
	Defense (USAF)	10

SECTION 4

THE NEXT GENERATION WEATHER RADAR *

A System for Locating and Tracking Severe Weather

INTRODUCTION

The most advanced operational meteorological radar system that modern technology can provide will soon be available to meteorological personnel of the Federal Government and the private sector. It is known as the Next Generation Weather Radar (NEXRAD), a technology that has been under development and testing for meteorological applications during the past 15 years.

The NEXRAD radar (officially designated the WSR-88D) will provide enhanced detection of weather phenomena and will lead to improvements in warning accuracy and lead time for weather events such as severe thunderstorms, tornadoes, hurricanes, flash floods, hail, strong winds, and turbulence. The need for the new weather radar network is critical. Many of the weather radars now in use were deployed by the principal user agencies in the 1960s. These aging radars are difficult to maintain and lack the technical capabilities to meet the resource protection challenges of the 1990s and beyond.

Each of the NEXRAD principal user agencies, i.e., the National Weather Service, Air Weather Service, Naval Oceanography Command, and Federal Aviation Administration, needs the advanced Doppler weather radar system to fulfill their respective weather-related mission requirements. Since the NEXRAD program was officially established in 1979, the NEXRAD Joint System Program Office (JSPO) has managed the cooperative effort to develop, manufacture, and deploy the WSR-88D.

NEXRAD PROGRAM HISTORY AND ORGANIZATION

Conventional, reflectivity weather radars were the mainstay of the National Radar Network during the 1960s. These radars provided information on precipitation location by measuring the strength of radar signal echos reflected from water droplets, ice crystals, and hail. Radar operators were able to pinpoint areas of heavy rain and storm cells that could possibly produce hail, and identify shapes in the radar echo patterns known as "signatures" indicating the possible occurrence of severe weather. Timely, dependable, and accurate diagnosis of damaging winds and tornadoes was difficult to achieve. The scientific community began to explore applications of the Doppler principle as a means of solving the wind measuring problem.

It is well known that the sound of a siren from an ambulance appears to rise (increase in sound wave frequency) and then fall (decrease in sound wave frequency) as the vehicle approaches and then moves away. This phenomenon is known as the "Doppler Effect". Similar frequency changes take place with radio waves transmitted from a radar when they are reflected from targets

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* Most of the material for this article was provided by E. Don Sarreals, Special Assistant to the Director, NEXRAD Joint System Program Office. The current Director of JSPO is Samuel P. Williamson. Dr. Kenneth C. Crawford contributed information relating to operational performance and evaluation of the prototype NEXRAD and to training of forecasters in the use of NEXRAD data. Dr. Crawford was the Meteorologist-in-Charge at the Weather Service Forecast Office at Norman, Oklahoma at the time of the NEXRAD operational tests. He is currently Director, Oklahoma Climatological Survey at the University of Oklahoma.

that are moving toward or away from the radar. These frequency changes are directly proportional to the speed of the target and can be measured. When the targets are raindrops, dust, or other particles moving with the winds within a storm, a Doppler weather radar can determine storm wind circulation patterns. During the 1960s, research scientists explored the potential of Doppler radar to improve tornado and severe thunderstorm warning. Published results of Doppler weather radar experiments confirmed that Doppler radars, with narrow beam-widths, were sensitive to precipitation motion and tornado-related signatures could be identified in the Doppler radar data. Based on these encouraging results, a field experiment was planned to test Doppler radar's ability to detect tornadoes, large hail, damaging winds, and dangerous turbulence on a routine operational basis as would be required for the National Radar Network.

In the fall of 1976, scientists and engineers from the Environmental Research Laboratories, National Severe Storms Laboratory, and National Weather Service met to plan the Doppler operational test. They were joined by the Air Weather Service and the Federal Aviation Administration. The combined personnel of these agencies then worked together on the program known as the Joint Doppler Operational Project (JDOP). JDOP was a success, serving to prove Doppler weather radar's ability to detect severe thunderstorms and tornadoes, and to advance flight safety for aircraft. It also served to improve radar signal processing design technology, increase Doppler radar image display capability, and advance the concept of using meteorological algorithms to assist in the analysis of the Doppler radar data.

In parallel with the JDOP activities, an interagency Working Group on Next Generation Weather Radar was set up under the direction of the Federal Coordinator for Meteorology. This Working Group was the focus for preparation of a concept paper outlining the approach for the development, procurement, and operation of a joint tri-agency national weather radar network. In July 1979, the Federal Committee for Meterological Services and Supporting Research approved the concept paper and the establishment of a Joint System Program Office (JSPO) to be the central focus for NEXRAD. The JSPO was staffed by members from the participating Departments and supported financially by the Departments. Recognizing the need for high level tri-agency guidance of the program, the NEXRAD Program Council was established in 1980, under the auspices of the Office of the Federal Coordinator for Meteorology (OFCM). This Council has been instrumental in guiding the development of the program since that time.

AGENCY MISSION RESPONSIBILITIES RELATED TO WEATHER RADAR

Within the Department of Commerce, the National Weather Service is deploying NEXRAD as a key component in a program of modernization and associated restructuring. NEXRAD's accurate, high resolution radar data provide detailed information on the structure, intensity, wind circulation, and movement of storms as well as continuous computation and mapping of rainfall amounts within its area of coverage. During the modernization program, NEXRAD's capabilities will be integrated with those from other technologies being implemented. These include the Automated Surface Observing System (ASOS), Wind Profiler, new super computers at the National Meteorological Center, and the Advanced Weather Interactive Processing System (AWIPS). Together they will provide improved weather forecasts for the public, and the aviation, marine, agriculture, and forestry industries. Weather warnings in the future will be more accurate and more timely. Advances in hydrologic services will allow improved warnings for floods and flash floods, better water resources management, and improvements in control of industrial, urban and agricultural run-off. The deployment of NEXRAD and the other components of the modernization program requires the concurrent implementation of major education and training programs to enable National Weather Service personnel to make maximum use of the new advanced technology

systems. The modernized National Weather Service will be able to provide new levels of safety to the American public, more effective mitigation of the harmful effects of storms, and enhance the economic competitiveness of the United States.

Within the Department of Defense (DOD), the Air Weather Service requires NEXRAD to support military operations and protect the assets of the United States Air Force and the United States Army on a world-wide basis. The Naval Oceanography Command will utilize NEXRAD products to support Navy and Marine Corps operations around the globe. NEXRAD products will be received via NEXRAD principal user processors (i.e., PUPs as described below) at the oceanography and meteorology components of the Navy and Marine Corps and will be used to support naval and amphibious operations. Over selected areas of the Pacific Ocean for example, NEXRAD will play a key future role in DOD's joint typhoon warning program. NEXRAD will be a significant component of the DOD's program to upgrade and update its weather services.

Within the Department of Transportation, the Federal Aviation Administration (FAA) will use NEXRAD products to help ensure the safe, timely, and cost-effective control of aircraft throughout the National Airspace System (NAS). Regional maps of precipitation intensity -- mosaics from up to 12 NEXRAD sites -- will keep FAA personnel informed of weather conditions and will allow the FAA to optimize routing of aircraft. NEXRAD is an integral part of FAA plans to implement state-of-the-art technology to enhance control and management of the National Airspace System.

THE NEXRAD SYSTEM

The NEXRAD system being acquired for the Departments of Commerce, Defense, and Transportation contains all of the components required to operate and support NEXRAD for its full life cycle. The system includes the basic NEXRAD radar unit, communications, a comprehensive NEXRAD training program, logistics support, a siting and facilities development function, and an Operational Support Facility in Norman, Oklahoma -- all presently under the management and direction of the NEXRAD Joint System Program Office.

Each NEXRAD site consists of a radar antenna, a radar data acquisition unit (RDA), a radar product generator (RPG), a site-unique principal user processor collocated with the RPG (referred to as the RPG operator position) many "associated" principal user processors (PUPs) with dedicated high-speed data links to the RPG, and communication ports. See Figure 4.1.

Radar Data Acquisition (RDA). This unit uses a 10 centimeter wavelength (S-Band) Doppler weather radar to collect high resolution reflections from atmospheric targets. S-Band was selected as the preferred operating wavelength for the long-range Doppler weather radar applications needed for the NEXRAD system. It permits more accurate measurement of precipitation than a comparable C-Band radar (5 centimeter wavelength), suffers less from signal attenuation by rainfall and is thus able to look through nearby storms to see more distant ones, and permits improved measurement of radial velocity. C-band radar is preferred for short-range applications. A computer processes the radar returns to create highly accurate digitized estimates of reflectivity, radial velocity, and spectrum width (i.e., the standard deviation of a velocity sample) known as base data. These base data elements are collected for multiple elevation angles to include almost the entire atmospheric volume from the surface to 70,000 feet and cover a range of 250 nautical miles (460 km) for reflectivity and 125 nautical miles (230 km) for the Doppler data, radial velocity and spectrum width. The NEXRAD narrow beam width, power, and high sensitivity

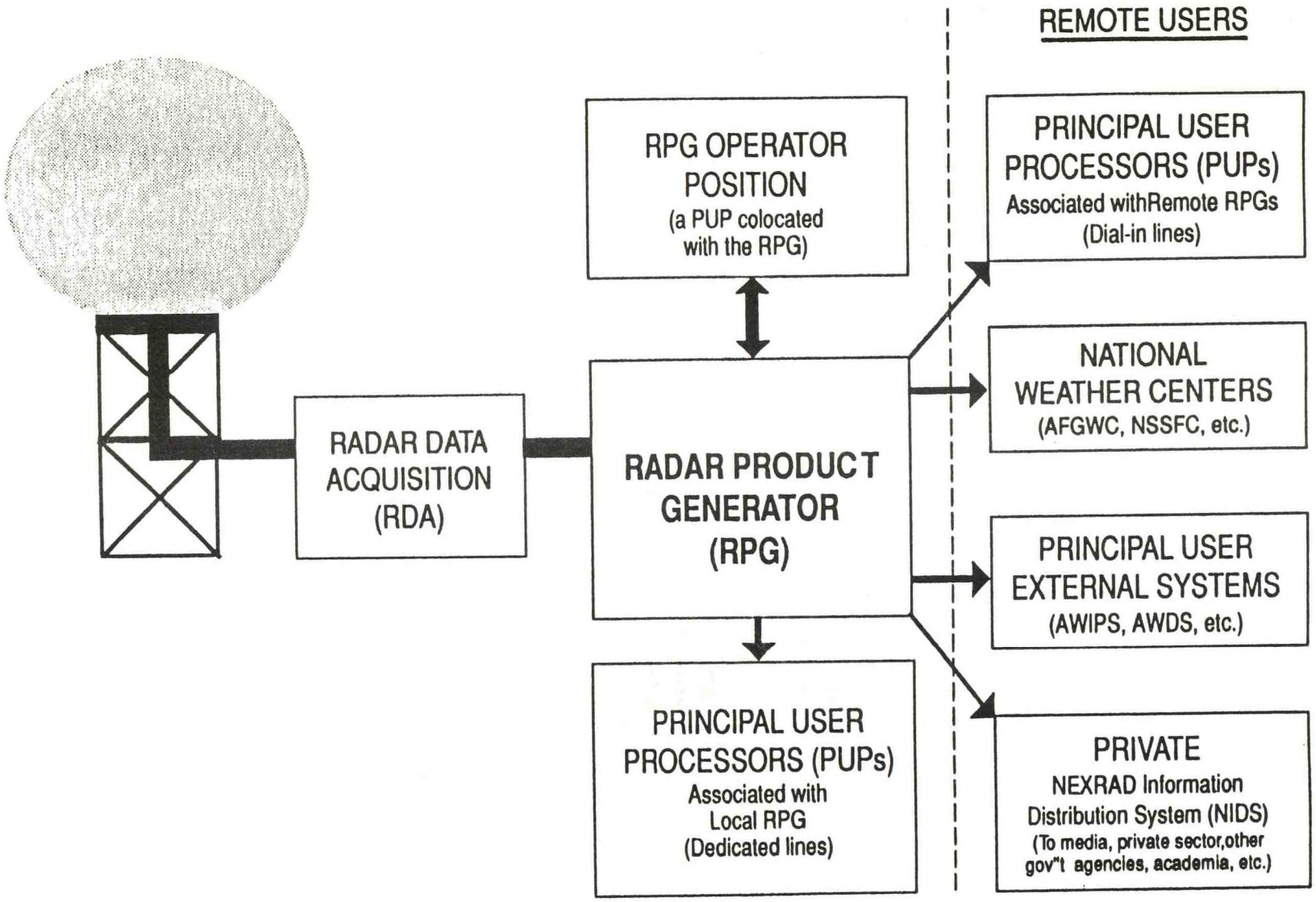

Figure 4.1 NEXRAD Major System Components and Simplified Flow of Products to Users

allow measurement of wind velocity when no precipitation is occurring based on reflections from tiny particles such as cloud moisture droplets and atmospheric dust. See Table 4.1 for a list of NEXRAD specifications.

Radar Product Generator (RPG). This unit turns the base data into displayable base product images. By application of software programs incorporating meteorological algorithms, computer-derived product image data are created to assist the meteorologist in analyzing storms and other weather phenomena. See Table 4.2 for a list of products. A Unit Control Position (UCP) connected to the RPG affords a forecaster/operator complete control of the entire NEXRAD unit. For example, the radar can be turned on or off, operating modes can be changed, and the mix of products can be modified. NEXRAD's communications capability is also controlled at the UCP. Colocated with the RPG is a special principal user processor that can edit, modify and correct the RPG products and return them to the RPG for distribution to all users of the radar products; this unit is referred to as the RPG operator position (RPGOP).

The RPG has several categories of ports for supplying data. The Federal Aviation Administration will have dedicated ports which are similar to the ports that supply NEXRAD products to the principal user processors (PUPs). The NIDS vendors (described below) will have ports that provide a set of preselected products. In addition, there will be dial-in ports some of which will be dedicated for high-priority users.

Principal User Processor (PUP). These units are advanced, interactive workstations that allow the forecaster to select, display, and manipulate the RPG products. All the PUPs "associated" with a specific NEXRAD site will have a dedicated communication link to the specific radar unit and will routinely receive NEXRAD products, but may dial into any other RPG to request data. (See Figure 4.1). The PUPs automatically generate alerts when preset alert criteria have been met. Other PUP capabilities include automatic generation and presentation of time lapse sequences, split-screen displays of multiple products, ability to magnify displays, and hardcopy color printouts of selected screen images. Timely dissemination of NEXRAD information to users will be enhanced by advanced network control, communication techniques, and data handling systems. The principal users' national weather centers, i.e., National Meteorological Center, National Hurricane Center, National Severe Storms Forecast Center within the NWS, Air Force Global Weather Central, and the FAA's Central Flow Control Facility will have assigned dial-in connections to support their missions.

NEXRAD Information Distribution System (NIDS). This system will allow external users such as local governments, universities, private meteorologists, the media, and other Federal agencies to access NEXRAD products. Four communications ports have been set aside on each NEXRAD radar product generator to serve the NIDS vendors who will have access to NEXRAD products on a near real-time basis. The NIDS vendors will provide NEXRAD products to their customers in the external user community such as TV stations, utilities, and private meteorologists. The vendors may also modify or "tailor" NEXRAD data to suit the special needs of their customers. The NIDS will begin operation as the early NEXRADs come on line. To be assigned a port, the NIDS vendors will be required to satisfy a set of conditions that assure access to products from all network radars for external users and competition between the vendors. Through NIDS, private hydrologists will be able to access NEXRAD rainfall displays and obtain a special hydrological data array transmitted directly to the hydrologists' computers. Using privately created run-off models they will be able to provide unique information for local communities with water resources or water drainage problems such as flash flooding of roads in low-lying areas. The NIDS vendors will provide sufficient communications to make it possible for the external user community to have timely access to NEXRAD products at no additional cost to the taxpayer.

Table 4.1 NEXRAD Radar Specifications

DESCRIPTION	FEATURE/PARAMETER
Radar Type	Coherent Pulse Doppler
Wavelength	10 cm, S-Band
Range	
Reflectivity Data	460 km
Velocity/Spectrum Width Data	230 km
Scan Strategies:	
Precipitation Mode:	
Volume Coverage Patterns	14 tilts in 5 min. or 9 tilts in 6 min.
Pulse Length	1.57 microseconds (short)
Pulse Repetition Frequency	Variable: 320-1300 pps
Clear Air Mode:	
Volume Coverage Pattern	5 tilts in 10 min.
Pulse Length	4.5 microseconds (long)
Pulse Repetition Frequency	Variable: 320-450 pps
Clutter Cancellation:	
Reflectivity Channel	30 dB
Doppler Channel	Selectable: 30 or 50 dB
Special Features	Built in on-line and off-line testing Automatic calibration

TABLE 4.2 NEXRAD Products

Reflectivity	Storm Tracking
Velocity	Weak Echo Region
Spectrum Width	Velocity Azimuth Display Winds
Combined Shear	Velocity Azimuth Display Plot
Combined Shear Contour	Combined Moment
Echo Tops	Storm Relative Velocity
Echo Tops Contour	Severe Weather Analysis Display
Composite Reflectivity	Severe Weather Probability
Composite Reflectivity Contour	Vertically Integrated Liquid
Layer Composite Reflectivity	1hr Precipitation Accumulation
Hail Index	3hr Precipitation Accumulation
Mesocyclone	Storm Total Precip Accumulation
Tornadic Vortex Signature	Supplemental Precipitation Data
Storm Structure	Cross Section
	Radar Coded Message

In addition to the above products from individual NEXRAD sites, composite national products will be prepared by national centers. An example is the National Radar Summary, a mosaic of reflectivity (precipitation) from all NEXRAD sites.

Network of NEXRAD Sites. The NEXRAD installations will include 175 or more Doppler weather radars, other associated equipment, and supporting services. A network of 137 NEXRAD sites will serve the continental U.S. -- 113 dedicated network NEXRAD radars operated by the National Weather Service and 24 supplemental NEXRAD radars operated by the Air Weather Service. In addition to the above "network" radars, DOD will have 17 sites on non-CONUS bases, FAA will have 13 non-CONUS sites, and the remainder for operations training, maintenance training, and system testing. Within the continental United States, the NEXRAD national weather radar network will perform continuous, comprehensive storm surveillance and provide pinpoint detection and tracking of hazardous weather events such as severe thunderstorms, tornadoes, and extreme precipitation that can result in flash floods. It will make possible improved forecasts of storm movement and location. The overlapping coverage of the dedicated network and supplemental sites allows the system to continuously track storms as they move from the coverage area of one NEXRAD unit to the next. Reporting will be achieved by means of a Radar Coded Message which will be automatically generated twice each hour. One set of reports each hour will be quality controlled by a special unit at the National Severe Storms Forecast Center and used to produce the National Radar Summary, a mosaic of the data from all sites.

ACQUISITION STRATEGY

The new Doppler radar is being acquired under the Guidelines for Major Systems Acquisition as set forth in the Office of Management and Budget (OMB) Circular A-109. The new system uses state-of-the-art, off-the-shelf components to minimize acquisition costs and procurement delays. In August 1980, the Mission Need Statement for joint procurement of the Doppler radar system was approved and the System Definition Phase of the Next Generation Weather Radar (NEXRAD) officially began with the Department of Commerce designated as the lead agency and the Secretary of Commerce as the Source Selection Official.

Initial work of the tri-agency Joint System Program Office (JSPO) centered upon implementing the source selection procedures for award of three System Definition Phase NEXRAD contracts. In February 1982, System Definition Phase contracts were awarded to Unisys Corporation (formerly Sperry), Raytheon Company, and the Ford Aerospace-Westinghouse Corporation team. The competing contractors defined design alternatives and system capabilities and generated cost estimates for evaluation. In July 1982, the JSPO assembled an Agency Requirements Team to "scrub" the NEXRAD technical requirements and minimize development costs. The algorithms and radar display products to be implemented were also determined at this meeting.

In April 1983, Unisys Corporation and Raytheon Company were selected to continue as competitors in the Validation Phase of the NEXRAD Program. Their task was to develop the NEXRAD software, to build and integrate the NEXRAD subsystems into a preproduction NEXRAD prototype, and to propose the NEXRAD production costs. During the Validation Phase an independent panel, chaired by the Deputy Director of the National Institute of Standards and Technology, thoroughly reviewed and revalidated the earlier (April 1985) NEXRAD technical requirements.

The NEXRAD Mission Need Statement was reaffirmed in November of 1987 and Unisys Corporation was awarded the NEXRAD contract. Under the Limited Production Phase option of the contract, Unisys successfully accomplished Operational Test and Evaluation and completed software development for NEXRAD's Initial Operating Capability. Unisys has begun to build and install the first 10 units as specified for the Limited Production Phase. In January 1990, the

Secretary of Commerce reaffirmed the NEXRAD Mission Need Statement and approved exercising the NEXRAD Full Scale Production contract option with Unisys Corporation.

OPERATIONAL TEST AND EVALUATION OF PROTOTYPE

The NEXRAD Program Council selected the Norman, Oklahoma, Weather Service Forecast Office (WSFO) as the central site for an operational test and evaluation of the prototype Unisys NEXRAD system with participation at Tinker AFB and the FAA Training Academy. The Air Force Operational Test and Evaluation Center conducted a rigorous five-month evaluation beginning in March 1989, utilizing a tri-agency test team of 160 people. The WSFO forecasting staff's experience with the prototype is summarized below.

The NEXRAD data are superior -- in quality, timeliness, and accuracy -- to the data provided by the old WSR-57 radar. The reflectivity data from NEXRAD are far better than the reflectivity data available from the WSR-57. In addition the new "velocity" data from NEXRAD are very useful. The small scale details provided by NEXRAD on evolving severe thunderstorms--heretofore almost completely missed by the WSR-57 network -- will be the basis for substantial improvements in severe weather warning capabilities, including longer lead times and lower false alarm rates.

Many challenges face operational weather units in preparing for NEXRAD technology and in exploiting the massive volume and the new types of data from this technology. Extensive initial and follow-on training will be required as NEXRADs are fielded and experience is gained by forecasters with varying backgrounds and abilities. The workload during storm episodes will increase because more precise data and information will be available. The workload will also be increased by the longer lead times for warnings and advisories and the capability to provide status reports on individual storms of interest to decision makers at several levels of government.

The fact that there are more data, better data, powerful processors, and sophisticated algorithms does not mean that the forecaster has an easier job. In fact, just the contrary is true. More information means more interpretation, more necessary knowledge and, in the end, more work to produce better forecasts and warnings. Forecasters will be able to warn more skillfully using NEXRAD. However, they must be well-trained and must be capable of assimilating NEXRAD data, along with data from other sources, and converting that information into appropriate advisories and warnings.

IMPLEMENTATION AND FUTURE PLANS

Implementation of the first operational NEXRAD is the top priority item within the NEXRAD JSPO; it will be installed at Twin Lakes, Oklahoma in late 1990 and will be operational by the Spring of 1991. The limited-scale production decision includes upgrading the preproduction unit at Norman, Oklahoma to production status, completing tests of the initial operating capability, delivering and installing equipment for maintenance training at the NWS Training Center, completing final preparations for operations training at Norman using the upgraded preproduction model and other equipment, and completing the NEXRAD functional and physical configuration audits.

The initial thrust of the National Weather Service's deployment of NEXRAD will be to support the Modernization and Restructuring of weather services. By the end of 1992, there will be a cluster of NEXRAD sites with overlapping coverage located in the Central and Southern Plains states and portions of the mid and lower Mississippi River Valley areas. Weather stations within this region will participate in the Modernization and Restructuring Demonstration which will validate the National Weather Service's modernization plans using NEXRAD, the Advanced

Weather Interactive Processing System, Wind Profilers, and Automated Surface Observing Systems. Also by the end of 1992, NEXRAD coverage will extend to other areas highly susceptible to severe or hazardous weather events such as the Lower Great Lakes Region, Middle and North Atlantic States, and Gulf Coast Region. Deployment will continue at the rate of four or five sites per month until 1996 when the last of the 175 NEXRADs will be delivered to the Government. Should the need arise, the Government has the option of acquiring up to 20 additional WSR-88Ds and 100 additional principal user processors (PUPs).

The Department of Defense will field progressively more sophisticated defense systems over the next several years. As a result, the military environmental support organizations have programmed or acquired state-of-the-art meteorological systems or technologies. NEXRAD will be one of the dominant technologies. Other technologies or systems include laser ceilometers, new satellite sensors, advanced communications equipment and associated sophisticated software. During limited and full scale production, the Department of Defense will install NEXRADs at U.S. bases as part of the national network as well as at key U.S. military support bases in several European countries, Asia, and U.S. territories in the Pacific. All of these systems contribute to the overall effectiveness and safety of military operations and will markedly enhance the protection of critical Department of Defense resources worldwide.

The Federal Aviation Administration (FAA) will obtain NEXRAD products from the dedicated FAA ports on the radar product generators (RPGs). Each Air Route Traffic Control Center (ARTCC) will receive displays of NEXRAD products from NEXRAD sites located throughout the ARTCC's area of responsibility. Region-wide views of weather conditions will allow the ARTCCs to optimize routing of aircraft. National Weather Service meteorologists working at the ARTCC's Center Weather Service Units will analyze the NEXRAD displays and will keep FAA personnel who control enroute and terminal air traffic informed of weather conditions. The FAA will install NEXRAD radars at sites in Alaska, Hawaii, Puerto Rico, Grand Cayman, and the Virgin Islands. The Raytheon prototype NEXRAD (from the competitive acquisition) has been transferred to the National Center for Atmospheric Research and is located near Denver, CO; this prototype provides FAA operational windshear alerts in the summer microburst season.

FACILITIES AND LOGISTICS

The facilities function includes selection of optimum sites for installation of the WSR-88Ds and their associated facilities. Radar sites must afford an almost unobstructed view of the radar horizon and provide the coverage required by the principal users. Selecting sites is only the beginning. At new radar sites, land is being acquired, utilities brought in, and the sites prepared for erection of radar towers.

Land acquisition, office design, construction and modification is being managed by the Special Engineering Projects Office in Kansas City, Missouri, for the National Weather Service (NWS). The Federal Aviation Administration has its own site selection process. Within the Department of Defense, real estate acquisitions are being managed by U.S. Air Force Headquarters, Air Staff; allied support to user sites is being provided by NWS headquarters Engineering Installation Division. No new military construction is required for NEXRAD as field offices need only minor modifications to accept the NEXRAD equipment.

The NEXRAD Operational Support Facility (OSF) in Norman, Oklahoma, is currently being organized. It will eventually be responsible for providing 24 hour field support to the NEXRAD system. It will have a tri-agency staff and be equipped to resolve both software and hardware

problems as they arise. Proposed future improvements to NEXRAD will be evaluated and tested at the OSF prior to being approved and implemented throughout the system.

The interagency aspects of NEXRAD operations have been defined and will be conducted under guidelines provided in the Federal Meteorological Handbook Number 11 (FMH-11), "Doppler Radar Meteorological Observations". The handbook is under preparation and will be published under the auspices of the Office of the Federal Coordinator for Meteorology (OFCM). The initial version of FMH-11 is being produced by the OFCM Working Group for Doppler Radar Meteorological Observations.

The NWS National Reconditioning Center in Kansas City, Missouri will manage the tri-agency depot repair function. The center will test and repair NEXRAD system components, perform system hardware quality control, and monitor the warranty on all equipment delivered to the Government. NOAA's National Logistic Supply Center in Kansas City will be the main spare parts facility for the NEXRAD system.

FORECASTING SKILLS AND TRAINING

Forecasting skills in the use of the NEXRAD products will be developed initially by upgrading the skills of current forecasters. This will be done by providing special training for forecasters who are already skillful with the old radar products but who will need extra courses and experience to use the velocity radar products and to use the higher quality and reliability of the signatures in the reflectivity products. As the NEXRADs are installed over a 5-year period, new forecasters will develop their skills from special courses and on-the-job experience.

Separately from the NEXRAD program, NOAA, the Air Force, and the University Corporation for Atmospheric Research (UCAR) have established a basic and comprehensive scientific education program for NWS and AWS meteorologists. This program is referred to as the Cooperative Program for Operational Meteorology, Education, and Training (COMET).

The initial training course for Doppler radar meteorological operations will begin in September 1990 at Norman, Oklahoma. In October 1990, maintenance classes for both National Weather Service and Air Force personnel will begin at the National Weather Service Training Center in Kansas City. During June-August 1992, Air Force training will move to Keesler AFB, MS. Training plans for the participating agencies include precursor training for both operations and maintenance personnel and on-the-job education and training following the formal classroom studies.

A software maintenance course will begin in February 1991 for personnel of the NEXRAD Operational Support Facility. Graduates of this course (taught in segments totalling 14 weeks) will have responsibility for life cycle maintenance and enhancement of the NEXRAD software after the production contractor departs. Air Force personnel will receive a course on how to install and checkout a WSR-88D at a site, and how to disassemble, move, and reinstall a WSR-88D at another site.

APPENDIX A

DEPARTMENT OF COMMERCE WEATHER PROGRAMS

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The National Oceanic and Atmospheric Administration (NOAA) is the principal meteorological agency of the Federal Government. By law, NOAA is responsible for reporting the weather of the United States, providing weather and flood warnings and forecasts to the general public, developing and furnishing applied weather services, and recording the climate of the United States. This mission is carried out within NOAA by the National Weather Service (NWS); the National Environmental Satellite, Data, and Information Service (NESDIS); the Office of Oceanic and Atmospheric Research (OAR); the National Ocean Service (NOS); and the Office of NOAA Corps Operations (NC).

NATIONAL WEATHER SERVICE

MISSION

The National Weather Service (NWS) has the principal responsibility for the plans and operations of the basic weather services and certain specific applied services. The primary mission of NWS is to help ensure the safety and welfare of the general public with respect to the effects of weather and to further the conduct of governmental and commercial activities which are affected by weather. In support of this mission, NWS:

- Issues warnings and forecasts of weather, flood and ocean conditions;
- Observes and reports the weather and the river and ocean conditions of the United States and its possessions;
- Develops and operates national meteorological, hydrological, and oceanic service systems;
- Performs applied meteorological and hydrological research;
- Assists in developing community awareness and awareness materials concerning weather related natural disasters;
- Participates in international hydrometeorological activities, including the exchange, coding and monitoring of data and forecasts, and also including the installation and repair of hydrometeorological equipment and systems overseas under the Voluntary Cooperation Program.

ENABLING LEGISLATION

The basic enabling legislation and authority for weather services are listed below:

- Organic Act of 1890 created the U.S. Weather Bureau in the Department of Agriculture;
- Enabling Act of 1919 allowed the U.S. Weather Bureau to enter into cooperative agreements for providing agriculture weather services;
- Flood Control Act of 1938 authorized the establishment, operation, and maintenance of the Hydroclimatic Network by the Weather Bureau for Flood Control; on July 1, 1940, the Weather Bureau was transferred from the Department of Agriculture to the Department of Commerce.

- Federal Aviation Act of 1958 outlined duties of the Secretary of Commerce for provision of weather observations and services to aviation;
- Reorganization Plan 2 of 1965 placed the "National Weather Service" (NWS) in the newly created Environmental Science Services Administration (ESSA);
- Reorganization Plan 4 of 1970 made the NWS a part of the newly created National Oceanic and Atmospheric Administration (NOAA).

SERVICES

NOAA provides around-the-clock weather and flood warning and forecast services to the public for the protection of life and property and to meet the needs of all segments of the economy. Weather services are provided by a nationwide network of offices that collect data, prepare state and local warnings and forecasts, and disseminate information to the population both directly and indirectly through the mass media. Data, analyses, forecasts, and outlooks used by field forecasters to prepare local forecasts are centrally processed by the National Meteorological Center (NMC). The NWS core mission also depends on the study, development, and testing of new methods for improving basic warning and forecast capabilities through research.

Local Warnings and Forecasts

Local weather services are provided through a national network of 52 Weather Service Forecast Offices (WSFOs), 220 more localized Weather Service Offices (WSOs) and 13 River Forecast Centers (RFCs).

Weather Warnings and Forecasts. Both WSFOs and WSOs issue local warnings of severe weather such as hurricanes, tornadoes, severe thunderstorms, flash floods, and extreme winter weather.

- WSFOs prepare forecasts for zones which are comprised of several counties that experience similar weather. Each WSFO has forecast responsibility for several zones which, together, comprise an area the size of an average state. WSFOs issue zone forecasts 4 times daily for a period out to 48 hours; a generalized statewide forecast twice daily; and a more general, extended 5-day forecast on a daily basis. WSFOs also provide the main field forecast support for the marine and aviation programs as well as guidance for the fire weather program.

- All counties in the United States are assigned to specific WSOs or WSFOs for warning purposes. These offices issue and distribute local warnings of severe weather for their assigned counties. WSOs adapt generalized weather forecasts to local areas and issue severe weather and flash flood warnings.

- To prepare local warnings and forecasts, WSFOs use forecast guidance prepared by the National Meteorological Center (NMC) that is based on worldwide meteorological observations. The National Severe Storms Forecast Center (NSSFC) and the National Hurricane Center (NHC) also provide central support for the local warning program.

- Weather Service Meteorological Observations (WSMOs) are additional sources of data for surface observations, upper air observations, and/or radar data. These observations are also used in the NMC data base for generating guidance products used by field forecasters.

River and Flood Warnings and Forecasts. RFCs prepare guidance used by WSFOs, and WSOs to issue flash flood watches, warnings, and river forecasts. RFCs provide forecasts of river stage and flow and related products and services for use by water resources managers and other users. Most WSFOs and WSOs support the RFCs by collecting and relaying hydrologic data. NMC provides central support to RFCs by forecasting the movement of large storms that are causing significant precipitation.

Marine Weather Services. Using weather analyses and forecast guidance provided by NMC, marine weather forecasters at coastal and Great Lake WSFOs issue wind, wave, weather, and ice warnings, forecasts, and other information for the population living and working along the sea coast, off-shore, on the Great Lakes and the high seas. Principal products include small craft advisories, gale, storm, tropical cyclone, and storm surge warnings; coastal, off-shore, and high seas forecasts; sea and swell forecasts; sea and lake advisories; and special weather forecasts to aid in the containment and clean up of oil spills and other hazardous substances in the marine environment. In support of Marine Weather Services the NWS operates the National Data Buoy Center (NDBC). This Center provides real-time operations, data acquisition and data processing, and distribution of meteorological/oceanographic data from sea and coastal buoys and ground stations. The NDBC also provides systems integration, deployment, maintenance and repair, and redeployment of data buoys and coastal ground stations. Legislation will be proposed to establish a Marine Waterways Trust Fund within the current Harbor Maintenance Trust Fund. Receipts collected through the Marine Waterways Trust Fund will be used to directly offset certain NOAA marine program costs. In FY 1991, $5,300,000 of Marine Weather Services program will be financed through the proposed Trust Fund.

Agricultural Weather Services. NWS provides the Nation with generalized agricultural weather services, including observations, and forecasts that improve agricultural efficiency, conserve energy, and protect the environment. At the direction of Congress, NWS issues warnings of low temperatures injurious to winter and spring crops, particularly in citrus and deciduous fruit-growing areas as well as specialized forecasts similiar to those available from the private sector. The 1991 budget proposes that users of these specialized services purchase them directly from the private sector.

Fire Weather Services. Designated NWS offices provide weather warning, forecast, and advisory services to Federal, state, and local wildland management agencies to support wildfire control and suppression activities. Localized weather forecasts are issued, as required, during a fire. NWS offices also provide site-specific forecasts and advisories to Federal natural resource agencies for prescribed burning and smoke management, insect and disease control, planting and cultivating new growth, preservation of watersheds, and promotion of wildlife habitat and recreational facilities. The 1991 budget proposes that state and local users of these specialized services purchase them directly from the private sector.

Tsunami Warnings. Tsunami watches and warnings for Pacific Ocean areas and Alaska are prepared and issued by the Tsunami Warning Center at Ewa Beach, Hawaii, and the regional center at Palmer, Alaska. NWS collects and analyzes observational data from an international network of seismological observatories and sea level observing stations which operate on a cooperative basis. The centers use the data to prepare watches and warnings covering all U.S. territories and states bordering on the Pacific Ocean and disseminate them to WSFOs, Federal and state disaster agencies, military organizations, private broadcast media, and other facilities that furnish warning information to the public.

Central Forecast Guidance

Over the last several decades, NOAA has made major improvements in forecasting synoptic-scale (large-scale, slowly evolving) weather. With continuing improvements in larger scale, centrally prepared weather guidance products for day 2 and beyond, implementation of NWS systems upgrades, advanced observations from the planned geostationary and polar-orbiting satellites, and the development of mesoscale predictive techniques for NWS field operations, NOAA can implement significant improvements in the severe weather and flood warnings program.

General Weather Guidance. The National Meteorological Center (NMC) provides centralized processing of data, analyses, forecasts, and outlooks required by field forecasters as a basis for local forecasting. The Center, using numerical forecasting techniques run on large computers, provides the NWS, other government agencies, private industry, and foreign users with guidance forecasts covering periods out to 10 days. When necessary, NMC provides guidance in tracking hurricanes (to 72 hours) and in forecasting the movement of large storms that cause significant precipitation.

In the course of its 24-hour-per-day, year-round operation, NMC receives approximately 50,000 surface observation reports daily, from land stations, 3,000 reports from ships, 4,100 upper air observations, and 3,000-4,000 reports from aircraft. Weather satellites provide cloud images, atmospheric temperature soundings, and sea-surface temperatures. Ocean buoys provide additional information on sea temperatures, ocean currents, and air-sea interactions. These data are processed, catalogued, used in the various forecast guidance model runs, and distributed widely to field offices, other government agencies, private subscribers, and overseas users.

NOAA will continue to incorporate improvements in general weather guidance by:

- Implementing second generation Regional Analysis and Forecast Systems (RAFS) models with higher resolution and improved physics to forecast severe thunderstorms, heavy rain, and snow more accurately;
- Implementing second generation hurricane models to predict the development and movement of hurricanes more accurately; and
- Continuing improvements in 1 to 2 day and 3 to 10 day forecasts as much as possible pending the availability of increased computer capacity to handle state-of-the-art physics, increasing resolution, and analysis.

Severe Storm Guidance. The National Severe Storms Forecast Center (NSSFC), Kansas City, MO, prepares and releases messages of expected severe local storms, including tornadoes. These Tornado or Severe Thunderstorm Watches, include information for public use and aviation services. NSSFC meteorologists continuously monitor weather developments and issue watches when needed. NOAA will continue to develop systems application programs designed to streamline use of the satellite and numerical weather prediction data by forecasters to improve severe storm guidance.

Hurricane Guidance. Two Hurricane Forecast Centers forecast the path and intensity of hurricanes, other tropical disturbances, and associated sea conditions. These two centers are the National Hurricane Center (NHC) in Miami, FL, and the Central Pacific Hurricane Center (CPHC) in Honolulu, HI. A portion of NHC's responsibility for public warnings rests with the Hurricane Warning Office at San Juan, PR. NMC provides forecast guidance on the track and intensity of hurricanes based on numerical models.

Special hurricane forecasting staff at NHC base their predictions, advisories, and warnings on subjective and objective methods. The hurricane forecasting functions at the NHC and CPHC are integrated with the regular forecasting functions of the Weather Service Forecast Offices at which these Centers are located. NOAA will continue to improve hurricane guidance through development of techniques and programs that maximize use of satellite data and through implementation and calibration of storm surge models.

Climate Guidance. The Climate Analysis Center prepares monthly and seasonal (90-day) outlooks; collects and analyzes data to depict current anomalies of climate; and develops predictive techniques, performs diagnostic studies of large-scale climate anomalies, and conducts stratospheric research, all to improve accuracy of climate outlooks. NOAA will continue to incorporate improvements in long-range climate guidance.

Atmospheric and Hydrological Research

NWS conducts applied research, building upon the more basic research conducted by NOAA laboratories and the academic community. Applied meteorological and hydrological research is integral to providing more timely and accurate weather and flood warning and forecast services to the U.S. public.

Meteorological Research. NWS will conduct meteorological research to develop, test, evaluate, and improve numerical models and analysis/forecast techniques used in weather and climate prediction including:

- Techniques for predicting mesoscale phenomena (e.g., heavy precipitation, tornadoes, and severe thunderstorms). These techniques will be developed and improved to use digital data from new observing systems such as NEXRAD (Next Generation Weather Radar) with doppler capability, and GOES-NEXT (geostationary satellites with higher resolution);
- Models to improve hurricane tracking, hurricane probability estimates, and tropical analyses;
- Storm surge models to assist in developing hurricane evacuation plans for additional coastal basins.

Hydrological Research. NWS will develop improved hydrologic and hydrometeorological models and procedures in support of the national flood forecasting and water resources forecasting programs including:

- Improvements to the Extended Streamflow Prediction model and its complementary models in the National Weather Service River Forecast System;
- Specialized flood and flash flood forecasting procedures using linked hydrological and meteorological models;
- Algorithms to combine NEXRAD precipitation estimates with data from satellites and other ground-based observation systems.

MODERNIZATION

A Strategic Plan for the Modernization and Associated Restructuring of the National Weather Service was submitted to Congress in 1989. Implementation of the plan will optimize efficiency and effectiveness of the mesoscale warning and forecast program and will include an operational demonstration and evaluation program as required by Public Law 100-685 to refine operational procedures and resolve implementation issues best addressed through actual field

experience. Continued improvements in larger scale, centrally prepared weather guidance products for day 2 and beyond through advanced forecasting models and the requested increased computer processing capability are essential to successful implementation of mesoscale forecasting in NWS field operation, where field forecasters will concentrate on the small-scale, short-lived processes that occur in the zero to 36 hour time-scale.

The National Implementation Plan, that will be submitted to Congress each fiscal year, will provide a planning framework and general strategies for accomplishing the transition. The interrelationships of all of the activities--facilities preparation, staffing augmentation, training, commissioning of systems, and realigning operations and services--have been planned so that the demonstration can begin in FY 1993. In addition to preparations for the demonstration, nationwide planning and implementation have begun: facilities preparation is on-going; training schedules for field personnel are being planned with necessary backup personnel to cover operational shifts; software development continues; new communications are being established; and all NWS offices are working on detailed site plans for the transition. The NWS modernization effort is a complex mix of internal NWS activities and multiple contractor efforts. Internal activities provide land, facilities, software, training, staffing, and new operational procedures.

Modernization and Associated Restructuring. The NWS has begun this process of change prompted by two factors: the need to apply advances in hydrometeorological science and technology to operational forecasting, and the need to replace obsolete and increasingly unreliable equipment.

These factors offer the opportunity to improve severe weather and flood warnings and forecasts through the acquisition of the following new, technologically advanced systems:

- Automated Surface Observation Systems (ASOS) to reduce time-consuming manual observations, provide continuous weather watch, and permit increased productivity of staff;
- Next Generation Weather Radar (NEXRAD) with doppler capability and sophisticated software to provide nationwide coverage for timely and accurate detection of severe weather and floods;
- Advanced Weather Interactive Processing System (AWIPS) to enable local forecasters to integrate, process, and transmit high-volume radar, satellite, upper air, surface observation data and guidance information;
- Class VII computer power at the NOAA Central Computer facility to accommodate advanced numerical weather prediction models and increased data to improve accuracy of forecast guidance.

These systems upgrades, coupled with observations from planned, advanced geostationary and polar-orbiting satellites and newly developed mesoscale forecasting techniques, will greatly improve the timeliness and accuracy of severe weather and flood warnings to the U.S. public. Improved capability to detect and predict the small-scale, short-lived (mesoscale) phenomena which cause the most destructive weather events will increase warning lead times for severe thunderstorms, tornadoes, high winds, and flash floods, as well as reduce false warnings.

NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE

The National Environmental Satellite, Data and Information Service (NESDIS) manages U.S. civil operational Earth-observing satellite systems, as well as global data bases for meteorology, oceanography, solid-earth geophysics, and solar-terrestrial sciences. From these sources it develops and distributes environmental data and information products and services critical to the protection of life and property, the national economy, energy development and distribution, global food supplies, and the development and management of natural resources.

An agency of the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), NESDIS was established December 1, 1982. It was formed by the merger of the former National Environmental Satellite Service (NESS) and Environmental Data and Information Service (EDIS).

NESDIS operates polar-orbiting satellites that monitor daily weather and surface conditions over the globe. It is also responsible for operating two geostationary weather satellites -- one that monitors the Atlantic Ocean and U.S. East and Gulf Coasts, and one that monitors the Pacific Ocean and West Coast. However, on January 21, 1989, the Western satellite, GOES-6, failed. The Eastern satellite, GOES-7, was moved to a centralized location on February 21, 1989. The location is adjusted between 108 °W and 98°W to provide maximum coverage during the Pacific and Atlantic storm seasons.

The second major area of NESDIS' responsibility is environmental data and information management and dissemination. NOAA gathers global data about the oceans, earth, atmosphere, space, and sun and their interactions to describe and predict the state of the physical environment. Many other agencies, organizations, and individuals, both domestic and foreign, collect similar data for particular uses and missions. Once the original collection purposes have been served, selected data flow to NESDIS data centers, which incorporate them into national environmental data bases that document the physical environment and its processes.

Environmental Satellite Service

SATELLITE OFFICES

The Office of Satellite Operations directs the operation of NOAA's environmental satellites and the acquisition of remotely sensed environmental data. It manages the Satellite Operations Control Center (SOCC) and Command and Data Acquisition (CDA) facilities that command and control, track, and acquire data from these environmental satellites.

The Office of Satellite Data Processing and Distribution directs the operations of NESDIS' central ground data processing facilities. It processes and distributes current weather satellite data and derived products to the National Weather Service and other domestic and foreign users. A system for the display and animation of satellite imagery from the GOES-TAP system has been installed in all Weather Service Forecast Offices (WSFO). The system, called the Satellite Weather Information System (SWIS), automatically acquires, stores, displays, and animates GOES imagery and superimposes guidance products from the National Meteorological Center with the imagery. WEFAX (Weather Facsimile) direct readout systems on NOAA's weather satellites enable users to receive, on relatively low-cost equipment, images and weather charts directly from the satellites.

National Weather Service's Satellite Field Services Stations (SFSSs) distribute processed geostationary satellite products to regional National Weather Service offices and other Federal agencies. The products also are made available to private groups at their expense. SFSSs are located in Washington, DC; Miami, FL; Kansas City, MO; Honolulu, HI; San Francisco, CA; and Anchorage, AK. The Anchorage, Washington, and San Francisco SFSSs distribute data from both the polar-orbiting and geostationary systems. The San Francisco SFSS also has the capability of receiving data from the polar orbiting satellites.

The Office of Research and Applications provides guidance and direction for NESDIS research and application activities. It coordinates the efforts of the Satellite Research Laboratory and Satellite Applications Laboratory. In addition, it assesses the requirements and goals of NESDIS research and applications programs, and evaluates their progress.

POLAR ORBITING SYSTEMS

The NOAA series of environmental polar-orbiting satellites replaced the ITOS system in July 1979. TIROS-N, the NASA prototype, was launched on October 13, 1978; and NOAA-6, the first NOAA-funded operational satellite of this series, was launched on June 27, 1979. In the years following, a series of NOAA polar orbiting satellites were launched. Currently operational are NOAA-10 and NOAA-11.

NOAA-funded satellites retain the NOAA name and are numbered consecutively beginning with the number immediately following that last used in the ITOS series. These satellites increase the accuracy of weather forecasting by providing quantitative data required for improved numerical weather forecast models. They carry advanced instruments to provide improved temperature soundings and microwave channels to facilitate sounding retrieval in cloudy areas. They also provide advanced multi-channel images and carry a data collection and platform location system. During the lifetime of the NOAA system, new instruments may be added or substituted for others. The first Advanced TIROS-N (ATN) satellite, NOAA-8, carried a search and rescue capability in addition to its standard instruments. NOAA-9 carries sensors to measure the Earth's radiation budget and ozone. The projected launch schedule and associated instruments for polar-orbiting satellites are shown in Table A.1.

NOAA spacecraft are five-sided, box-like structures that are 3.71 m long, 1.88 m in diameter, and 1,409 kg in weight, including expendables. NOAA-11, NOAA-10, and NOAA-9 operate in near-polar, sun-synchronous orbits of 849, 814 and 852 km, respectively, and provide environmental observations of the entire Earth four times each day. NOAA-11 crosses the Equator in a northward direction at 1354 local time. NOAA-10 crosses the Equator in a southward direction at 0730 local time and NOAA-9 crosses the Equator in a northward direction at 1702 local time. The orbital period of the satellites range from 101.23 to 102.2 minutes which produce approximately 14.2 orbits per day.

The NOAA series satellites carry four primary instrument systems. The Advanced Very High Resolution Radiometer (AVHRR) provides data for real-time transmission to both Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) users and for storage on the spacecraft tape recorders for later playback. Thus, the AVHRR instrument improves satellite services in stored and direct readout radiometer data for day and night cloud cover, sea-surface temperatures, and snow mapping. AVHRR read-out is accomplished by the following:

- Direct readout to ground stations of the APT class worldwide, at 4-km resolution, of the visible and infrared data; panoramic distortion is removed;
- Direct readout to ground stations of the HRPT class worldwide, at 1.1-km resolution, of all spectral channels;
- Global onboard recording of 4-km resolution data from all spectral channels; global area coverage for commanded readout for processing in the NOAA central computer facility at Suitland, MD;
- Onboard recording of data from selected portions of each orbit at 1.1-km resolution of all spectral channels, with local area coverage for central processing and sea-surface temperature measurements.

The TIROS Operational Vertical Sounder (TOVS) system combines data from several complementary sounding instruments on the spacecraft. These instruments are the High Resolution Infrared Sounder (HIRS/2), the Stratospheric Sounding Unit (SSU), and the Microwave Sounding Unit (MSU). The primary instrument providing tropospheric data, HIRS/2, is sensitive to energy from the visible to the carbon dioxide region of the infrared spectrum. This instrument is designed to provide data that permit calculation of temperature profiles from the surface to 10 mb, water vapor content at three levels of the atmosphere, and total ozone content. The SSU instrument, which is sensitive to energy in the carbon dioxide portion of the infrared spectrum, provides temperature information from the stratosphere. This instrument is provided by the Meteorological Office of the United Kingdom. The third instrument, the MSU, is sensitive to energy in the oxygen region of the microwave spectrum and will be used in conjunction with the two IR instruments. The microwave data permit computations to be made in the presence of clouds.

The Data Collection and Location System (DCLS) is provided by the Centre National d'Etudes Spatiales of France and is called the ARGOS DCLS. The ARGOS DCLS provides a means to locate and collect data from fixed and moving platforms. It provides two services not available in the geostationary meteorological satellite data collection system. First, it has the capability to determine platform location, using an inverse Doppler technique. Second, it is able to acquire data from any place in the world, but more particularly in the polar regions, beyond transmission range of the geostationary satellites.

The Space Environment Monitor (SEM) measures solar proton flux, alpha particle and electron flux density, and energy spectrum and total particulate energy distribution at spacecraft altitude. The three detectors included within this instrument are the Total Energy Detector, Medium Energy Proton and Electron Detector, and High Energy Proton and Alpha Detector. This instrument augments the measurements made by NOAA's geostationary satellites. The data from the SEM are processed at Suitland, MD, and transmitted over a dedicated data link to NOAA's Space Environment Laboratory at Boulder, CO, within one hour of the spacecraft readout. The NOAA series data, as well as the geostationary series data, are used to monitor the state of solar activity, which has a significant effect on terrestrial communications, electrical power distribution, and high-altitude aircraft flight.

In addition to the four primary instrument systems, the NOAA series spacecraft contain the Solar Backscatter Ultraviolet Radiometer and the Earth Radiation Budget Experiment. The Solar Backscatter Ultraviolet Radiometer (SBUV/2) is a non-scanning (fixed nadir viewing) spectrometer designed to measure scene radiance and solar spectral irradiance from 160 micrometers to 400

micrometers. Data obtained from the instrument will be used to compute the amount and vertical distribution of ozone in the Earth's atmosphere on the sunlit side of the Earth.

The Earth Radiation Budget (ERBE) has two components. One is a non-scanner instrument with four earth-viewing radiometers, two of which are wide angle (limb to limb of the Earth), while the other two are medium angle (10° earth central angle). A fifth radiometer is a shuttered, sun-viewing monitor. The wide and medium angle radiometers each have a total channel (0.2 to 50 um), and a shortwave channel (0.2 to 5 um). The sun-viewing radiometer measures the total solar spectrum (0.2 to 50 um). A second component of ERBE is a cross-track scanner instrument with three earth-viewing radiometers having a 3° by 4.5° field-of-view. The spectral intervals of the radiometer are shortwave (0.2 to 5 um), longwave (5 to 50 um), and total (0.2 to 50 um).

NOAA-9 and future polar satellites carry instruments for the operational monitoring of atmospheric ozone (the SBUV/2 is only carried on the afternoon or PM satellite) and will contribute to experimental monitoring of the Earth's radiation budget with the ERBE on NOAA-9 and NOAA-10 only. NOAA-8 and future polar satellites carry search and rescue (SAR) transponders, used to improve the detection and location of distress signals. This project is an international effort committed to global coverage for the search and rescue mission. The United States operates and maintains the SAR Mission Control Center and three ground stations. The ground stations receive Doppler signals directly from the satellite and process the information to provide the location of distress transmissions.

The ground system, required to receive large volumes of digital data from NOAA satellites, consists of two major subsystems -- the Data Acquisition and Control Subsystem (DACS) and the Data Processing and Services Subsystem (DPSS). The DACS includes components at the Wallops, VA, and Fairbanks, AK, Command and Data Acquisition (CDA) stations; the Satellite Operations Control Center (SOCC) at Suitland, MD; and the Western European Station at Lannion, France. All the DPSS components are in the NOAA facility at Suitland.

DACS is used to command and control the spacecraft, monitor its health via housekeeping telemetry, and retrieve and transmit the spacecraft environmental data to the DPSS processing and data handling facility. The delivery of NOAA system data from the CDAs to Suitland is accomplished by General Electric using the American Communications, Inc. commercial satellite communications network. This system, which includes Earth stations at Suitland, Wallops and Fairbanks, delivers the data to SOCC. These data are immediately passed on to the DPSS subsystem for initial processing.

During three (occasionally four) sequential orbits, the spacecraft is out of range of both NOAA CDA stations. To eliminate the resultant time delay in the receipt of the high-priority sounding data during the "blind" period, a Western European readout station was established at Lannion, France. This station acquires stored sounding data and transmits it to the United States via the eastern GOES satellite.

The DPSS ingests the raw satellite data and pre-processes and stores them along with appended auxiliary information, such as Earth location and quality control parameters.

TABLE A.1 PROJECTED SATELLITE LAUNCH SCHEDULE

POLAR-ORBITING SYSTEM

Satellite Designator	Planned Launch Date*
NOAA D+	CY 1990
NOAA I	CY 1991
NOAA J	CY 1992
NOAA K	CY 1993
NOAA L	CY 1995
NOAA M	CY 1996

Instruments for Advanced TIROS N Series

AVHRR	Advanced Very High Resolution Radiometer
SEM	Space Environment Monitor
SBUV	Solar Backscatter Ultraviolet Radiometer
SAR	Search and Rescue Instrument
ERBE	Earth Radiation Budget Experiment
HIRS	High Resolution Infrared Sounder
SSU	Stratospheric Sounder Unit
MSU	Microwave Sounder Unit
DCLS	ARGOS Data Collection and Location System

GEOSTATIONARY SYSTEM

Satellite Designator	Planned Launch Date*
GOES I	CY 1991
GOES J	CY 1992
GOES K	CY 1996
GOES L	CY 1997
GOES M	CY 2001

Instruments for GOES Series

SEM	Space Environment Monitor
DCS	Data Collection System
GIS	GOES Imager and Sounder
SAR	Search and Rescue (starting with GOES I)

*Launch date depends on performance of prior spacecraft.
+NOAA D does not carry the SBUV, SAR, or ERBE.

GEOSTATIONARY SATELLITE PROGRAM

The geostationary satellite program began in 1966 as an operational experiment in which the imaging capability and weather broadcast system of the NASA Applications Technology Satellites 1 and 3 were used. This program became an operational reality following the launch of NASA's Synchronous Meteorological Satellites (SMS) 1 and 2 in 1974 and 1975. These satellites were the prototypes for NOAA's Geostationary Operational Environmental Satellites (GOES).

Since GOES-1 was launched on October 16, 1975, seven more GOES satellites have been put into orbit. GOES-7, launched in March 1987, is currently positioned at 107.1°W. The next launch of a geostationary satellite, GOES-I, is currently scheduled for late 1990. At that time NOAA will locate one spacecraft at 75°W and another at 135°W. This will provide repetitive viewing of the development and movement of destructive weather systems, such as thunderstorms, hurricanes and major mid-latitude storms over much of North and South America and adjacent oceans. The projected launch schedule and associated instruments for geostationary satellites are shown in Table A.1.

The VISSR Atmospheric Sounder (VAS) is the principal instrument on the geostationary satellites starting with GOES-4. The VAS has both imaging and sounding capability. The VAS provides near-continuous cloud viewing with resolutions of 1, 2, 4 and 8 km in the visible wavelengths and 8 km and 16 km in the infrared wavelength. Full Earth disc pictures are available at 30-minute intervals throughout the day and night; partial disc pictures can be obtained at more frequent intervals to meet special requirements such as viewing development and movement of severe storms.

The concept of obtaining atmospheric soundings from geostationary satellites is being tested. GOES 6 and 7 are being used in an operational demonstration program to determine the capability of the VAS. Results have been excellent, and an operational demonstration of a ground system to use the VAS data to improve NOAA's operational weather analysis and forecasting programs is underway. The additional capabilities of the VAS are the multi-spectral imaging. The VAS has 12 infrared channels which are used to derive temperature and moisture profiles over selected areas. Sounding from a geostationary satellite affords several advantages over sounding from a polar-orbiting satellite. They are (1) constant surveillance, (2) constant viewing geometry, (3) better determination of temporal and spatial gradients, (4) easier comparison with radiosondes, and (5) synoptic large-area coverage. Starting with GOES-I, the systems will be capable of simultaneous imaging and soundings, a technique that was shared with GOES-7.

The VAS demonstration program has resulted in a VAS Data Utilization Center (VDUC) interconnecting the NWS's three major centers with NESDIS. Future development and direction of operational meso-meteorological systems will be influenced by the outcome of this VAS demonstration. The GOES also carry a Data Collection System which is used to collect and relay environmental data observed by a variety of remotely located platforms, such as river and tide gages, seismometers, buoys, ships, and automatic weather stations. These satellites rebroadcast imagery, meteorological analyses, and other environmental data to remote locations using the weather facsimile (WEFAX) system. Data are collected for warnings of solar activity using the Space Environment Monitor. This instrument is similar to the SEM on board the NOAA series S/C and consists of a Magnetometer, a Solar X-Ray Telescope, and an energetic particle monitor.

SATELLITE COMMUNICATIONS SYSTEM (SATCOM)

The NESDIS Telecommunications System is a complex network of voice, teletype, and data grade transmissions sent via satellites, microwave, and terrestrial cable services.

A major component of the system is the Office of Satellite Operations which consists of the Satellite Operations Control Center (SOCC) and two Command and Data Acquisition Stations at Wallops, VA, and Fairbanks, AK. The Office of Satellite Operations is responsible for the operation and safety of NOAA polar and geostationary satellites and for providing satellite data to the Office of Satellite Data Processing and Distribution in Federal Building 4, Suitland, MD.

Another major component is the Central Data Distribution Facility (CDDF) at the World Weather Building in Camp Springs, MD. The CDDF is connected in turn with the Fairbanks CDA station, and the six Satellite Field Services Stations. The Fairbanks CDA station also relays satellite data by land line and microwave circuits to the Anchorage SFSS and the NWS WSFOs at Anchorage and Fairbanks. The WSFO at Juneau, AK, receives satellite data from the Anchorage SFSS. By the end of FY 1988, SATCOM consisted of over 60 data links required for the operation of the satellite data processing and distribution system.

SUPPORTING RESEARCH PROGRAM FOR FY 1991

The requirements and goals addressed by NESDIS Supporting Research in FY 1991 include:

- NOAA's role in the national effort on the study of climate and global change (as detailed in the interagency report of the Committee on Earth and Environmental Sciences);
- The modernization effort of the National Weather Service (per P.L.100-685) and the mesoscale initiative that supports a national program;
- The improvement of the monitoring of the global ocean and the management of resources in the coastal zones;
- The management of data that will be needed to support the above;
- The evaluation, validation and implementation of new products and services from GOES-I; these will support the NWS modernization;
- The continuation of products and services from the polar orbiting satellite system.

Research and the development of applications of environmental satellite data are devoted to the improvement of and development of improved techniques for quantitative and qualitative products and services. These serve national and international programs in weather analysis and forecasting; climate diagnosis; and other programs for agriculture, fisheries and coastal zone management, energy; and other weather, land and environmental applications. The data from current NOAA operational satellites in both polar and geostationary orbits, and research satellites operated by other nations and by NASA and DOD are used to develop improved techniques and algorithms for the definition of the global, three-dimensional structure of the atmosphere (both temperature and moisture structure) that are essential for numerical weather analysis and forecasting.

The geostationary environmental satellites provide nearly continuous imagery and multi-spectral data in the visible and infrared for study and applications. These studies lead to the understanding of the genesis and life cycles of severe storms (from thunderstorms to hurricanes and winter snow storms) and the morphology and evolution of the mesoscale systems (small time and space scales) in which they form. This research leads to the application of data from GOES-I, its analysis and application with the other modernization tools of NEXRAD, Profiler, ASOS, AWIPS, etc.

Climate analysis, diagnosis and monitoring performed by the National Meteorological Center's Climate Analysis Center depend upon global satellite observations of the incoming and outgoing radiation. Knowledge of this "heat" or "radiation-budget" of the earth-atmosphere system is essential to the national and international research on the Earth's climate and environment. Research with satellite data is the key to understanding the effects of clouds as regulators of incoming and outgoing radiation that may lead to long term net warming of the globe. Applications research continues to improve estimates of the global distribution of atmospheric aerosols, their effect on climate, and on other satellite measurements. Satellites provide the only global measurement of ozone. Monitoring its distribution and concentration is critical to understanding the fate of this important atmospheric compound.

Monitoring sea surface temperature with satellite's will continue to be a focus of research for climate diagnosis and other applications. The passive microwave and other multispectral data from DOD's meteorological satellites and international satellites contributes to improvements in the measurement of this important parameter. Research and development on the use of satellite data in coastal marine areas continues. These are algorithms for estimating temperature, turbidity, and productivity for bays and estuaries. These satellite observations combined with aircraft and in-situ oceanic data contribute to development of dynamic models of coastal processes.

Improvement in the methods for estimating precipitation from satellite data is important for flash floods on the local scale, and, on the global scale, important to the understanding of the effects of the release of latent heat of condensation in both numerical weather forecasts and in numerical climate models. Other measurements from satellites requiring continued study and improvements are solar insolation, the "vegetation-index" of biomass concentration, and winds derived from cloud motions. These contribute to understanding of the hydrologic and biogeochemical cycles.

The scientists at NESDIS continue to provide expertise and advice for the specification of sensors, processing systems and technical requirements for the development of future satellite systems.

Environmental Data Bases

NATIONAL CLIMATIC DATA CENTER

The National Climatic Data Center has the principal responsibility to manage the national climatological data program, to include data and information services. To meet the responsibility, the Center:

- Performs all data management functions regarding data acquisition, archiving, retrieval, indexing quality assessments, evaluations, synthesis, dissemination, and publication of data

from global and national observation networks that have enduring value to the Nation and are sufficient to describe the climate;

- As a designated agency Federal Records Center, operates the Center for NOAA for processing, storage, and servicing of retrospective meteorological records;

- Prepares and provides special products and services to users as required as a basis for regulatory standards and policy decisions;

- Maintains national and global data bases for analyses of long-term climate trends and for monitoring global change;

- Provides facilities, data processing support, data exchange, and expertise, as required, to meet U.S. commitments to foreign nations, international organizations, and to the World Meteorological Organization's programs. In this capacity, NCDC operates the World Data Center-A for Meteorology under the auspices of the International Committee of Scientific Unions.

The modernization of observing networks with the use of new technology and the increased concern on global climate change throughout the world have increased the challenge of managing climate data and serving the research community. To meet this challenge, NCDC will be focusing on the development and implementation of new data processing systems to adapt for the processing of data from the use of new technologies in observing meteorological variables; and to prepare and structure baseline data sets to meet the national needs for monitoring climate change.

Climate Data Management

The management of climatic data has become increasingly complex as new automated high volume observing systems replace traditional manual systems. First, these new systems have necessitated a change in the concept of processing data for the climate data base. New automated observing systems have made it possible to effectively quality control data for random errors on site, leaving the more complex quality control to identify systematic errors and biases to the NCDC. Second, the data from the new systems must be integrated with the historical data, and third, the requirements for accurate homogeneous long series data sets on a national, regional and global scale is placing an additional demand on data management and user services that may require the reprocessing of entire long-series data bases.

In FY 1991, the NCDC's plans are to:

- Initiate a technology upgrade (i.e., computers, on-line storage, communication, etc.) to meet the data management and services through the 1990's;

- Implement new processing systems to account for the changed concept in processing data from automated systems and to accept new data streams;

- Study the characteristics of data collected with automated systems versus manually observed data and begin the development of techniques to treat data to form homogeneous long series data bases;

- Working with the World Meteorological Organization, participate in the preparation of a high priority global data set to monitor climate change;

- Perform the Decennial Census of the national climate by summarizing data for 1981-1990;
- Prepare climate perspectives studies to place contemporary climate into historical perspective;
- Reanalyze and/or reprocess long-series data sets and produce global/regional baseline data sets;
- Enhance the operation of the World Data Center to concentrate on the collection and exchange of international historic climate data needed to complete long series data sets;
- Participate in NOAA data management programs as required to support global change.

Climate Services

The demand for the basic climatic data and information services has been increasing annually. The recent concern for climate change has placed an increased need to readily identify the availability of data bases and to service large volumes of data. NOAA has implemented a NOAA Master Directory and will be expanding the capabilities of this directory that will help users access data. The NCDC plans to develop an interface between the NCDC data inventory system and the NOAA directory to provide more information to users. An automated system to allow users to browse (review available data products), to order and for cost accounting will be implemented. Expanded on-line access to data bases is planned.

NATIONAL OCEANOGRAPHIC DATA CENTER

The National Oceanographic Data Center (NODC) supports climatic services and research through its data management and data services activities. The NODC provides data management for major climate-related studies such as the Tropical Ocean-Global Atmosphere (TOGA) program, the World Ocean Circulation Experiment (WOCE), and the Joint Global Ocean Flux Study (JGOFS). The NODC also provides data products and services individually to researchers as well as to members of the operational marine community (e.g., the Navy, Coast Guard, shipping industry).

Data Management

The NODC is working closely with the academic community to provide data management for global change research programs. Three joint centers have been established with university groups to focus on different aspects of data management for global change:

- Joint Environmental Data Analysis (JEDA) Center with the Scripps Institution of Oceanography, University of California at San Diego;
- Joint Archive for Sea Level (JASL) with the University of Hawaii;
- Joint Center for Research in the Management of Ocean Data (JCRMOD) with the University of Delaware.

The JEDA Center is providing management of subsurface thermal data in support of TOGA. Initially this activity covered only data from the tropical Pacific Ocean, but it is extending its task

of intake, quality control, and analysis of available upper ocean thermal data to include the entire Pacific Ocean (November 1988), the Indian Ocean (August 1989), and the North Atlantic Ocean (in 1990). As of November 1989, the TOGA tropical Pacific thermal database assembled by the JEDA Center contained 64,272 temperature profiles (see Table A.2). An annual report issued by the NODC provides the user community with detailed inventory information on the TOGA subsurface thermal database.

Through the creation of the Joint Archive for Sea Level, the NODC is assisting researchers at the University of Hawaii in the acquisition, processing, quality assurance, archiving, and dissemination of sea level data from a network of island-based and coastal tide gages. The network consists of stations in the Pacific Ocean Sea Level Network originally established as part of the North Pacific Experiment (NORPAX), which began in 1974, as well as stations operated by many national and foreign agencies. As of January 1990, the initial archive of sea level at the NODC will include hourly, daily, and monthly sea level values for 83 stations. New data will be added to the archive once a year with about an 18-month lag after the year in which the data were collected.

Activities at JCRMOD have revolved around data management for WOCE, in particular the design of a WOCE data management system. This is an NSF-funded project with the College of Marine Studies at the University of Delaware. An online information system called Oceanic is now providing WOCE program information to principal investigators and other researchers.

The National Science Foundation agreed to support NODC's proposed U.S. Joint Global Ocean Flux Study data management responsibilities. The NODC Northeast Liaison Officer stationed at Woods Hole Oceanographic Institution (WHOI) has been designated as the U.S. JGOFS Data Manager. A prototype system has been designed to allow for inventorying, tracking, quality control, processing, documentation, and archiving of U.S. JGOFS data. As an ancillary activity, the NODC has assembled a global chlorophyll data set derived from NODC data files and other sources. This task was undertaken with NASA sponsorship and with assistance of scientists at the University of Miami. A copy of the data set has been provided to NASA for use by researchers who wish to compare in situ data with satellite data from the Coastal Zone Color Scanner (CZCS). NASA's CZCS browse system now allows users to search for and display data corresponding to the CZCS frame being viewed. The initial data set contains 9,000 records for the time period November 1978-May 1980, but is expected to grow to at least 17,000 records for the entire CZCS sampling period extending through June 1986.

Data Services

In FY 1989, the NODC fulfilled a total of 6,706 user requests; it achieved new record high totals for the number of digital data requests (880) and for the total volume of digital data disseminated (103.5 Gigabytes).

In July 1989, the National Oceanographic Data Center released its first ocean data compact disc. Designated as CD-ROM NODC-01, this compact disc contains over 1.3 million temperature-depth and salinity-depth profiles taken in the Pacific Ocean between 1900 and 1988. It is accompanied by menu-driven data access and display software provided on a single high density floppy disk. Developed as an experimental prototype CD-ROM NODC-01 is being provided to researchers who agree to test it and to provide their evaluation to the NODC. It is planned that this will be the first in a series of compact discs holding major portions of NODC's global data archives.

In April 1987 the NODC began disseminating ocean data from the Exact Repeat Mission (ERM) of the U.S. Navy Geodetic Satellite (GEOSAT), which started in October 1986 to provide the first long-term global observations of sea level, wind speed, wave height, and ice topography. Until a failing power supply greatly reduced GEOSAT's data collection ability by late 1989, GEOSAT data subscribers were provided monthly data tapes containing data from two 17-day ERM orbital cycles. In addition, NODC also received a special global wind/wave data set derived from the first phase of GEOSAT operations. The data set provides radar cross section, wind speed, and significant wave height for the GEOSAT Geodetic Mission from March 1985 through September 1986. Although specific plans for a successor to GEOSAT are not yet final, NODC expects to archive and disseminate that altimeter data also.

With assistance from WDC-A, Oceanography, NODC has compiled inventories of ocean measurement (oceanographic station data and salinity, temperature, density) programs that have repetitive sampling at the same locations for long time periods. A total of 27 time-series data sets ranging in minimum duration from five years for North Pacific Ocean Weather Stations and related sections to more than 30 years for the CALCOFI sections have been identified and researched. A total of 56 North Atlantic sections have also been fully inventoried. Final manuscript has now been completed for both inventories. A third inventory covering the remainder of the World Oceans is currently in work. Each data set constitutes the basis for a new data product that will be available on magnetic tape from NODC and WDC-A.

As a result of a reorganization within NOAA's National Environmental Satellite, Data, and Information Service (which includes NODC and two other NOAA data centers), management responsibility for the NOAA library system has been delegated to the NODC. The NOAA Library and Information Network is now administered by the Library and Information Services Division within the NODC. The Network consists of:

- the NOAA Central Library in Rockville, MD;
- regional libraries at major NOAA facilities in Miami, FL, and Seattle, WA;
- more than 30 field libraries and information centers at other NOAA locations throughout the United States.

Over the past several years the NODC has developed and refined an online information system called NOSIE (for NODC Ocean Science Information Exchange). An improved version is undergoing testing and will be available in 1990. NOSIE can be accessed over the NASA SPAN network and by direct dial-up. It will also soon be available via Omnet/Sciencenet over Telemail.

Technology Enhancements

The NODC has begun implementation of an Ethernet local area network (LAN). The initial phase links 16 PCs with NODC'S VAX 11/785 that serves as the data processing host. A VAX 11/750 presently serves as the communications host linking NODC to outside networks. The NODC has also begun testing a A ShareBase 700 database machine (with 6 Mb memory and a 1.2 Gb magnetic disk subsystem) that is planned to serve as a prototype NODC database host. To augment digital data bases available for climate research, the NODC has initiated a project to capture previsously undigitized data sets. In late 1989 the NODC acquired a Kurzwell Intelligent Scanning System that will enable hard copy data to be more easily incorporated into its data files.

TABLE A.2 NODC TOGA Database

(*Tropical Pacific temperature profiles received through November 1989 for area 30°N-30°S and 70°W-120°E)

	Data Type			
Year	Radio Message	Delayed Mode	Total	%Delayed
1986	3,260	8,376	11,636	72%
1986	2,895	11,744	14,629	80%
1987	5,467	11,513	16,980	68%
1988	4,928	7,224	12,152	59%
1989	8,247	628	8,875	7%
TOTAL	24,797	39,485	64,272	61%

NATIONAL GEOPHYSICAL DATA CENTER

Program Description

The National Geophysical Data Center (NGDC) carries out a number of programs which provide data for research in meteorology and climatology. Of particular interest is NGDC's program to assemble global information on paleoclimate and cooperate in research projects to employ the combined global paleoclimate data base for climate model verification and climate change studies. Continued support for this program from the NOAA Climate and Global Change Program (CGCP) is expected.

NGDC has actively sought and acquired many paleoclimate data bases derived from tree-rings, lake and bog sediments, marine sediments, ice cores, and other geological and biological sources. Catalogues and inventories of paleoclimate data contained in ice cores, lake varves, and marine varves, have been completed and are currently being prepared for publication. Objectives of the program are to cooperate with other NOAA and academia researchers to better describe the global effects of annual to century scale climate change; to identify and better understand the causes of this climate change; and to improve the ability of separating man-induced climate change from the natural variability.

Long-term, global records of solar variability are assembled at NGDC both as a record of past conditions and for their continuing value for comparison with new measurements of various forms of solar energy output variations reaching Earth that may affect meteorological conditions. For example, the longest running direct observations are sunspot numbers that track the nominal

11-year periodic solar cycle back to the early 17th century. From early in the 20th century there are continuing records of solar flare observations and since the time of World War II, these have been supplemented by solar radio emission recordings. For about one 11-year solar cycle there are direct satellite measurements of changes in the "solar constant" tracking the slow variation of radiant solar energy that warms Earth and seems to follow the sunspot cycle. These data are studied at NGDC and made available to the research community through publications and on a variety of media including floppy and optical discs.

NGDC, through its affiliated contract data center, the National Snow and Ice Data Center (NSIDC) maintains several cryosphere-related datasets of interest to meteorology and climatology. These include a collection of historical photographs of glaciers; temperature, pressure, and position data from satellite-queried drifting buoys placed on the central Arctic pack ice; and data from the DOD-NOAA sea ice chart digitizing programs. In addition, NSIDC provides data management services for the Coordinated Eastern Arctic Experiment and the Second Greenland Ice Sheet Program (GISP II); and is developing gridded sea ice products (sea ice concentration and multiyear ice fraction) based upon passive microwave data collected by the Scanning Multichannel Microwave Radiometer on Nimbus 7 and the DMSP Special Sensor Microwave Imager. The passive microwave data sets are being distributed on CD-ROMs. Under NOAA Climate and Global Change Program (CGCP) sponsorship, NSIDC is studying ways to utilize the ingest and output data streams from the Naval Polar Oceanography Center's Digital Ice Forecast and Analysis System for climate research. NSIDC is also developing an improved global snow cover model for the Air Force Global Weather Central.

In addition, NGDC has had a long history of compiling various digital global databases including land topography, geomagnetic anomalies, heatflow, historical volcanic activity, and ocean bottom samples, drilling data, and bathymetry. These databases will be improved and enhanced and new global baseline and thematic databases (e.g. vegetation indices, ecosystem classifications, land use, terrain characteristics, soils, permanent ice cover, seasonal snow cover) will be acquired and compiled. Models of the global climate use these databases for model parameterization and data-model intercomparisions. It is expected that these data bases will play an important role in the NOAA CGCP.

OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH

Environmental Research Laboratories

Environmental Research Laboratories (ERL) R&D programs support NOAA space and meteorological services and are oriented toward providing, understanding, and developing techniques and technologies to form the basis for improvements in the Nation's weather services. These important functions encompass the missions of several ERL laboratories.

Special emphasis is placed on improving severe weather and hurricane forecasts and warnings. Severe weather is any major natural hazard such as flash floods, strong winds, thunderstorms (including tornadoes and hail), and heavy snowstorms. ERL laboratories will continue to conduct both inhouse and cooperative research with other NOAA components, joint institutes, and universities.

OBSERVING TECHNOLOGY

The Profiler Program Office of ERL, located in the Forecast Systems Laboratory, has accepted two prototypes of the wind profilers that will make up the planned 30 station demonstration network in the central U.S. Installation of the 30 prediction systems began in FY 1990, and will continue into FY 1991. Wind data from this network will be used to assess the operational impact of this new technology and will become a key part of future mesoscale research in ERL.

The Wave Propagation Laboratory (WPL) continues to operate three automatic tropospheric wind profiling radars and total water (i.e., vapor and precipitation) measuring radiometers in Colorado during FY 1990. Only two of the wind profiling radars are co-located with radiometers. Observations from the WPL and Profiler Program Office systems contribute to development and test methods for effective use of continuous profile data to improve NWS short-range, local forecasts. The data will continue to be used in real time by the Denver National Weather Service and surrounding Forecast Offices, and for research by ERL, the National Center for Atmospheric Research, and university researchers.

WPL will continue studies to improve the accuracy and height resolution of wind, temperature, and humidity profiles. Low-altitude vertical temperature profiles comparable to those of the radiosonde are currently being produced by the Radio Acoustic Sounding System (RASS). The altitude is extended by combining the RASS measurements with TIROS N satellite data. Development of both the RASS and the thermodynamic (temperature/moisture) remote sensing profilers will continue in FY 1991. The development of a high resolution interferometric sounder (HIS) began in FY 1990 and will continue into FY 1991. The remote sounder will provide ground based measurements of atmospheric temperature and humidity profiles and trace constituents. Integration of a vertical temperature and humidity profiling system with the demonstration wind profiling network will begin in FY 1991.

The technology of infrared Doppler lidar and multifrequency radars, will be advanced by continued application to wind, aerosol, and turbulence studies, as well as to convective storms.

SEVERE WEATHER ANALYSIS AND FORECASTING RESEARCH

The National Severe Storms Laboratory (NSSL) in Norman, OK, focuses its research to understand and forecast severe convective storms and their associated weather hazards such as hail, high winds, heavy rain, lightning and turbulence. The parameters of storm development and intensification are identified by incorporating observations from Doppler weather radar, satellites, remote-sensing wind profilers, instrumented aircraft, and lightning location networks. NSSL provides significant technical and scientific support, including research and development, for the NOAA/USAF/FAA NEXRAD program.

NSSL will continue to develop techniques to identify and warn of lightning hazards, to aviation and the general public, in cooperation with the National Weather Service. Immediate technology transfer will be effected by close association with the Oklahoma National Weather Service Forecast Office in Norman, OK.

In FY 1990, ERL continued to transfer knowledge of convective weather systems and associated heavy rainfall but at a reduced level as a result of reduced participation in courses at the NWS training center and fewer visits and interactions with NWS centers, regional headquarters, and forecast offices. This reduced level of activity will be continued in FY 1991.

The Forecast Systems Laboratory's (FSL) Program for Regional Observing and Forecasting Service (PROFS) in Boulder, CO, is continuing to improve the effectiveness of short-range, locally specific, weather services. The improvements are achieved through a program of applied forecasting research and development based on new understanding of the storm development as determined by the research community. PROFS integrates these advances with emerging technologies, advanced observational systems (such as NEXRAD, VAS, and the Profiler), and conventional data. These quasi-operational systems are realized in specific hardware/software configurations of the highly flexible PROFS Exploratory Development Facility, with extensions into the Denver WSFO under the NWS AWIPS program. These advanced capabilities will be evaluated to reduce the risks of AWIPS procurement, and to improve forecast and operations, as precursors to the NWS forecaster work-station of the 1990s.

PROFS will continue its emphasis on data application from the GOES VISSR Atmospheric Sounder (VAS), Doppler radar, and the Profiler as inputs to its quantitative mesoscale analysis and prediction model, thus expanding service improvement efforts to include nonsevere as well as severe weather, to assist NWS modernization and restructuring, and to upgrade National Meteorological Center operations.

MESOMETEOROLOGY AND PRECIPITATION FORECASTING AND WARNING RESEARCH

The NSSL and FSL develop techniques to improve short-term forecasts of significant weather events. Through detailed case studies and regional climatologies, ERL scientists have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storms complexes. Activities underway include studies of the precipitation structure of mesoscale convective systems, of interactions between mesoconvective systems and the larger environment, of satellites to infer storm development and rainfall, and of winter storm forecasting procedures.

FSL will continue an effort begun in FY 1987 to develop enhancements to the NWS operational LFM numerical model. The goal is to provide a continuing stream of improvements in the operational numerical guidance provided twice daily to weather forecasters.

HURRICANE ANALYSIS AND PREDICTION RESEARCH

The Hurricane Research Division (HRD) of the Atlantic Oceanographic and Meteorological Laboratory performs research to improve operational hurricane forecasts and warnings. HRD's hurricane field program uses highly instrumented NOAA P-3 research aircraft to acquire unique data which are analyzed to describe and understand the dynamics and energetics of the hurricane's inner intense core.

HRD develops numerical hurricane models using these and other sophisticated data to analyze and predict hurricane behavior. During FY 1988, HRD gathered synoptic-scale Omega Dropwindsonde (ODW) data during this century's strongest hurricane -- Gilbert. Analyses will continue in FY 1991. HRD will continue to provide data necessary to develop a next generation objective analysis scheme, as well as to support NWS real-time hurricane forecasting.

In addition to the HRD research, the Geophysical Fluid Dynamics Laboratory (GFDL) at Princeton, NJ, models the genesis, development, and decay of tropical storms, including small-scale features within hurricane systems, using multi-nested models of the storm system and its environment. FY 1991 plans of GFDL and HRD include research to:

- Improve understanding of the genesis, development, and decay of tropical depressions by investigating the thermo-hydrodynamical processes using numerical simulation models;
- Study small-scale features of hurricane systems, such as the collective role of deep convection, the exchange of physical quantities at the lower boundary, and the formation of organized spiral bands;
- Investigate the capability of numerical models in the prediction of hurricane movement and intensity;
- Develop next generation operational hurricane prediction model.

NUMERICAL ANALYSIS AND PREDICTION MODELING

GFDL conducts long-lead-time research to understand the predictability of weather on both large and small scales and carries out experimental applications of this understanding of NOAA missions. Three main areas of weather research are covered by the GFDL program -- Experimental Prediction, Hurricane Dynamics (discussed earlier), and Mesoscale Dynamics.

Experimental prediction research is carried out with the National Meteorological Center to determine the predictability of global atmospheric circulation on extended time scales. FY 1991 research plans are to:

- Develop more accurate and efficient atmospheric and oceanic Global Circulation Models (GCM's) suitable for monthly and seasonal forecasts;
- Identify important external forcing mechanisms for the forecast range of several weeks to several months; accurately specify initial states of the atmosphere, oceans, soil, and snow-ice;
- Investigate the influence of additional internal processes such as orography, cloud-radiation interaction, and cumulus convection upon atmospheric variability on the seasonal time scale;
- Study the mechanisms of various atmospheric phenomena such as blocking, orographic cyclogenesis, equatorial ocean-atmosphere interaction, tropical circulations, and teleconnections.

Mesoscale dynamics research seeks to understand the practical limits of mesoscale predictability and the interaction of mesoscale phenomena with the larger and smaller scales.

The Wave Propagation Laboratory, through cooperative agreements with the National Center for Atmospheric Research, continues to apply four-dimensional data assimilation modeling techniques to simulate Profiler Network observations. Results have demonstrated the importance of co-locating RASS temperature capabilities with wind profilers and will provide information for determining the necessary density of an operational wind profiler network.

SPACE ENVIRONMENT SERVICES

The National Oceanic and Atmospheric Administration and the USAF Air Weather Service jointly operate the National Space Environment Services Center in the Space Environment Laboratory (SEL) in Boulder, CO. The Center provides forecasts, alerts, indices, and summaries of disturbances occurring on the sun, in space, in the geomagnetic environment, and in the upper atmosphere. The services are used by the DOD, DOT, DOC, DOI, DOE, NASA, NSF,

commercial users, and the research community: (1) to optimize the operation of technical systems that are adversely affected by disturbances in the space environment, and (2) to carry out research in the solar-terrestrial environment. Examples of the adverse effects include loss or reduced efficiency of communication systems, radiation hazards to personnel and systems in space and on high altitude aircraft, degradation of surveillance and monitoring systems for defense, errors in navigation systems, and perturbations of satellite orbits.

The Center serves as the International World Warning Agency for the solar-terrestrial environment. It collects international data in real time, provides Ursigram and World Days Service, and meets additional specific needs of other Government agencies. The Center distributes data to other countries and issues a consensus set of daily forecasts for international use.

The Center operates with observations received from agencies that make their data available in real time and, in return, receive the services to meet their own needs. Agencies making major contributions of data include DOD, NASA, DOC, NSF, DOE, and DOI. The Space Environment Laboratory cooperates directly with NOAA/NESDIS to receive solar x-ray, particle, in situ magnetic field, and plasma data from the Space Environment Monitors on GOES and polar-orbiting NOAA satellites.

Data are collected, stored, and displayed for analysis; products are distributed through the Space Environment Laboratory Data Acquisition and Display System (SELDADS II). Services are distributed via teletype and digital data links (primarily operated by other agencies), via the SELDADS, by radio broadcast (WWV), by mail, by recorded telephone messages available to commercial dial-up users, and by low-cost commercial satellite broadcast service.

Planned FY 1991 research will continue development of solar prediction techniques using data which simulate those expected from the Solar X-ray Imager, to be flown on GOES-NEXT. Research will continue to insure full utilization of imager data in operational forecasts during the GOES-NEXT era. Additionally, research will begin on interplanetary scintillation maps and their use as a forecasting tool.

NATIONAL OCEAN SERVICE

The National Ocean Service (NOS) develops, implements, and manages programs in physical, biological, chemical, and geological oceanography and establishes a scientific information base on which to support development of national policy for oceans and their users. NOS coordinates and supports marine activities pursued by other NOAA components (National Weather Service, National Marine Fisheries Service, Office of Oceanic and Atmospheric Research, and National Environmental Satellite, Data, and Information Service), and provides products and services that support meteorological, climatic, and environmental programs.

The objective of the Ocean Services Program is to improve the Nation's ability to observe and predict physical changes in the global and coastal ocean environment on all temporal and spatial scales. To accomplish this mission, the NOS Office of Ocean Services manages a broad program to: modernize and enhance ocean data collection; provide timely quality assurance for operational marine data sets; develop techniques and interactive systems to analyze and predict marine processes; issue analyses and forecast guidance products of the marine environment; and distribute data and products to a wide range of Government and private sector users.

The ocean observing program provides an end-to-end data management approach. User requirements for operational and research applications are routinely solicited, reviewed, and coordinated in an attempt to establish consensus and identify cost-effective solutions. The Office maintains an inventory of all available long-term observing systems; the development and deployment of new ocean observing platforms are leveraged against the existing observing capabilities. Quality assurance is provided on the data sets through automated procedures onboard the platforms and interactive procedures at data processing facilities. Real-time data are disseminated on a variety of communications networks operated by NOS, NWS, and NMFS.

The Ocean Services Program provides operational marine analyses and forecast guidance material in support of NOS, NWS, and NMFS field offices. Analyses, interactive guidance products, and numerical model output are produced at and disseminated from three National Centers: the NOAA Ocean Products Center (Camp Springs, MD) which provides marine weather and physical oceanographic products; the Navy-NOAA Joint Ice Center (Suitland, MD) which provides global, regional, and local sea and Great Lakes ice products; and the NOAA Center for Ocean Analysis and Prediction (Monterey, CA) which provides analyses, assessments, and forecast guidance of biochemical and ocean climate processes.

OFFICE OF NOAA CORPS OPERATIONS
AIRCRAFT OPERATIONS CENTER

The Aircraft Operations Center (AOC) supports several NOAA missions, in particular, it operates a fleet of aircraft which are used to support NOAA's research and development programs to improve weather, marine, and climate services. It also provides weather reconnaissance support to NOAA programs, other Federal agencies and international programs approved by the Aircraft Allocation Council. Light aircraft provide aerial photography for nautical and aeronautical charting and living marine resources surveys.

AOC was established in October 1983 to consolidate the management of all aircraft used by NOAA. Fourteen aircraft located throughout the United States are managed by AOC at Miami International Airport in Florida.

NOAA's atmospheric and oceanographic research and reconnaissance operations are supported by two fully instrumented WP-3D aircraft which carry state-of-the-art environmental research equipment. The aircraft research and navigation systems provide detailed spatial and temporal observations of a wide range of atmospheric and oceanic parameters. AOC develops and calibrates specialized instrumentations, integrates user-supplied instruments into the automated systems, and processes and analyzes data sets obtained from various field programs.

AOC aircraft provide high density/accuracy hurricane data to the National Hurricane Center in near real-time. Storm data are transmitted via the aircraft satellite data link to upgrade forecasting models of hurricane track/intensity. The AOC aircraft have primary responsibility for reconnaissance of tropical storms and hurricanes over foreign airspace that may be restricted for military operations. AOC augments USAF operational aircraft reconnaissance with high-density, high-accuracy data when storms are within 24 hours of landfall of the Continental US and whenever DOC needs exceed DOD resources. AOC also provides a quick response capability for investigation of storm activity east of 80°W longitude from August 1 through September 30 each year.

APPENDIX B

DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates a military environmental service system to provide specialized worldwide meteorological and oceanographic prediction services in support of military forces. This service directly supports all phases of military operations, from strategic planning to tactical operations. The U.S. Navy's Naval Oceanography Command and the U.S. Air Force's Air Weather Service are the primary military performing agencies. The Army and Marine Corps each have a small specialized weather support capability, but depend upon the primary weather services for most support. The military weather services contribute to the national and international weather observing capability by making conventional observations on land and at sea where there is no other conventional weather observing capability and where the observations are most needed to meet military requirements. In addition, DOD maintains special observing capabilities such as the Defense Meteorological Satellite Program to meet unique military requirements. Observational data are sent by military communications networks to military and civil facilities in the United States and overseas.

UNITED STATES ARMY

OVERVIEW/ORGANIZATION

Army Operational Support

The U.S. Army provides two kinds of direct weather support to the Army combat mission. These are upper air observations for artillery fire support missions and limited surface weather observations to support some Army weapon systems.

Artillery Meteorological Crews are assigned to Artillery units at division level, to Field Artillery Brigades, and to Separate Brigades with a direct support Artillery Battallion. Army soldiers regularly take tactical air observations to support Artillery units during tactical training exercises or at permanent Army Artillery Ranges.

Intelligence personnel on the Maneuver Brigade and Battallion staff take aperiodic, limited surface weather observations in the forward combat areas, below the level where the USAF has responsibility for observations.

The Training and Doctrine Command (TRADOC), through its proponent schools, manages the development of training programs, field manuals describing support procedures, and requirements for weather support personnel and equipment. The Field Artillery School is responsible for upper air weather support, and the Intelligence Center and School is responsible for all other tactical weather support.

Headquarters, Department of the Army, Office of the Deputy Chief of Staff for Intelligence (ODCSINT) is responsible for Army overall weather support policy and procedures for both tactical operations and peacetime training support. Office of the Deputy Chief of Staff for Operations is responsible for validating and prioritizing weather support requirements and programs to meet those requirements.

Army Operational Support Provided by the USAF

Under joint agreements, the USAF provides tactical forecasting and observing support during field exercises and contingencies and similar support during peacetime training at fixed locations and Army airfields. The USAF provides the personnel and observing equipment for tactical observations taken by the Air Force in the field, and the Army provides the tactical communications, equipment, and vehicles to support the USAF weather teams.

In garrison locations the Army provides facilities, on post communications to the Air Force Weather Station and from the Weather Station to Army user locations. Army also provides Army-unique training, and logistics support to the USAF weather support personnel. The USAF provides and maintains standard USAF weather fixed-locations communications and observing equipment, usually at Army Airfield Weather Stations.

Weather Support for RDT&E

Under the joint weather support agreement with the USAF, the Army has responsibility for weather support for research, development, test, and evaluation (RDT&E) to support the Army ground combat mission. Air Force Regulation 105-3 and Army Regulation 115-10 task the Air Force to provide climatological support to Army research and development activities. The Army Materiel Command (AMC), through the Atmospheric Sciences Laboratory (ASL), supports and provides two types of service to RDT&E:

(1) ASL Meteorological Teams provide operational forecasting and observation support at a total of fourteen RDT&E locations including test ranges in Alaska and Panama, and other Army R&D facilities. This support also includes a worldwide mobile weather observation capability. In association with this opertional support to RDT&E, ASL also develops and operates special environmental observation equipment to support weapons system development, other Army tests, and Department of Defense missions. ASL used its mobile support capability to provide tailored forecasting and observation support to several major tests for the Army and other DOD efforts in FY 1989. In addition, the quick response team produces near real time data reports to assist test directors in evaluating test results while still in the field. The Meteorological Teams and research scientists also used specially developed imaging equipment and transmissometers to help quantify smoke munitions effectiveness. This support comprises more than 50% of ASL's mission funding.

(2) ASL is the focus of Army technology-based weather support to research and development (R&D). It employs meteorologists, atmospheric scientists, and other highly qualified technical experts to meet the weather support requirements of R&D in all the Army mission areas. ASL supports several programs that range from basic research to preliminary prototype development. Major categories of ASL work include: (a) descriptions of atmospheric effects for the design of weapons systems, tactics, doctrine, and training; (b) atmospheric sensors and systems; and, (c) meteorological models and tactical decision aids.

In conjunction with ASL, several other AMC and Corps of Engineers (COE) facilities provide associated weather support to Army RDT&E.

(1) The AMC Army Research Office (ARO) manages, in cooperation with civilian universities and colleges, Army basic research programs in atmospheric sciences that support mesoscale weather forecasting, electromagnetic propagation in the atmosphere, and planetary

boundary layer atmospheric physics. ARO also has oversight over the Army Center for Geophysics, Colorado State University, which performs broad-based, basic research in the atmospheric sciences.

(2) The COE Engineer Topographic Laboratories (ETL) provides applied climatological support to Army R&D and manages the AirLand Battlefield Environment (ALBE) demonstration. ALBE coordinates efforts from several environmental support laboratories into a comprehensive support system. ALBE builds weather and terrain information into tactical decision aids. ALBE decision aids demonstrate the weather and terrain effects on Army operational capabilities and display them in a form that shows the impact on Army war fighting capabilties. ASL develops the weather effects decision aids that are part of the ALBE program. ASL provides weather observing equipment and personnel to support ALBE field demonstrations. ALBE will develop environmental effects tactical decision aid software that can be transitioned to future operational systems.

(3) The U.S. Missile Command, RDT&E Center, Aerophysics Branch develops climatological models and reports on atmospheric criteria to support specific design efforts. Missile design climatology is used to establish satisfactory criteria for weapon systems and program development efforts.

(4) The COE Cold Regions Research and Engineering Laboratory provides weather support to Army R&D relating to weapons systems and other missions in the winter environment. Climatological studies, such as a comparison of U.S. seasonal weather at test facilities to potential threat area weather conditions are done to assist weapon system tester and developers. Other winter weather projects focus on measuring how winter weather conditions affect heat budgets and contrast of targets to the background, and application to operational support systems.

TRADOC PROGRAMS

TRADOC Schools have a dual mission in R&D support and in operational support. Some R&D functions are done by the Directorate of Combat Developments (DCD), while the Directorate of Training and Doctrine (DOTD) carries out some operational functions.

The DCD at the TRADOC schools writes the concepts on which solutions to deficiences are based. Solutions may be in new training programs, new organizations or changes in force structure, or in development of new equipment. When new equipment is the solution to a weather support deficiency, DCD writes the requirements documents and works jointly with the Communications and Electronics Command (CECOM), the materiel developer for weather support equipment, to design and develop the new equipment.

The DOTD designs and teaches new courses that are needed at the schools that deal with weather support or incorporate new weather support procedures into existing courses. The Field Artillery School and Intelligence School are the primary schools that provide weather related training. However, the Aviation School, Chemical School and Engineer School also incorporate weather support into their training programs. The Intelligence Center and School has a key role in establishing joint operational procedures which Air Weather Service which is promulgated in joint tactical support concepts, manuals, and regulations.

The Field Artillery School (USAFAS), in conjunction with CECOM, has developed the Meteorological Data System (MDS) to meet the upper air observation requirements to directly support Artillery and indirectly other Army mission areas in the heavy forces. The Army will complete fielding of MDS in FY 1990. USAFAS and CECOM are also planning to purchase the

Meteorological Measuring System (MMS) after FY 1991 to meet the needs of the light forces. The MMS will be a smaller and more tactical upper air observation system and will be deployed with Light Infantry, Airborne, Air Assault, and Artillery Reserve Components.

The Intelligence Center and School (USAICS), in conjunction with CECOM, will finalize the requirements and development documents for the Integrated Meteorological System (IMETS) in FY 1990. IMETS will provide tactical communications for USAF Weather Teams and automate weather support data processing and distribution to tactical Army command elements. USAICS is also updating a joint Army and Air Force concept for tactical weather support. In conjunction with the Air Force, USAICS published FM 34-81/AFM 105-3, Weather Support for Army Tactical Operations, in August 1989. This is the joint doctrine which describes the organizations, shared responsibilities, and general procedures for weather support in wartime situations. Air Force personnel and Army equipment for USAF Weather Teams, that support tactical units, are based on this joint manual.

The Combined Arms Combat Development Activity integrates and coordinates proponent schools weather support activities with the other mission areas and Army-wide plans. Headquarters, TRADOC is the final TRADOC approval authority for weather support activities before they are submitted, as appropriate, to the Department of the Army for final approval.

RDT&E PROGRAMS CONTENT

Atmospheric Sciences Laboratory, White Sands Missile Range, NM is the AMC resource dedicated to atmospheric research relevant to the needs and level of interests of the Army. ASL programs encompass several investigations into atmospheric effects on war fighting capabilities and systems.

Atmospheric Effects programs include developing theories and techniques dealing with environmental effects on image and acoustical propagation through the atmosphere, incorporating weather effects realism into war gaming, and providing a better understanding of battlefield atmospheric effects on electro-optical weapon systems. A sampling of Atmospheric Effects programs are the Restoration of Turbulence-degraded imagery; 4-D Image Simulation Model of Battlefield Thermal Sources; Resonant Aerosol Particle Breakdown and Scattering; Acoustic Propagation Models; and Weather Effects information for Army Systems Development.

In the Sensors and Systems area, objectives of investigation include theories and techniques for atmospheric sensing, developing proof of concept prototypes (eg. IMETS), atmospheric profiling techniques, and a baseline automated surface sensing system. Programs in this area include the Distributed Processing of Meteorological Information, and the Meteorological Integration Techniques Demonstration.

Modeling efforts have been developed that deal with atmospheric behavior, application of weather satellite data, tactical decision aids for target acquisition, NBC and smoke operations, and target area weather. Examples of these programs are the Target Area Meteorological Data Assimilation Technique, and the 4-D Probabilistic Chemical Concentration Model of Simple Terrain.

ASL also provides support to the High Energy Laser (HEL) test and evaluation technology demonstrations through a specialized branch. In addition to the operational forecasting and observing to a wide range of test ranges and missions, ASL develops and operates one-of-a-kind meteorological systems supporting technology based research and other RDT&E not done by the Meteorological Teams.

The Target Contrast Characterizer was developed by ASL to determine atmospheric effects on image propagation.

The Research Visible and Infrared Transmission system measures electro-magnetic transmission at several wavelengths, along several paths to help establish weapons systems efficiencies in adverse weather conditions.

The Mobile Atmospheric Profiler System measures optical transmission parameters in testing electro-optical and laser systems.

The Simultaneous Multispectral Absolute Radiometer Transmissometer helps validate mathematical models of atmospheric effects on electro-optical systems.

The Multispectral Imagery Data Acquisition System simultaneously sees an image in visible and infrared wavelengths. This allows researchers to characterize the movement of parcels of air or smoke.

The Transportable Atmospheric Characterization System measures atmospheric constituents that affect millimeter wave propagation.

The Surface Automated Meteorological System is a self-contained, mobile weather observing system that can collect data from remote locations by RF link or landline.

UNITED STATES NAVY

OVERVIEW/ORGANIZATION

Within the U.S. Navy, meteorological and oceanographic support is provided globally to units based ashore and at sea. These include environmental personnel and resources assigned to naval shore and afloat staffs, U.S. Marine Corps aviation weather units, test stations and ranges, shipboard weather offices, and activities of the Naval Oceanography Command. Personnel and resources from the naval research, development, logistic, and training components are also included. Naval Systems Commands, laboratories, research facilities, and training commands constitute various additional components.

Primary support is provided by activities and detachments assigned to the Naval Oceanography Command. Shore field activities within the Naval Oceanography Command having meteorological responsibilities include a primary numerical processing center, three regional Naval Oceanography Centers, two Naval Oceanography Command Centers, eight Naval Oceanography Command Facilities, over 50 Naval Oceanography Command Detachments, two Naval Oceanography Command components, and the Naval Oceanographic Office.

The Fleet Numerical Oceanography Center, Monterey, CA, operates the master computer center and functions as the hub of the Naval Environmental Data Network. The Naval Environmental Data Network is designed for product distribution among the major Naval Oceanography Command activities. Through linkage with DOD and NOAA environmental satellite systems and U.S. Air Force and NOAA data distribution centers, Fleet Numerical Oceanography Center acquires global coverage of environmental data. A joint agreement exists between the Air Force, Navy and NOAA to share processing tasks and environmental product lines of mutual interest to all parties from DMSP, GOES and NOAA TIROS satellites. From these data, basic and applied numerical (computer) products are generated for distribution via the Naval Environmental Data Network and other communications systems for use by other activities in producing specific support products and services.

The three regional Naval Oceanography Centers--the Naval Western Oceanography Center at Pearl Harbor, HI; the Naval Eastern Oceanography Center at Norfolk, VA; and the Naval Polar Oceanography Center at Suitland, MD--are assigned broad geographical fleet support services and related matters within their specific areas of responsibility. The Naval Western Oceanography Center is responsible for the Pacific and Indian Ocean areas; Naval Eastern Oceanography Center for the Atlantic and Mediterranean Sea areas; and the Naval Polar Oceanography Center for the Arctic and Antarctic areas. They utilize numerical products from the Fleet Numerical Oceanography Center to provide environmental broadcasts and tailored support in response to specific requests from the operating forces.

The two Naval Oceanography Command Centers are located at Rota, Spain, and on the island of Guam. Naval Oceanography Command Center, Rota, assists Naval Eastern Oceanography Center in the Mediterranean Sea area. Naval Oceanography Command Center, Guam, assists the Naval Western Oceanography Center with provision of environmental services in the Western Pacific and the Indian Ocean areas. Both of these centers provide fleet environmental broadcasts and tailored support in a manner similar to the regional centers. Naval Oceanography Command Center, Guam, has an additional responsibility for operation of the "Joint Typhoon Warning Center" (with the Air Weather Service of the U.S. Air Force), providing tropical warnings to USAF, issuing tropical cyclone warnings to U.S. interests in the Western Pacific and Indian Oceans.

Seven Naval Oceanography Command Facilities at Brunswick, ME, Jacksonville, FL, San Diego, CA, Yokosuka, Japan, Cubi Point, Republic of the Phillipines, Keflavik, Iceland, and Bermuda provide limited area, local and aviation environmental forecast services, as well as direct support for ship and submarine staffs. Five of these activities command detachments. Primary forecast guidance from Fleet Numerical Oceanography Center is utilized by all facilities; the overseas facilities augment this guidance with data from local sources. The eighth facility, Naval Oceanography Command Facility, Bay St. Louis, MS, is responsible for Naval Reserve matters of the Naval Oceanography Command and the management of programs concerning Naval Oceanography Command training, climatology, meteorological and oceanographic equipment, and publications and forms.

There are 47 Naval Oceanography Command Detachments located worldwide. This number may increase depending on requirements. Although primarily located at Naval Air Stations, several are being located at Naval Stations to provide services to sea-going units. Each is established under an Officer-in-Charge or Chief Petty Officer-in-Charge who reports to a designated shore/field activity. The majority of these detachments are oriented to provide direct environmental support, including aviation meteorological and oceanographic services, within their local areas. Detachments within the contiguous states utilize the basic and applied numerical products from both the National Meteorological Center and the Fleet Numerical Oceanography Center to provide meteorological and oceanographic services. Oceanographic products prepared by Naval Oceanographic Office are also utilized. Overseas detachments utilize foreign and Air Weather Service (AWS) products, as available, in addition to Fleet Numerical Oceanography Center numerical products. Three of the detachments are oriented to provide specific technical support; such functions include coordination of the Navy's climatological program at the National Climatic Data Center at Asheville, NC, coordination and circuit management with the USAF Automated Weather Network (AWN) at Carswell AFB, TX, and liaison and coordination with the USAF Global Weather Center at Offutt AFB, NE.

Naval Oceanographic Office operations are directed primarily to oceanography and Mapping, Charting and Geodesy (MC&G) matters. However, oceanography and meteorological climatology

are included in many of their publications and appropriate atmospheric/oceanographic data bases are maintained for this purpose. On-scene environmental support capabilities such as the Integrated Command Acoustic Prediction System, Geophysical Fleet Mission Program Library, and Tactical Environmental Support System (known as "TESS") provide in-situ tactical oceanographic support to operational forces. In addition, an Operational Oceanography Center established at Naval Oceanographic Office will begin near real-time processing of remotely sensed oceanographic data (primarily NOAA TIROS Multi-Channel Sea-Surface Temperature). By July 1991, these data will be provided to Fleet Numerical Oceanography Center for numerical model input and specific regional forecasts.

Oceanographic/meteorological units are permanently assigned to 39 aviation-capable U.S. Navy ships. These units, staffed with officer and enlisted personnel and equipped in accordance with their designated support functions, are integral to the command to which they are assigned. Smaller units, termed Mobile Environmental Teams are temporarily assigned to Navy ships upon request to meet short-term support requirements. These METs, available from six Naval Oceanography Command activities (Rota; Norfolk; San Diego; Yokosuka; Cubi Point, and Pearl Harbor) are outfitted with their own portable equipment. Navy ships without dedicated units also contribute by providing vital meteorological and oceanographic observations, frequently from data-sparse oceanic areas. Technical guidance is provided by the Naval Oceanography Command.

U.S. Marine Corps (USMC) garrison aviation weather units are staffed with USMC meteorological personnel. They function and are supported in a manner similar to Naval Oceanography Command Detachments but under USMC management. These weather units are integral to Marine Corps aviation activities and provide support to assigned activities and tenant organizations thereof, which include nine major air stations in the contiguous United States, one in Hawaii, and two in Japan.

The Fleet Marine Force aviation units, also staffed with meteorological personnel, are indigenous to each of the twelve Marine Air Groups. They operate and maintain meteorological mobile facilities to provide environmental support during tactical operations. The units are task organized to respond to the commander's requirements according to the mission, functioning independently as required. While in garrison, the weather personnel and equipment augment and support the host activity's weather unit.

PROGRAM DESCRIPTION

The Navy's meteorological Operational Support programs are designed to satisfy validated fleet requirements. They include surface and upper atmospheric observations programs, flight forecasting services, tailored forecasts, and optimum track ship routing for naval and naval contract vessels, local and operating area forecasts, tropical cyclone warnings, local severe weather forecasts, high seas and winds forecasts, manual and numerically-derived analyses and prognoses, statistical and climatological studies, and a wide range of mission-specific and tactical support products to the operating forces of the U.S. Navy.

The FY 1991 budget includes programs that address a total of 184 validated requirements. Efforts are focused in three broad areas: shipboard tactical environmental support; upgrades to Fleet Numerical Oceanography Center, Naval Oceanographic Office and other Naval Oceanography Command centers and their data distribution networks; and, enhanced capabilities at Naval Oceanography Command shore-based aviation support activities. Efforts in the FY 1991 program address both the Systems Acquisition and Operations Support categories. They are highlighted below.

Tactical Environmental Support System (TESS). TESS is a modular, computer-based support system designed to provide Navy decision-makers with meteorological/oceanographic assessments and forecasts and to integrate air/ocean data with sensor/weapon platform parameters to assess system performance. Scheduled for initial operational deployment during FY 1991, TESS will function as the operational, resident air/ocean master data base. Data sources will include in-situ sensors, meteorological and oceanographic satellites, U.S. and foreign radio weather broadcasts and data fields prepared ashore, principally at the Fleet Numerical Oceanography Center. Its applications and capabilities extend well beyond those of an automated weather information system (AWIS) because of the extensive ocean acoustic analysis and prediction capabilities, and data bases containing tactical sensor and weapon systems parameters for use in tactical decision aids hosted in the system.

Acquisition strategy for TESS is to build upon an interim capability based on the Navy-Standard Desktop Tactical Support Computer. This interim capability (known as TESS(1) and TESS(2)) was implemented as a non-research and development effort, and was completed during FY 1989. A total inventory of over 70 units exists with installations keyed to major fleet combatants and selected shore activities with significant command and control responsibilities. The follow-on system, TESS (3), will rehost the existing TESS capabilities while providing significant new enhancements.

Primary Oceanographic Prediction System. Existing computer systems at the Fleet Numerical Oceanography Center have reached their limits in terms of computational speed, memory, and processing architecture. Further improvements in atmospheric models, and development of global, eddy-resolving ocean models requires computational capabilities which exceed those of the current systems. New capabilities are required at the Naval Oceanographic Office/Naval Oceanographic and Atmospheric Research Laboratory complex in Bay St. Louis, Mississippi. These emergent requirements have been documented, validated and funded; with the recommendation that the Primary Oceanographic Prediction System be procured beginning in FY 1990. This system will consist of two Class VII supercomputers; one located at the Stennis Space Center complex in Mississippi; the second to replace existing Class VI machines in use at the Fleet Numerical Oceanography Center in Monterey, California. Extensive communications links between these activities will provide backup capabilities.

Satellite Data Receiver/Recorder, AN/SMQ-11. The AN/SMQ-11 has been developed as the next generation satellite receiving-recording system for use aboard major afloat combatants and at selected sites ashore. It is replacing a variety of existing Navy satellite reception systems. The SMQ-11 is composed of a dual-planar array antenna system and two equipment cabinets for data processing. It has the capability to process encrypted transmissions from the Defense Meteorological Satellite Program (DMSP) as well as imagery from national civil satellite systems (TIROS, GOES). Satellite information from this system can be provided to the Tactical Environmental Support System (TESS) for additional processing and applications. Additional planning is underway to exploit data from other satellite systems (foreign and domestic) projected for the early 1990's. Production of the AN/SMQ-11 commenced in FY 1987. A total inventory of 74 units is programmed.

Atmospheric Modeling. The primary goal of this effort is to improve fleet readiness and safety of ships and aircraft, and to enhance weapon system performance through the application of new numerical modeling technology. Weather prediction problems contain three elements: observation, forecasting, and product utilization. Improvements in product utilization are primarily being addressed within the TESS program, previously described. Several efforts are underway to

enhance the quantity, quality, and optimum utilization of observational data. Procurement of a portable mini-rawinsonde system began in FY 1988, and was completed during FY 1989. The system consists of a surface receiver/processor and lightweight balloon-borne expendable sensor package capable of measurements of pressure, temperature, humidity, and wind speed and direction. The Shipboard Meteorological and Oceanographic Observing Program and the Automated Surface Observing System (ASOS) programs are developing shipboard and shore-based systems for improving the timeliness, quality, and reliability of meteorological and oceanographic measurements. Development efforts undertaken by the National Weather Service have been leveraged in Navy's selection of the NWS Automated Surface Observing System for Navy use ashore. Requirements at sea are unique to Navy, but will utilize proven, off-the-shelf technological components and equipments where possible. Efforts within the Shipboard Meteorological and Oceanographic Observing System have been merged with TESS(3) development, as the sensors provide inputs directly into TESS at sea. Significant efforts are underway to optimize the use of satellite data in Navy numerical modeling. Continued upgrades to the Navy's global atmospheric prediction system (NOGAPS) spectral model are planned, incorporating asynoptic and remotely-sensed data.

Next Generation Weather Radar (NEXRAD). Principle User Processing Station (PUPS) associated with NEXRAD will provide significant improvements in radar analysis of meteorological features and severe weather over the United States. Navy is participating in the NEXRAD program, and will draw upon NEXRAD radars for coverage over Navy forecast areas. In some cases, Navy property was made available for the installation of the radar. NEXRAD PUPS will be procured by Navy during FY 1991 to display imagery from NEXRAD systems covering operational areas. NEXRAD will not totally replace other meteorological radars for Navy, because a number of locations overseas will not be covered by the NEXRAD system.

Digital Ice Forecasting and Analysis System (DIFAS). The DIFAS system of the Joint Ice Center (Navy/NOAA) is a comprehensive workstation-based system which ingests data from a variety of sources, allows for interaction between data sets, and produces ice analysis and forecast products in the form of screen displays, hardcopy charts, alphanumeric messages and gridded output products. Implemented during FY 1989, but with improvements scheduled for the following two fiscal years, the DIFAS will use the following data for all areas of ice coverage:

- TIROS AVHRR (Advanced Very High Resolution Radiometer) visible, IR and NIR imagery;
- NMC Guidance Products;
- Fleet Numerical Oceanography Center Guidance Products, including GEOSAT/SALT ice edge and SSM/I (Special Sensor Microwave Imager) ice parameters;
- Aerial ice reconnaissance;
- Ship, drifting buoy, and shore reports;
- Climatological summaries and archived data sets, including bathymetry.

Products produced by DIFAS fall into three categories: graphic products, alphanumeric messages, and gridded data in a format chosen for ease of encoding, retrieval, and manipulation.

Summary. The impact of these programs on fleet readiness and operational capabilities is significant. By the end of FY 1991, a logical framework will be in place to ensure that a survivable, responsive and layered network can provide in-situ as well as shore-based support to the operating forces of the U.S. Navy.

UNITED STATES AIR FORCE

METEOROLOGICAL SERVICES

The Air Weather Service (AWS) of the Military Airlift Command (MAC) is tasked by Air Force Regulation (AFR) 23-31 to provide or arrange for staff and operational weather services to active and reserve United States Air Force (USAF) and Army units, designated unified or specified commands, and other agencies as directed by the Chief of Staff, USAF. The primary AWS mission is to support Air Force and Army combat operations in wartime. During peacetime, AWS prepares for this role by practicing special wartime support procedures and by providing or arranging daily weather support to its military customers. AFR 23-31 also defines certain related environmental and scientific support requirements to other DOD and U.S. Government agencies, foreign governments, or individuals. Collection, processing, and dissemination of atmospheric and space environmental data are intrinsic to such support.

The Office of Management and Budget Circular A-62, 13 November 1963, divides meteorological services into two types--basic and specialized. Although involved in both services, AWS is more heavily oriented toward specialized services. The general functions involved in providing meteorological services include:

- Observing weather conditions;
- Communicating meteorological data and information;
- Preparing analyses and forecasts;
- Issuing and disseminating forecasts and warnings;
- Providing specialized support.

Observations

Meteorological observations are frequently classified as surface, upper air, radar, or satellite observations. Observation and sensing of the space environment are discussed under Space Environmental Forecasting Program below.

Surface observations are taken by AWS personnel in support of military operations and analysis and forecasting. Observations at both Air Force and Army locations (fixed and tactical) are manually prepared with some atmospheric elements being sensed by instruments and some directly by the observer. These observations are made available to local users and are also collected by the Automated Weather Network (AWN) for transmission to the Air Force Global Weather Central (AFGWC) and to other military and civil locations throughout the world. In FY 1990, there are 189 AWS surface observing locations or facilities in the continental United States (CONUS) and overseas.

Upper air observations provide a major input for numerical analysis and forecasting. Most of this information is obtained from U.S. civil and foreign sources, as well as rawinsonde (fixed and mobile) facilities operated by AWS. Additional upper air information from data-void areas is obtained from in-flight pilot reports from both military and civil aircraft.

Weather radar is a principal source of information for making short term warnings of severe weather. AWS operates 91 fixed weather radar sets (21 at overseas locations) and five tactical weather radar sets. Two of the CONUS sets are a part of the U.S. basic weather radar network;

nine are used in a backup capacity. Also, fifteen of the AWS weather radars are used to support the National Hurricane Operations Plan. The tactical weather radar sets are used to support contingency operations.

The DOD meteorological satellite system provides a large volume of cloud, upper air and space environmental data for strategic and tactical support and is the most important single source of global weather data. The Defense Meteorological Satellite Program (DMSP) is the DOD operational environmental satellite system managed by the Air Force to support worldwide military requirements. On-board sensors provide to the AFGWC and FNOC visible and infrared (IR) images of the entire globe, temperature soundings, auroral electron counts, and other specialized environmental data. DMSP also supplies direct, real time readout of regional cloud-cover information (visible and IR) to selected military terminals located around the world.

The present DMSP satellite series (Block 5D-2) uses an Operational Line-scan System (OLS). Beginning with the fourth (Block 5D-1) series satellite the infrared spectral window was narrowed to 10.5 to 12.5 micrometers to reduce the amount of absorption by ozone and water vapor. The visible detectors were selected to optimize distinction among clouds, ground, and water. It uses both stellar and inertial references, together with on-board processors, to maintain stability and pointing accuracy. The DMSP also flies a microwave temperature sounder (SSM/T) which provides vertical temperature and height profiles of the atmosphere. Satellite F-8, launched in June 1987, carried the first microwave imager (SSM/I) providing new capabilities to observe rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data.

Communications

The utility of observations of meteorological elements depends on an effective communications network. The USAF global weather communications system provides for the collection of alphanumeric meteorological data, delivers these data to weather centrals and forecast facilities, and distributes centrally-produced products to the user. The Air Force Communications Command (AFCC) system consists of conventional weather teletype networks; high-speed automated digital facilities; long-haul, point-to-point teletype data circuits; facsimile networks; and radio and teletype intercept facilities.

The Automated Weather Network (AWN) is the backbone of military weather communications. High-speed computers interconnected with 2400-4800 baud circuitry are used to deliver foreign and domestic weather data to designated users. Weather intercept sites in key overseas areas obtain weather data from foreign weather broadcasts for AWN delivery to the AFGWC. The AWN also delivers these data to the Navy's Fleet Numerical Oceanography Center and to NOAA's National Meteorological Center. Overseas collection and dissemination teletype networks are driven by the AWN Automatic Digital Weather Switch (ADWS) computers at Hickam AFB, HI, and RAF Croughton, UK. The CONUS ADWS at Carswell AFB, TX, drives the CONUS Meteorological Data System (COMEDS) and special teletype systems within the CONUS, an integral part of the weather collection and dissemination function. COMEDS serves as the prime communications system for the collection and dissemination of military Notice to Airmen (NOTAM) message traffic to all DOD CONUS users.

The Communications Front-End Processor (CFEP) at Offutt AFB, NE, is the hub of the facsimile system, providing graphic data to worldwide military users. CFEP drives the separate networks serving the CONUS, Alaska, Europe, Central America, and the Pacific, using computers to store and forward required products.

Preparation of Analyses and Forecasts

The primary center for providing weather analyses and forecasts for Air Force and Army operations is the AFGWC at Offutt AFB, NE. The AFGWC employs over 700 scientists and technicians (military and civilian). AFGWC uses ten mainframe production computers and an interactive graphics and imagery system. The computer-based operation of AFGWC uses a "build-and-apply" concept. Worldwide weather data are relayed to AFGWC via the AWN and blended with civil and military meteorological satellite data to construct a real time, integrated environmental data base. Scientific computer programs further digest the data to construct models of the atmosphere and to forecast its future behavior. Final tailoring of the data is accomplished for application to the specific problem of the decisionmaker. A significant improvement in the interaction between forecaster and machine was accomplished with the achievement in 1986 of Full Operational Capability (FOC) of the Satellite Data Handling System (SDHS) at AFGWC; SDHS consists of 35 interactive workstations capable of high-speed interaction with satellite and conventional meteorological data to prepare forecasts and other environmental products. Operational transition to SDHS was completed in February 1990, providing man-machine-interactive computer support to virtually all tasks formerly performed manually within AFGWC. The Federal Plan for Mutual Support and Cooperative Backup Among Operational Processing Centers designates AFGWC as backup for the NWS's facsimile network, NMC's computational center for aviation wind forecasts, and NWS's National Severe Storms Forecast Center.

In support of tactical military operations, AWS operates centralized units consisting of AFGWC, USAF Environmental Technical Applications Center (USAFETAC), fixed theater Forecast Units (FUs), deployed Tactical Forecast Units (TFUs), and fixed Weather Support Units (WSUs). Normally weather support is a mix of centrally and locally produced meteorological products. AFGWC is generally responsible for forecaster aids (analyses and prognoses) and other operational support products which are for general purpose use by meteorologists who apply the information to specific areas or missions. Theater Forecast Units are specifically named units, e.g., the Korean Forecast Unit designated to provide forecast services and products from a fixed location for a specific geographical area, tactical operation, or exercise. A Tactical Forecast Unit provides the same services as a theater FU; however, it is activated and deployed to support a specific contingency, activity, or exercise which is not or cannot be supported by theater FUs. FU/TFU forecasts may be direct applications of AFGWC or theater FU products or may be refined based on information available locally at the FU/TFU. AFGWC directly supports deployed weather teams whenever the theater FU lacks support responsibilities, a TFU is not established, or during the period when the deployed TFU is not yet operational.

Dissemination of Forecasts and Warnings

The Air Force and Army require worldwide meteorological services to support specific operational and planning activities. Military users require meteorological information directed to the needs of weapon systems being developed or used; command and control systems; Army firing units; research, development and evaluation; training and deployment of military forces; and contingency operations.

AWS contributes to the unique global needs of military aviation and makes its information available to civil aviation. AWS provides flight weather briefings, air/ground radio services, tailored observations, forecasts, watches, and warnings for unique military requirements.

An aspect of special emphasis in military weather support is the need to provide adequate decision-assistance to commanders and resource managers. To fulfill this requirement, designated AWS personnel serve as part of the working staff of supported Air Force and Army units. In this

capacity, AWS identifies all weather sensitive areas of the supported operation, monitors the weather service provided in these areas, and provides expert advice when weather threatens to restrict training or combat operations. This AWS effort helps ensure that Air Force and Army units are able to fulfill their missions in spite of adverse weather, and it results in efficient use of weather resources by gearing them to mission essential support needs.

Deployed weather teams are the basic units supporting customers in a tactical theater. These teams provide surface and upper air observations often by using tactical weather observing equipment, staff weather officer services, and forecasting support. The Tactical Weather System, Tactical Weather Radar, tactical meteorological satellite direct readout terminals, and tactical communications terminals provide the means to acquire vital meteorological data within a theater. A high frequency radio broadcast system that will transmit alphanumeric and facsimile products to the theater weather support force is planned. This system will consist of a number of regional broadcast stations. The system at Elkhorn AFB, NE has been fully operational since 1988. Systems are being installed at other sites and will become operational over the next several years.

Specialized Support

The USAF Environmental Technical Applications Center (USAFETAC), Scott AFB, IL, provides environmental data and specialized studies to support the USAF, U.S. Army, and other Government agencies. Typical support satisfies requirements for assessments of natural environmental effects on military plans, weapon systems, facilities, and intelligence activities. USAFETAC collects environmental data from its parent organization (AFGWC), then sorts, checks, stores and employs these data to produce tailored products. USAFETAC also operates a facility collocated with the National Climatic Data Center in Asheville, NC, that exchanges data and shares some facilities with that civil agency. USAFETAC typically collects, quality assures and applies worldwide surface and upper air observations; a three-dimensional cloud analyses extracted from meteorological satellite imagery (Realtime Nephanalysis);a global analysis of snow cover; solar, geomagnetic and space observations and indices; and many other specialized environmental data sets.

In addition to the specialized support provided by USAFETAC, the AWS supports an array of specialized requirements of the Air Force and Army. Some of these are described below.

AWS integrates Army weather support into its overall support concept. AWS personnel are trained and oriented on applicable Army organizations, concepts of operations, and weather sensitivities of Army operations and equipment. AWS support units are aligned and integrated with the Army intelligence organization. Support products are in a form which is directly usable and understandable by Army personnel and are integrated into Army communications systems. Mobile and fixed meteorological equipment for use in Army support is programmed by AWS. In a tactical environment, direct forecast support is normally provided down to corps, divisions, separate brigades, regiments, echelon-above-corps, aviation brigades, armored cavalry regiments, ranger regiments, and special forces groups (as well as subordinate battalions deployed at forward operating bases). Observer support is provided to all levels identified above.

AWS provides meteorological support to the Nation's space and missile programs. This includes a wide range of weather observing services at the Air Force Eastern Space and Missile Center and the Kennedy Space Center. AWS also provides launch forecasting service for NASA's manned and unmanned launches and for commercial launches from the Kennedy Space Center.

AWS provides specialized meteorological services for the Air Force Western Space and Missile Center at Vandenberg AFB, CA, and the Pacific Missile Range which includes Pt. Mugu

and San Nicholas Island, CA, and Barking Sands, HI. AWS also supports the White Sands Missile Range, NM, the Kwajalein Missile Range, and other DOD research and test facilities.

The Air Force and the Navy operate the Joint Typhoon Warning Center on Guam under the Naval Oceanography Command Center, Guam. The Center provides tropical cyclone warning services to DOD units and other US subscribers in the area west of 180 degrees to the east coast of Africa in both hemispheres.

The Air Force and NOAA operate the Joint USAF/NOAA Space Environment Services Center at Boulder, CO. The center provides space environmental data, products, services, and solar forecasts to a wide variety of customers, including AFGWC.

Through the AFGWC, AWS directly supports DOD Special Strategic Programs, the National Command Authority, the National Military Command System, and the National Security Agency. Tailored environmental support products are disseminated to these customers worldwide.

Planned Enhancements

USAF and Army operational requirements for environmental support are the basis for all AWS actions to improve existing or acquire new capabilities. AWS assesses these requirements and attempts to satisfy them through either hardware acquisitions or technique development.

AWS plans to modernize its base-level weather support systems. This includes an Automated Weather Distribution System (AWDS) and the Next Generation Weather Radar (NEXRAD). Both of these systems have funds programmed for their R&D and acquisition phases.

The AWDS will automate the handling of weather data by incorporating the latest state-of-the-art data processing, communications, and display technologies. The data-handling function will maximize forecaster capability. A modular design will permit AWDS to be operated in a fixed or mobile environment and minimize staffing requirements. Initial installation is planned for late 1990 with completion of overseas and tactical installations by 1995. AWDS will be able to receive information from the National Weather Service through the AFGWC via the AFOS at the AFGWC. (AFOS is the NWS system also known as "Automation of Field Operations and Services").

To enhance AWDS in base weather stations and to expand the capabilities of forecasters in a tactical wartime environment, the AWDS Pre-Planned Product Improvement (AWDS P3I) will provide the following capabilities: inter-system interoperability, High Frequency radio for transportable AWDS, increased local graphic distribution, multiple software improvements, improved meteorological satellite ingest, and forecaster assistance through numerical models and advanced processing techniques.

AWS plans to significantly enhance its tactical warfare weather support capability through employment of the Battlefield Weather Observation and Forecast System (BWOFS). BWOFS involves the development of two capabilities: 1) Electro-Optical Tactical Decision Aids (EOTDA) to provide weather support for electro-optical target acquisition, weapons guidance, and reconnaissance systems, and 2) the Pre-Strike Surveillance/Reconnaissance System (PRESSURS) to acquire weather observations in uncontrolled or enemy controlled areas of the battlefield. PRESSURS capabilities are linked to advances within the DMSP, especially the Mark IV-B Tactical Terminal, scheduled for first deployment 30 June 1992. The Mark IV-B will put full DMSP capabilities in the hands of the tactical user.

NEXRAD is being procured under the auspices of the NEXRAD Joint System Program Office. NEXRAD will be an automated, digitized, S-band Doppler system that will be jointly developed, procured, operated, and maintained by DOD, NOAA, and FAA within the CONUS and by the USAF and Navy overseas. The system will be designed to incorporate the latest technological advances in Doppler radar, data processing, communications, and display. The CONUS NEXRAD network will satisfy weather radar requirements in support of the general public, the military, and the entire spectrum of the aviation community. Installation of the NEXRAD is planned between 1990 and 1994.

The Improved Weather Reconnaissance System (IWRS) became operational in 1989. This system incorporates the new USAF inertial navigation system for improved positioning. It automatically gathers data, provides improved flight level winds, and has a windsounding capability. Increased volumes of highly accurate data are relayed by satellites from reconnaissance aircraft to agencies for use in hurricane prediction models.

The analysis and forecast preparation capability of the AFGWC has been enhanced by the implementation of the Advanced Weather Analysis and Prediction System (AWAPS). The AWAPS program hardware consists of a Class 6 computer for processing numerical models and two database computers to supply data to the Class 6 computer and to store and handle the increased resolution products from the Class 6 computer. The two Sperry 1100/70 database computers became operational in late 1984. The Cray X-MP Class 6 computer became operational during early 1985. Two new software models were implemented by the AWAPS. AWAPS software consists of the AFGWC developed High Resolution Analysis System (HIRAS), the Global Spectral Model (GSM) and the Relocatable Window Model (RWM). The latter two models were developed under contract by NOAA's National Meteorological Center (NMC). The three models will provide a significant increase in the accuracy and resolution of analyses and forecasts at the AFGWC.

The final model acquired under AFGWC's Advanced Weather Analysis and Prediction System (AWAPS) is the Relocatable Window Model (RWM), a regional and relocatable analysis and forecast model suite designed for military application. Limited operational use of the RWM has already been made. The model will provide non-cloud fields to the Battlefield Weather Observation and Forecast System (BWOFS) in FY 1991 and will achieve its final operational capability, including cloud forecasting, in FY 1992.

An Improved Point Analysis Model (IPAM) will be implemented at AFGWC and USAFETAC in FY 1990, with final operational capability established in FY 1991. The IPAM will construct gridded cloud depictions and vertical profiles of atmospheric pressure, temperature, density, absolute humidity, precipitable water and winds. In addition, IPAM will construct pseudo-surface weather observations, a 24-hour surface weather history, and the aerosol parameters needed as inputs to atmospheric transmission models. IPAM will take advantage of new data sources and updated or new climatological data and models. Improvements to IPAM will be made through FY 1994 by means of the Improved Point Analysis Model Technology Transition ($IPAMT^2$) Program.

Enhancements will be made to the global and regional numerical weather prediction models running at AFGWC by adding post-processors to generate cloud forecasts from model forecasts of the relative humidity. It is expected that for forecasts longer than about 9 hours, the skill of global and regional numerical cloud forecasts will exceed that of forecasts now produced by the trajectory/trending engineering cloud models now in use at AFGWC.

Changes will be made to models and applications at AFGWC to take advantage of the promising, new Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Water Vapor Profiler (SSM/T-2) and a new Upper Atmospheric Sounder associated with the DMSP Special Sensor Microwave Imager and Sounder (SSMIS). The SSMIS Upper Atmospheric Sounder will produce credible temperature soundings to approximately 70 km.

The Air Weather Service upgraded its support to Air Force base disaster preparedness personnel by fielding the Geophysics Laboratory's Air Force Toxic Chemical Dispersion Model (AFTOX). Support to electronic warfare was improved by fielding the Naval Ocean Systems Center's Integrated Refractive Effects Prediction System (IREPS).

The MARK IVB Tactical Terminal program will procure a total of sixteen terminals to replace the aging MARK IIAs, IIIs, and IVs. Four of the MARK IVB terminals will be mobile, the other twelve will be fixed. In addition to providing satellite imagery, the MARK IVB terminals will be able to accept and use data from the DMSP Microwave Imager, Microwave Temperature Sounder, Microwave Water Vapor Profiler, and the TIROS Advanced Microwave Sounding Units A and B to produce both uniform gridded data fields and traditional meteorological products. The MARK IVB contract was awarded to Lockheed Corporation in October 1988. In January 1988, the Air Force awarded four competitive concept studies for Block 6, the follow-on to the Block 5D-2/5D-3 satellites. The objectives include lowering DMSP system life cycle cost, and assessing cost effective options for increased survivability, interoperability, and remote sensing capability. The Navy (oceanography) and Army (tactical support) are participating in the Block 6 studies.

SPACE ENVIRONMENTAL SERVICES

Many DOD systems operate in, or are affected by, conditions above 50 kilometers. The space environment includes the near-Earth regions of the thermosphere, ionosphere, and magnetosphere, as well as the regions that influence them such as the heliosphere (solar) and interplanetary space. The AWS provides basic and specialized space environmental support to military electromagnetic communications, surveillance, and warning systems which operate in this environment. AWS provides environmental forecasting and specialized services in the major technical areas of: (1) specification and forecasting of ionospheric conditions, (2) specification and forecasting of neutral atmospheric conditions, (3) specification and forecasting for the magnetosphere, (4) specification and forecasting of solar flare and solar particle events, and (5) providing geomagnetic and solar indices to users for determining upper atmospheric density variability.

The current hub of the AWS space environmental forecasting program is the AFGWC Space Environmental Support Branch which provides the only operational space environmental support within the DOD. The AWS is now moving space environmental support functions and manpower positions to a new facility, the Space Forecast Center (SFC). Initial operational capability of the SFC will occur in 1991, with final operational capability established by 1992. Ionospheric conditions have a profound effect on radio wave propagation. The SFC will have the capability to give real-time reports on ionospheric conditions and the capability to forecast and predict ionospheric disturbances. Ionospheric models under development will be ready for customer use after the SFC becomes operational.

The Air Weather Service also participates with NOAA in the joint operation of the National Space Environment Services Center (SESC) in Boulder, CO. The SESC provides basic solar-geophysical

analyses and forecasts to AFGWC and serves as a contingency backup for AFGWC space environmental support.

Data Sources

USAF operates and funds for a variety of ground-based and space-based solar-geophysical sensors. The Solar Observing Optical Network (SOON) is comprised of AN/FMQ-7 solar optical telescopes located in Puerto Rico, New Mexico, Hawaii, Australia, and Italy. The Radio Solar Telescope Network (RSTN) is comprised of four AN/FRR-95 solar radio telescopes in Massachusetts, Hawaii, Australia, and Italy.

USAF operates, or funds for the operation of, numerous other geophysical sensors as shown in Table B.1.

Data Provided

Space environmental support encompasses the present state and forecasts of the Sun, the interplanetary medium, the near-Earth space environment, and the ionosphere.

Solar Flares. The SOON (AN/FMQ-7) was specifically designed to provide consistent, rapid flare observations and data for reliable, short-term forecasting of solar flares and their effects. Currently, the actual work on exploitation of SOON data by applying advanced modeling techniques is being accomplished by the Air Force's Geophysics Laboratory, Hanscom AFB, MA, and NOAA's Space Environment Laboratory (SEL) located at Boulder, CO. SOON optical data are complemented by radio frequency measurements via the Radio Solar Telescope Network (RSTN). Radio data provide flare observations despite cloud cover and permit tracking of solar disturbances through the solar atmosphere.

Geomagnetic Index. AFGWC monitors variation of the Earth's magnetic field through the use of ground-based magnetometers. Data from these sensors are processed at AFGWC to develop a geomagnetic index which is transmitted to users for real-time use in density models. Recently, AFGWC has expanded its magnetospheric monitoring by using real-time high energy particle data from operational DOD geostationary spacecraft as well as magnetospheric observations from the GOES satellites.

Ionospheric Variability. AFGWC forecasters monitor the state of the ionosphere, the Sun, and the magnetosphere in order to provide notifications and forecasts of ionospheric irregularities. Short term forecasts for high frequency communications systems can be provided in real time as can specification and forecasts of electron density profiles and total electron content. The primary long-range forecast requirements are for HF radio propagation.

Event Notification. Since the state-of-the-art in accurately forecasting solar and geophysical events is limited, AWS has concentrated on providing rapid notification to system operators of actual solar events which could degrade the performance of their systems. Rapid event notification is provided for decision assistance to all levels within the military chain of command. The Proton Prediction System model upgrade has enhanced AWS forecasts of solar proton events. AFGWC notifications of these events are provided within minutes of detection of a disturbance and are specifically tailored for each system operator.

Table B.1 Geophysical Sensors of Space Environment

Sensor	Purpose	Locations
Polarimeters	Measure total electron content of ionosphere	Eleven, N. Hemisphere
Ionosondes	Measure ionospheric electron density profiles	Eleven, N. Hemisphere
Magnetometers	Measure changes in geomagnetic field	Six, mid-high latitude
Defense Meteorological Satellite Program	Measure precipitating electron flux, ion flux, ion density, electron and ion temperature, and provide optical auroral pictures	Polar orbit
DOD Spacecraft	Measure high-energy and low-energy electrons and protons	Geostationary orbit
Solar X-ray Imager (USAF funds for FY90)	Locate positions of solar flares, measure solar x-ray and extreme ultraviolet fluxes	Geostationary orbit

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Planned Enhancements

AWS plans to upgrade the Space Environmental Support System in several areas: ground-based observing, space-based observing, and forecast capability.

Ionospheric measurements will be improved by replacing five analog ionosondes with digital systems and adding 14 digisondes to the AWS Network. A new ionospheric height analysis model will be installed in the 19 digisondes. Ionosonde data will be added from southern hemispheric sources. Seventeen Transionospheric Sensing System (TISS) units will use signals from the Global Positioning System (GPS) to calculate total electron content and scintillation parameters. In 1989, AWS began phasing out the current network of magnetometers and use data from a 9-component US Geological Survey Network. The Solar Electro-Optical Network (SEON) of optical and radio telescopes will be upgraded and given new capabilities -- an ability to locate solar flares on the Sun by radio wavelength means and enhanced magnetograph capabilities. The SEON will be consolidated from six sites to five sites, and possibly to four if technology permits. New space environment sensors will fly on future Defense Meteorological Satellite Program (DMSP) satellites. A Solar X-Ray Imager (SXI) will be flown on the GOES Next series. The SXI will monitor solar emissions in the extreme ultraviolet (EUV) and X-ray portions of the solar spectrum. These data will be downlinked to the National Space Environment Services Center in Boulder, CO and transmitted to the Space Forecast Center (SFC) in real time. Initiatives are being considered to obtain solar wind and interplanetary magnetic field data from sensors located outside the magnetosphere.

The Space Forecast Center (SFC) will be the focal point of space environmental support to the DOD. Located at Falcon AFB, CO, the SFC will consist of a 37-person team dedicated to providing support to a variety of customers. Real-time data will be received at the SFC from a number of sources: DMSP, GOES, and other satellite systems; SEON sites; and ground-based magnetometers, the TISS, and ionosondes. The SFC teams will use those data and new space environmental models and forecast techniques to produce alerts, warnings, and other products for elements of the DOD (USSPACECOM, SAC, NORAD, etc). New space environmental models will interact with state-of-the-art computer systems: global Ionospheric Models, Neutral Atmospheric Models, a Magnetospheric Model, and Integrated Space Environmental Models.

The Ionospheric Models will consist of a specification and a forecast component, both of which will be in advanced development at the Geophysics Laboratory in FY 1990. The specification component will be the Ionospheric Conductivity and Electron Density (ICED) model, upgraded by addition of high-latitude and southern hemispheric enhancements and provided with the capability to use data from the Defense Meteorological Satellite Program space environmental sensors and other real-time data sources.

The Neutral Atmospheric Models consist of a parameterized forecast model and a more detailed specification model. The forecast model is the University of Michigan Vector Spherical Harmonics (VSH) parameterization of the Thermospheric Ionospheric General Circulation Model (TIGCM). The specification model is the TIGCM itself. The neutral atmospheric models will specify and predict global neutral densities, winds, and temperatures from 90 to 1500 km in the atmosphere. The models will incorporate measurements of neutral density, solar extreme ultraviolet radiation, interplanetary magnetic field orientation, and high-latitude ion convection and auroral zone energy measurements from DMSP sensors.

The Magnetospheric Model, now in its third year of advanced development, will provide specification of magnetospheric particle fluxes and geomagnetic activity levels. The model is a parameterization of the Rice University Convection Model. The model incorporates geomagnetic index inputs, available solar wind and interplanetary measurements, geostationary energetic particle measurements and ion convection and low-latitude auroral boundary inferences from Defense Meteorological Satellite Program DMSP sensors.

The Integrated Space Environmental Models, now in the planning stage, will provide an interplanetary model to carry shocks in the solar wind plasma from the Sun's corona to the Earth's magnetopause. An energy transfer model will be used to convey interplanetary energetics to the Magnetospheric Model and other space environmental models, based on interplanetary magnetic field conditions. A coupling model will be used to provide output fields from one space environmental model as inputs to the other models, and feedbacks will be provided among the models so they act as a single system. Solar models will not be ready for operational use until the mid- to late-1990s.

SUPPORTING RESEARCH

The objective of the Air Force meteorological research program is to develop equipment and techniques for observing and predicting meteorological conditions that affect military systems and operations. Requirements for research and technology in meteorology are expressed in Air Force Technology Planning Objectives, Mission Area Analyses, and Statements of Operational Needs. In addition, the Air Weather Service provides guidance in the form of documented geophysical requirements. The Geophysics Laboratory (GL) at Hanscom AFB, MA, has the

mission responsibility within the Air Force to conduct both in-house and contractual basic research, exploratory development, and advanced technology development in the environmental sciences, including meteorology. Its exploratory development program in meteorology emphasizes moisture and cloud numerical weather prediction, ground-based and satellite remote sensing, climatological studies, boundary layer meteorology, cloud physics, atmospheric density, and battlefield weather observing and forecasting. Research and development for the Defense Meteorological Satellite Program (DMSP) is also conducted.

In the area of moisture and cloud forecasting, research is being conducted on global and regional scales. Research with a mesoscale cloud model focuses on improved boundary conditions and accounting for local forcing. New moisture-to-cloud algorithms are being developed based on a comparison of global model cloud forecast errors with Air Force Global Weather Central (AFGWC) operational cloud forecasts. New physical parameterization schemes for cumulus convection, boundary layer processes, and radiation (including input from satellite sensors) have been developed and are being tested on the global model. The initial regional model was completed and is undergoing testing and modification. The long-range goal of this work is to transfer a revised numerical weather prediction model to AFGWC by FY 1990/91. Forecaster effectiveness in an automated operational environment, such as the Automated Weather Distribution System (AWDS), is being evaluated using GL's Advanced Interactive Meteorological System (AIMS). More work is planned to evaluate how continuous wind measurements from a vertically pointing very high frequency (VHF) radar will contribute to numerical modeling and realtime monitoring of developing mesoscale weather systems. An assessment of the utility of "expert system" techniques in short-range weather forecasting is being pursued. A new effort called the Advanced Meteorological Processing System (AMPS) is underway. AMPS will incorporate "expert system" techniques and numerically-based approaches to receiving and processing copious amounts of weather data from new observing systems. New procedures will be used to process and combine weather radar and satellite imagery to automatically estimate cloud motions. These motions can then be integrated to allow mapping cloud and precipitation systems in three dimensions. Research efforts will remain constant in this area.

In the ground-based remote sensing area, automated doppler weather radar techniques are being developed for identifying regions of potential hazardous clear air turbulence and aircraft icing. Doppler techniques are also being developed for precise short-term forecasts of thunderstorm precursor phenomena. These techniques will be incorporated into the jointly-procured (DOD, DOC, and DOT) WSR-88D Doppler Weather Radar (also known as NEXRAD). Coherent polarization diversity weather radar techniques to derive hydrometeor characteristics, such as particle size distribution, orientation, and thermodynamic phase, are being tested. A new task is underway to evaluate the potential of ground-based remote sensing techniques including a VHF wind profiler, a microwave doppler weather radar, and a loransonde system to provide accurate and continuous vertical profiles of the horizontal winds in clear and cloudy air and for all seasons of the year.

To support satellite meteorological requirements, improved inversion algorithms are being developed to compute more accurate vertical temperature and water vapor profiles from satellite measurements at far-infrared and microwave wavelengths. An additional effort is planned to establish a versatile cloud-truth data field which is essential for evaluating new cloud algorithms that use satellite observations. A study will evaluate the use of microwave imagery information for mapping meteorological parameters such as rain rate, ocean surface wind speed, and soil moisture. Techniques will be developed to incorporate microwave imagery data into the cloud analysis programs at AFGWC. The present level of support will continue for this research to develop new analytical methods in satellite meteorology. The ultimate goal is to more accurately depict cloud

characteristics; i.e., cloud height, cloud thickness, phase, and rain areas. Techniques will also be developed to use satellite data to determine tropical storm location, intensity, and thermodynamic structure. A new effort, supported by DMSP, is underway to develop a tactical cloud analysis system using satellite-sensed data and imagery.

In climatological technique development, weather simulation models are being developed to replicate numerically typical weather sequences for operational applications. Research in modeling clouds and visibility is being expanded to include additional atmospheric elements, specifically a mesoscale environmental simulation package to provide a realistic sequence of weather events at any given location. This model will allow environmental factors to be considered in the design stage of weapon systems and for application to war games. Research into specifying the probability of simultaneous cloud-free viewing from multiple sites under various cloud conditions is ongoing. Climatological studies of rainrate duration modelling and analysis of high resolution cloud photographs taken in orbit are nearing conclusion. These studies are used to quantify the distribution of cloud sizes, of clear intervals, and of the variation in apparent cloud cover as viewing angle changes. Climatological studies supporting reentry vehicles will begin and research into methods of predicting triggered lightning strikes to aircraft and launch vehicles will continue.

In boundary layer meteorology, work on developing toxic chemical dispersion models for various scenarios will be completed in FY 1990. AWS is now reviewing the toxic chemical dispersion model for smooth terrain and uniform wind fields (AFTOX) and is considering this model as a replacement for the current dispersion model. A heavy gas dispersion model was developed and is now available to DOD users. A user's manual has been written for the terrain-induced surface wind flow model developed in FY 1986. A complex terrain dispersion model, which combines AFTOX and the wind flow model will undergo further development and testing. An updated terrain dispersion model will be delivered to AWS in FY 1990.

The major thrust of the cloud physics program is to develop computerized mathematical models for forecasting the micro physical structure of clouds and cloud systems, given macroscopic statements about the nature of the atmosphere. The weather attenuation program will continue extremely high frequency (EHF) data reduction and interpretation and will test the microphysics of the cloud model against available data sets. This program includes simultaneous measurements of EHF attenuation and detailed microphysics of the clouds, rain and snow, and snow in the melting layer.

The objective of the atmospheric density work is to develop very accurate methods to measure and predict density of the neutral atmosphere in the altitude range of 90 to 1500 kilometers. Current density models do not achieve the levels of accuracy required by the Air Force, so new measurements of density will be made using recently developed, well calibrated, and highly accurate instruments. These new measurements will be the basis for an upper atmospheric global circulation model that incorporates current physical understanding of the processes that drive the upper atmosphere. Models will be used to calculate accurate trajectories of satellites, reentry vehicles, and even space debris.

The battlefield weather program will emphasize developing low-cost, expendable instrumentation to measure humidity, visibility, infrared wavelengths, and the macroscopic characteristics of clouds and cloud systems. A system capable of collecting weather information in battle areas under enemy control has undergone advanced development and test range demonstrations are continuing. Electro-optical tactical decision aids (EOTDAs) are being developed for use on Air Force standard microcomputers at base weather stations around the world.

EOTDAs for low-light-level TV, infrared, and 1.06-micrometer laser systems will be upgraded to include new targets, backgrounds, and systems such as night vision goggles used by special operations forces. Additional resources will be applied to transition new atmospheric research products in areas such as cloud analysis and forecasting to operational capabilities at AFGWC.

The present level of support for atmospheric sciences research will continue. In evaluating Air Force needs, it was decided to continue a new program in triggered lightning prediction at a modest level of support. Another initiative will investigate improved techniques for target area climatologies, and analytical efforts in satellite meteorology (e.g., lidar) for determining realtime target area weather. These new techniques will support current and next generation reentry vehicle requirements. Successful completion of the weather attenuation experiment and subsequent data analysis has made available the necessary resources for these new efforts and has provided flexibility to start a new project to develop a tactical cloud analysis program.

APPENDIX C

DEPARTMENT OF TRANSPORTATION WEATHER PROGRAMS

FEDERAL AVIATION ADMINISTRATION

RESPONSIBILITIES FOR AVIATION WEATHER

The Federal Aviation Administration (FAA) is responsible for the safety and separation of aircraft and the efficiency of flight operations. The adequacy of aviation weather information contributes significantly toward fulfilling these responsibilities. FAA makes recommendations to the U.S. Department of Commerce on civil aviation meteorological services, provides specialized equipment at certain airfields, observes and reports the weather at about 360 airports, distributes weather data over civil communications systems, and provides the principal means for disseminating weather advisories and information to pilots.

Weather information for pilots is made available through Flight Service Stations (FSS), recorded messages broadcast over navigational aids, special weather broadcasts, telephone answering systems, and by the Direct User Access Terminal (DUAT) system provided by private vendors. Air Route Traffic Control Centers have weather service units manned by National Weather Service (NWS) meteorologists to assure that vital weather information is available to controllers and pilots.

FAA maintains a continuing research program to improve aviation weather service to the users of the National Airspace System (NAS). FAA also engages in engineering efforts to improve weather observations, meteorological workstations, and communications related to aviation.

The Aviation Weather Program is aimed at progressively improving the timeliness and accuracy of weather information provided to aircrews and to the Air Traffic Control (ATC) system to reduce the number of weather related accidents and incidents and to increase both system capacity and fuel savings by reducing weather related delays. Facets of the program are conducted in close cooperation with the NWS. Wherever practical, the objectives of this program are accomplished by enhancing existing and planned air traffic control and flight service station system components and facilities for the collection, processing, and dissemination of significant weather information.

PROGRAMS FOR AVIATION WEATHER

En Route Weather Radar Program

This program supports the definition, development, and implementation of the Next Generation Weather Radar (NEXRAD) for en route applications. NEXRAD will provide accurate aviation-oriented products concerning reflectivity, wind velocity, and turbulence indicators.

Radar presentation available to ATC today came essentially from aircraft target detecting radars not true weather radars. Improved weather data from NEXRAD provided to ATC through the Real-time Weather Processor (RWP) will increase aviation safety and fuel efficiency. In addition to the benefits to be gained in today's system, future automated ATC functions and improved traffic-flow management require reliable and accurate weather data so that projected maximum fuel savings and manpower productivity gains based on these improvements can be realized.

FAA is emphasizing the development of algorithms that take advantage of the improved detection of precipitation, wind velocity, and turbulence, and provide new or improved aviation-oriented products.

To improve hazardous weather detection, reduce flight delays, and improve flight planning services, the joint NEXRAD program provides several aviation weather products related to wind, wind shear, turbulence, thunderstorm detection, storm movement prediction, precipitation, hail, frontal activity, and mesocyclones-tornadoes. In FY 1990, research activity will concentrate on the development of icing, wind shear, and other aviation-related algorithms.

Terminal Doppler Weather Radar (TDWR)

This program consists of the procurement and installation of a new terminal weather radar based on Doppler techniques. TDWR units will be located to optimize the detection of microbursts and wind shear. In addition, it will have the capability to identify areas of precipitation, turbulence, thunderstorm location, and storm movement. TDWR's will be integrated with the existing Low Level Wind Shear Alert System (LLWAS) at many airports.

Microbursts are weather phenomenon that consist of an intense downdraft with strong surface outflows. They are particularly dangerous to aircraft that are landing or departing. The TDWR scanning strategy will be optimized for microburst/wind shear detection. The radar will be located on or near the airport operating areas.

Algorithms for the automatic detection of microbursts, wind shear, and gust fronts are being developed by the FAA. Data collected with the FAA transportable Doppler weather support facility (at Memphis, TN, Huntsville, AL, Denver, CO and Kansas City, MO) provided the primary basis for development and validation of the algorithms. This facility was used to evaluate the operational aspects of TDWR and will continue to support the enhancement and development of wind shear algorithms by deployment at the Orlando, Florida Airport.

A contract was awarded in November 1988 for 47 turnkey TDWR installations at sites specified by FAA. Field implementation will occur in the 1992 to 1994 time frame. The alphanumeric display and the situation displays will be located in the tower cab and the approach control radar room. The displays were tested operationally in 1988 and 1989 at Denver, Stapleton and Kansas City International Airports. Further ergonomic tests of these displays will be carried out at Orlando in 1990.

In FY 1990, development will continue on the enhancement of the microburst detection algorithm to provide an indication of where these phenomena are forming. This will provide advance warning of wind shear conditions. Development will continue on the integration of data from both TDWR and LLWAS.

Other Weather Radar Programs

The present Air Route Surveillance Radars provide weather data for the Air Route Traffic Control Centers (ARTCC) out to 200 nautical miles. A new Air Route Surveillance Radar (ARSR-4) will provide the ARTCC's with accurate multiple weather levels out to 250 nautical miles. This will be the first en route radar with the ability to accurately report targets in weather. The ARSR-4 will be used to provide weather information until NEXRAD is operational in the

Rocky Mountain area. Even after NEXRAD is in place, ARSR-4 will provide supplemental weather information for areas NEXRAD does not cover.

The ARSR-4 is a joint Federal Aviation Administration/United States Air Force (FAA/USAF) funded project. Forty joint FAA/USAF radar sites will receive the new ARSR-4 radar during the 1992-1994 period.

Airport Surveillance Radar-9 (ASR-9) Weather Modular Enhancement

The Weather Modular Enhancement will be developed as an add-on modification to the existing ASR-9 radars and will provide Air Traffic controllers information on low level wind shear associated with microbursts in the vicinity of the ASR-9 radars at those airports that will have a TDWR. Initial testing on the radar room displays will take place at Orlando International in 1990. Presently, the ASR-9 weather data that is available consists of the six levels as defined by the National Weather Service. In addition, the feasibility of gust front detection is being investigated.

Low Level Wind Shear Alert System (LLWAS)

LLWAS provides pilots with information on hazardous wind shears that might create unsafe conditions for aircraft landings or departures. It is a phased program that includes initial installation and operation at a total of 110 airports. The current phase will be completed by late 1990 and consists of a wind sensor located at center field and five sensors near the periphery of the airport. A computer processes the sensor information and displays wind shear conditions to air traffic controllers for relay to pilots.

In the second phase, modifications will consist of improving the algorithms associated with the basic system, correcting sensor siting (including height), incorporating data recorders, and updating the computers. Field implementation of these modifications will be completed in FY 1991.

The long-term modifications include expanding the network of sensors out to three miles from the touchdown line, developing algorithms for improved microburst detection, and installing new information/alert displays which enable controllers to provide pilots with runway specific, head wind gain or loss estimates. These improvements will increase the system's wind shear detection capability and reduce false alarms. Improvements are also expected to reduce maintenance costs. Implementation began in 1988. There are now two enhanced systems. For FY 1990, the FAA has budgeted for 17 additional enhanced systems.

In the future, LLWAS and TDWR will work in conjunction providing a synchronous alarm of wind shear to the air traffic. Development of a system is underway that will integrate the signals from these two systems into a single wind shear display for the air traffic controller. Investigation is also underway on how integrated wind shear information can best be communicated or displayed to the pilot.

Automated Surface Weather Observing Program

This includes the activities of the FAA in acquiring automated surface weather observing systems; acquiring related data acquisition systems; and development, test, and evaluation of weather sensors.

AWOS/ASOS Acquisition. Automated surface weather observations will provide aviation-critical weather data (e.g., wind velocity, temperature, dew point, barometric pressure, cloud height, visibility, precipitation type, occurrence and accumulation) through the use of automated sensors. It will process these data, and allow dissemination of output information to a variety of users, including pilots via computer-generated voice.

The FAA has a need to deploy as soon as possible Automated Weather Observing Systems (AWOS) at 200 airports to provide the basic aviation weather products directly to pilots approaching the airport. The majority of these systems would be installed at various non-towered airports to enhance aviation safety and the efficiency of flight operations by providing real-time weather data at airports that currently do not have local weather reporting capability. Some of these systems will be used to support an air traffic operational evaluation at former flight service locations that currently employ contract weather observers. The FAA has awarded a contract to acquire these systems based upon the specification established to qualify candidate AWOS systems for procurement by state and local governments. These systems, which are built to the standards of quality necessary to ensure the safety of flight operations, are available off-the-shelf as a commercial product.

The FAA has asked NOAA to procure, install, operate, and maintain Automated Surface Observing Systems (ASOS) at the remaining airports where the FAA provides observations and at additional non-towered airports without current weather reporting capabilities. A preproduction contract has been awarded to two vendors, with the production contract award scheduled for the last quarter of FY 1990. The FAA will be sponsoring, as part of a reimbursable agreement with NOAA, at least 537 systems with an option for 233 additional systems.

Automated Weather Observing Systems (AWOS) for Non-Federal Applications. The majority of airports within the National Airspace System (NAS) do not have a local weather reporting capability. For example, operations for commercial operators under instrument flight rules are restricted at over 1,300 airports because of the unavailability of weather observations.

Under the Airport Improvement Program (AIP), state and other local jurisdictions may justify to the FAA their need to enhance their airport facilities. Upon approval, these improvements may be partially funded by the FAA using dollar resources from the Airway Trust Fund. The local airport authority becomes responsible for the remainder of the funding necessary to complete the procurement, as well as the funding for the regular maintenance necessary to maintain the system. The addition of an AWOS is one of the improvements that qualify for AIP funding assistance. Systems that qualify must meet certain standards which are defined in an FAA Advisory Circular on Non-Federal Automated Weather Observing Systems.

There are currently three versions of the non-Federal AWOS. The AWOS I system contains sensors to measure wind speed and direction, ambient and dewpoint temperature, altimeter setting, and density altitude. The AWOS II contains the AWOS I sensors plus a visibility sensor, and an AWOS III adds a cloud height sensor to an AWOS II. The requirements for two additional versions are in final coordination for approval. An AWOS A will provide only altimeter setting and an AWOS IV will include AWOS III plus the option for precipitation identification, thunderstorms and/or runway surface condition. Most important, all versions are required to have the capability to broadcast a minute-by-minute update of the current weather to the pilot by radio, using a computer generated voice output from the AWOS. This AWOS may also have the capability that enables the pilot (or other user) to call the AWOS on a telephone and obtain the current weather

observation during his preflight activities. In addition, the observation may be transmitted to the data bank within the national weather network.

AWOS/ASOS Data Acquisition System (ADAS). ADAS will function primarily as a message concentrator collecting weather messages from AWOS and ASOS automated surface observation equipment located at controlled and noncontrolled airports within each air traffic control center's area of responsibility. It will distribute minute-by-minute AWOS/ASOS data within the center in which it is installed, and provide for national distribution of AWOS hourly and special observations through FAA's Weather Message Switching Center Replacement (WMSCR) facilities. This will make weather observation data available to pilots and air traffic controllers on a timely basis within the "local" area, and provide necessary distribution of the data to NWS, and other users. Field implementation of ADAS is planned to start in 1991 and be completed in 1993.

Weather Sensor Development, Test and Evaluation. This activity (1) evaluates new systems and techniques for the measurement of surface weather parameters, (2) tests the capabilities of improved weather sensors, and (3) supports research studies on weather conditions that are hazardous to flight operations.

Because of the importance of reliable, complete and timely surface observations to aviation safety, and the need to reduce the cost of obtaining these observations, the FAA supports advanced weather sensor development activities. The work is conducted primarily by the NWS and the National Oceanic and Atmospheric Administration's (NOAA) Environmental Research Laboratory. Sensor technologies being investigated include: (1) improved visibility detection; 2) current type and amount of precipitation; 3) lightning detection systems; 4) runway surface conditions; and 5) sensors which can detect freezing rain.

Work continues in the development of freezing rain sensors, precipitation identification sensors, and lightning detection systems. In FY 1991, effort will focus on implementing lightning detection systems into ASOS.

Flight Service Station Automation System (FSAS)

This program will improve user access to weather and Notice to Airmen (NOTAM) information, simplify flight plan filing, and provide a flight service station automation system that will meet the projected increases in demand for flight services without proportional increases in staff. Automation is being developed and implemented in two stages: 1) FSAS Model 1 (limited automation), and 2) Model 1 Full Capacity (full automation).

The first Model 1 system was commissioned in 1986. As of December 1988, there were 39 Automated Flight Service Stations and 13 Flight Service Data Processing Systems (FSDPS's) operating with Model l. In addition to the 39 Model 1 AFSS's, there are seven AFSS's operating with the American Satellite Leased Service A & B System (LABS). Fifteen more AFSS's will be commissioned by 1993 for a total of 61 AFSS's. All of these facilities will be converted to Model 1 Full Capacity (MIFC). The first field MIFC systems was delivered March 1990 and the last system will be delivered in December 1992. MIFC will provide sufficient hardware and software to drive all of the terminals in the 61 AFSS's.

Direct Users Access Terminal (DUAT) system has been operational since February 1990. Pilot users will be able to access Weather and NOTAMs and file their IFR and/or VFR flight plans from their home or office personal computer.

Graphics Weather Displays Systems (GWDS) in the AFSS's consists of a variety of different systems. FAA intends to provide a Standard National GWDS to replace the interim systems now in use.

Weather Message Switching Center Replacement (WMSCR)

WMSCR replaces the Weather Message Switching Center (WMSC) located at FAA's National Communications Center (NATCOM), Kansas City, MO, with state-of-the-art technology. It will perform all current alphanumeric weather data handling functions of the WMSC and the storage and distribution of Notices to Airmen (NOTAM). It will rely on FAA's National Airspace Data Interchange Network (NADIN) for a majority of its communications support. The system will accommodate graphic data and function as the primary FAA gateway to the National Meteorological Center and, therefore, will be the principle source of NWS products for the National Airspace System.

To provide for geographic redundancy, the system will have nodes in the NADIN buildings in Atlanta, GA, and Salt Lake City, UT. Each node will support approximately one-half of the United States and continuously exchange information with the other to ensure that both have identical national data bases. In the event of a nodal failure, the surviving one will assume responsibility for the entire network. The implementation of WMSCR will allow the closing of NATCOM. The system is expected to be operational by 1992.

Data Link Processor (DLP)

DLP will implement data link weather services to aircraft utilizing the discreetly addressed data link capability of the FAA's Mode S surveillance system. It will receive downlink requests for weather products from aircraft, formulate replies and return them to the pilot via the data link. This will improve air-ground communications services by expanding the pilot's ability to access desired weather information while operating on the airport surface or in flight. It will also reduce the workload of flight service specialists and air traffic controllers who currently provide the only means of such access.

Initially, the data link services to be implemented will be those for which automated data bases currently exist, or are planned to be operational in the near term. These include alphanumeric products such as SIGMET, AIRMET, surface observations, terminal forecasts, winds aloft, pilot reports and alphanumeric radar summary information. Installation of this system is scheduled to begin in 1990. The DLP will be enhanced in 1993 to support additional weather and ATC tower applications and to provide expanded data link communications functions in support of ATC data link services.

National Airspace Data Interchange Network (NADIN)

The NADIN II Packet Switched Network is being implemented to serve as the primary interfacility data communications resource for a large community of NAS computer subsystems. The network design incorporates state-of-the-art packet switching technology into a highly connected backbone network in order to provide extremely high data flow capacity and efficiency to the network users. NADIN II will consist of operational switching nodes at each Area Control Facility and two network control centers (and nodes) at the National Aviation Weather Processing Facilities at Salt Lake City and Atlanta. It will interface directly to such systems as the Weather Message Switching Center Replacement (WMSCR), Real-Time Weather Processor (RWP), Meteorological Weather Processor (MWP), Data Link Processor (DLP), AWOS/ASOS Data Acquisition System (ADAS), Traffic Management System (TMS), Consolidated NOTAM System (CNS), and Area

Control Computer Complex (ACCC), and may be used as the intrafacility communications system between these (collocated) users as required.

Central Weather Processor (CWP)

CWP will improve the dissemination of weather information throughout the National Airspace System (NAS), to pilots, air traffic controllers, flight service specialists, traffic management specialists, and NWS meteorologists assigned to weather service units in the air traffic control centers and the central flow control facility. It will provide specialized automated tools to these meteorologists to enhance their ability to summarize hazardous weather information and ensure that the latest and best information is disseminated to all users. CWP will also provide for a near-real-time, area mosaic of weather radars (NEXRAD) for subsequent distribution to controller displays. These improvements are necessary to help reduce the high percentage of accidents and delays directly related to weather.

The CWP is composed of two elements. The first is a commercially-available Meteorological Weather Processor (MWP) which will be procured through a series of 5-year leases. This will provide current meteorological data for the preparation of short-term aviation forecasts and severe weather advisories by the NWS meteorologists assigned to the FAA centers. The second element is a Real-Time Weather Processor (RWP) which will automatically create unique NEXRAD-based mosaic products. The RWP will send these products, along with other time-critical weather information to controllers through the Advanced Automation System (AAS) and to pilots via the enhanced Data Link Processor and Mode S data link.

Initial MWP services will be available in 1990. The MWP leased in the second 5-year period will interface with the RWP which should become operational in 1995. The MWP will also interface with NWS offices to permit a rapid flow of weather information to and from each FAA center. Future leases of the MWP will consider the possibility of utilizing services available from AWIPS (Advanced Weather Interactive Processing System) sponsored by the National Weather Service.

Requirements for the CWP and other agencies' automated weather information systems are being integrated by the Committee for Automated Weather Information Systems (CAWIS) working under the auspices of the AWIS Program Council. The intent of this activity is to avoid unnecessary duplication of development effort and to assure the sharing of information and products in the operational phase.

Weather Processing

The Committee for Automated Weather Information Systems (CAWIS), under the direction of the Program Council within the Office of the Federal Coordinator developed a National Plan which integrates requirements, development and implementation activities associated with AWIS programs and projects of the Department of Commerce, the Department of Defense and Department of Transportation. Under this plan, the departments are cooperating in the review, clarification, and allocation of requirements to the various specialized elements of the planned National AWIS. New interface requirements are being defined and plans for product sharing are being developed. In addition, new interfaces with elements of the NAS will be developed to support the CWP weather information dissemination function. Included is an interface with the DLP to provide NEXRAD mosaics for communication to the pilot, and receive Pilot Weather Reports from aircraft in flight.

This project translates these new interface requirements into verified interface designs and product specifications which, when they are approved for implementation, will be included in the CWP program.

Centralized Weather Information Processing

This is a new project to develop an integrated weather data base for generating route-oriented alphanumeric and graphic products that are consistent and machine readable.

Activities include the identification of weather-information sources appropriate for a centralized data base, development of a suitable structure for this data base, specification of machine-readable output products, and development of a rigorous set of algorithms for the generation of these products.

Airborne Wind Shear Detection and Avoidance

This project will develop requirements for airborne wind shear devices that provide the flight crew with the ability to reliably detect hazardous wind shear along the intended flight path, with sufficient time to avoid it.

In 1987, the FAA and NASA entered into a 5-year Memorandum of Agreement through which NASA will provide unique national resources for the study, analysis and verification of requirements for "forward-looking" sensors such as Doppler radar and Doppler lidar. These resources include NASA's Aircraft Landing Dynamics Facility to evaluate the full-scale effects of heavy rain, aircraft simulation capabilities, the ability to perform four-dimensional microscale atmospheric modeling, and instrumented flight-test facilities. The two agencies will develop the functional and performance requirements for airborne wind shear detection and avoidance, and will transfer the results of this effort to manufacturers to accelerate their development and certification programs.

In FY 1989, the effort focused on full-scale simulation tests of candidate system configurations of sensors, flight controls and cockpit displays. FY 1990 will be the first opportunity to perform flight tests of candidate airborne wind shear detection and avoidance concepts based upon the previous year's analysis and experiments.

It is projected that in FY 1991 airborne remote detection technology and onboard processing of ground-based data will be developed and evaluated.

Improved Aircraft Icing Forecasts

This initiative is to establish a comprehensive multi-year research and development effort to improve aircraft icing forecasts as recommended in the, "National Plan to Improve Aircraft Icing Forecasts". This plan was jointly developed under the aegis of the Federal Coordinator for Meteorological Services and Supporting Research by the Department of Transportation, Department of Defense, Department of Commerce, National Aeronautics and Space Administration and the National Science Foundation to provide the National Weather Service with an improved aircraft icing forecast capability. The objectives of this program to be completed by FY 1994, are to develop an icing severity index, icing guidance models, and a better comprehension of synoptic and mesocale conditions leading to icing. The end result of this effort will be improved icing forecasting capability, to be operational in 1996. Pilots will be provided with more timely and accurate forecasts of actual and expected icing areas by location, altitude, duration, and potential severity.

UNITED STATES COAST GUARD

Among the U.S. Coast Guard's activities is the collection and dissemination of meteorological information for the benefit of the marine community. In pursuit of this aim, the Coast Guard provides use of information and facilities to the National Oceanic and Atmospheric Administration (NOAA), specifically the National Weather Service (NWS) and the National Data Buoy Center (NDBC).

Coast Guard seagoing cutters submit weather observations to the National Weather Service and the U.S. Navy. Certain coastal stations submit weather observations to the National Weather Service. Additionally, NWS sensors on Coast Guard Large Navigational Buoys automatically transmit data to NWS centers. These data are utilized by the NWS in formulating its forecast products. NWS weather forecasts are disseminated in part by the Coast Guard through radio broadcasts to commercial and private vessels. Certain shore stations maintain visual displays authorized by the NWS to provide weather warnings to boaters.

In 1989 the International Ice Patrol, a Coast Guard unit, began air-deploying satellite-tracked drifting buoys equipped with barometric sensors in the northwest Atlantic. These data are available to all users through GTS.

U.S. Coast Guard Marine Science Technicians receive basic training in meteorology as a major part of the training for their specialty.

The Coast Guard supplies a staff of up to 15 personnel to the NDBC (costs reimbursed by NOAA at its facility in Mississippi) to provide technical expertise in the operation and management of the project. In addition, the Coast Guard makes available vessel, shore and aircraft support for stationing, monitoring and maintaining buoys.

Meteorological activities are coordinated by the Ice Operations Division of the Office of Navigation Safety and Waterway Services at Coast Guard Headquarters. The Coast Guard NDBC operation is managed at the Coast Guard Headquarters by the Short Range Aids to Navigation Division of the Office of Navigation Safety and Waterway Services. Field management of meteorological activities is a collateral function of the Coast Guard area staffs.

No Coast Guard unit is dedicated solely to meteorology; all facilities perform a variety of missions. No capital investments in meteorological facilities are planned or contemplated.

FEDERAL HIGHWAY ADMINISTRATION

In the 1987 Highway Act, Congress authorized the expenditure of $150 million for the Strategic Highway Research Program (SHRP). SHRP is administered by the National Research Council through an agreement with the American Association of State Highway and Transportation Officials and the Federal Highway Administration.

SHRP is conducting research over five years in four specific areas: asphalt, concrete and structures, long-term pavement performance, and highway operations. In highway operations, research is concentrated primarily in improving maintenance cost-effectiveness and snow-and-ice control.

Research is being conducted in support of highway operations to investigate technologies to help reduce costs in snow-and-ice control through more efficient and timely assignments and uses of resources. One objective is to reduce the time delay between input of pavement condition data and output of the local weather forecast. This will produce a more timely and accurate road weather forecast, yielding a large cost savings. SHRP is also investigating the applicability of pavement sensors and micrometeorological stations for providing realtime information on pavement condition.

APPENDIX D

WEATHER PROGRAMS OF OTHER AGENCIES

DEPARTMENT OF AGRICULTURE

Weather, is the most important factor influencing the Nation's variability in crop yields and related production. The Nation's food and fiber products are a critical resource impacting our domestic and international economic position and have taken on new dimensions in foreign affairs and national security. The recent expansion in export markets has reduced stocks and benefitted our farm sectors as global consumption of certain grains has exceeded production the last three years. The U.S. Department of Agriculture (USDA) conducts supporting research that focuses on understanding the interactions of weather and climate with plants, animals, forests and forest ecological systems and assists the Department of Commerce in determining farmers' needs for the weather information and in disseminating such information to them.

The World Agricultural Outlook Board (WAOB), in cooperation with the National Weather Service's Climate Analysis Center monitors the daily weather patterns around the world. The WAOB agricultural meteorologists convert the weather data into information to assess crop development and yield potential for all major commodity crops in major producing areas of the world. Special weekly briefings are provided to the Secretary of Agriculture and the economics and commodity analysts of USDA. The Senate and House Agricultural Committees also requested periodic briefings on crop relating drought effects in 1988 and 1989.

Historically, the Forest Service (FS) has collected meteorological data to assist in the control of forest fires and the management of smoke from prescribed burning. However, other FS activities also need weather data to ensure sound management decisions. Therefore, a national weather program was establish to coordinate all FS meteorological activities and to meet the increasing need for diverse weather information. The major objectives of the program are to: improve quality control of weather data, improve the design and operation of data collection networks, increase data recovery from the weather stations, and upgrade station maintenance. Meteorological data collected by manual weather stations and Remote Automated Weather Stations (RAWS) support research of weather effects on forestry management, forest fires, smoke management, visibility protection in wilderness areas, and atmospheric deposition. A weather information management system and a library to archive all FS weather data is being developed in cooperation with the Regional Climate Centers of the National Climate Program. The Forest Service monitoring network will provide essential data for use in Global Change work.

The Soil Conservation Service (SCS) operates a network of 1400 manual snow courses and over 550 automated data collection sites in conjunction with a snow telemetry project (SNOTEL) for the western United States and Alaska. The primary objective of the project is to forecast streamflow for the coming spring runoff season. These measurements are made in cooperation with other Federal, state and local agencies, power companies, irrigation companies, and the provincial Government of British Columbia.

Water supply forecasts help irrigators make the most effective use of available streamflow for achieving their agricultural production goals. Farmers who collectively irrigate more than 10 million acres of land in the western United States benefit from water supply forecasts. Other Federal agencies and private organizations also use water supply forecast information to help them carry out their missions. These forecasts also help the Federal Government in administering international water treaties.

Beginning in FY 1987, SCS implemented a new 5-year initiative to upgrade the SNOTEL data collection system at a total cost of $5 million. This effort continues and includes upgrading 510 data collection sites in the existing SNOTEL system with new state-of-the-art equipment and

adding about 40 additional sites. The data collection site upgrade will include replacement of snow pillows, transducers, damaged precipitation gages, antennas, towers, solar panels, batteries temperature sensors, and deteriorated shelter houses.

Supporting Research

The mission of the USDA supporting research program is to develop and disseminate information and techniques to ensure an abundance of high-quality commodities and products while minimizing any adverse effects of agriculture in the environment.

The research efforts of the Agricultural Research Service (ARS) relate directly to the effects of climate on agricultural production and the natural resource base. They are directed toward developing technologies and systems for: 1) managing precipitation and solar energy for optimum crop production; 2) improving our understanding of water-plant-atmosphere interactions; 3) optimizing the use of energy, water, and agricultural chemicals; 4) reducing plant and livestock losses from pests and environmental stress; 5) developing improved techniques for irrigation and drainage; and 6) minimizing the adverse effects of climate and weather, including atmospheric contaminants, on atmospheric production and the environment.

The Cooperative State Research Service (CSRS) coordinates research programs in the state agricultural experiment stations, the 1890 Land Grant Distributions, and cooperating forestry schools. These institutions conduct a wide variety for research applicable to agriculture and forestry. Meteorological research in these institutions is practically all climatological. A proportion of each state's program is consolidated into broad Regional Research Projects. Animals and plants are subjected to many climatic stresses and are therefore the focal point of much of this research. Work begun in FY 1990 to evaluate plant response to changes in levels of ultraviolet radiation as part of the Global Change research program will be significantly expanded through the CSRS competitive Grants program in FY 1991. The work is coordinated with EPA's UVB program and will support assessment efforts to develop related national policy on environment.

Forest Service research includes efforts to: understand and control forest fire initiation by lightning; improve the translation of mid-range forecast elements to describe forestry conditions, incorporate drought information into fine management decision-making and better describe how regional climatic variability affects the use of daily weather information by foresters. The FS long term monitoring network will provide critical data for use in the Global change research work.

Investigations by the National Agricultural Statistics Service (NASS) support domestic crop estimating programs for major commodities. Promising studies are underway to develop models relating weather parameters and associated variables to corn ear weight and wheat head weight. Results from previous efforts to develop models for short term forecasting have also had only limited success. Research will continue in this area with the expectation that the relationships between weather variables and crop yield will improve as better plant process models become available.

The NASS program to explore the use of satellite and weather data for assessing crop conditions is continuing. A preliminary investigation of polar orbiting meteorological satellite data showed a good relationship between crop condition and reflectance data as determined by the agreement between measured and forecast final corn and soybean yields. The crop conditions assessment procedures, based on meteorological satellite data, are being automated and near real time applications are being explored.

DEPARTMENT OF ENERGY

The Department of Energy (DOE) supports meteorological services at nine of its laboratories and at the Nevada Test Site. Services include climatological summaries, general weather forecasts, and items specifically in support of laboratory operations such as environmental monitoring, atmospheric sciences research, and hazardous material release assessments. The National Weather Service Nuclear Support Office at the Nuclear Test Site provides continuing meteorological services required by the safety and technical programs associated with all forms of nuclear and non-nuclear experiments conducted at the test site and other locations.

DEPARTMENT OF INTERIOR

Specific financial data for the Department of the Interior's (DOI) Atmospheric Science Research Programs are reported through the Subcommittee for Atmospheric Research; however, operational program budgets are reported in this Plan. The narrative below describes the full range of meteorological activity in the Interior Department.

The Bureau of Reclamation's Project Skywater is one of DOI's important meteorological activities. The objectives of Project Skywater are the further development of weather modification technology to increase precipitation and the transfer of existing technology to user groups in situations where its application for increasing water supplies appears promising.

Other Bureau of Reclamation activities including water scheduling, flood hydrology, irrigation project management, and reservoir operations, as well as projects related to the development of wind and solar energy resources, also require the collection and use of meteorological data. Currently, Reclamation operates approximately 400 hydrometeorological data collection platforms (DCPs) and collects near real-time data through a GOES Direct Readout Ground Stations (DRGS) in Boise, ID. Multi-agency work is also proceeding in projecting potential effects of climate change on western water resources and Bureau operations.

The Geological Survey's Water Resources Division collects precipitation, stream flow, and other climatological data for a number of projects concerning rainfall/runoff and hydrologic processes. Currently, the Geological Survey collects hydrometeorological data from approximately 1,800 GOES DCPs through seven DRGS. Precipitation and dryfall atmospheric deposition samples are collected in a number of studies for the determination of atmospheric contribution to the chemical constitutent loads to runoff, and for defining the effect of atmospheric desposition on water quality and the aquatic environment. The Geological Survey provides lead agency coordination for the atmospheric deposition monitoring program of the Interagency Task Force on Acid Precipitation.

The Geological Survey is continuing a joint research program with NASA to map snowpack water equivalent using satellite passive microwave techniques. Comparison of data collected by the Department of Agriculture's Soil Conservation Service Snow Telemetry (SNOTEL) sites, by Survey field teams, and through instrumentation by other agencies is being made to test the feasibility of making near real-time assessments of snowpack from space. The Survey also carries out research in past climate change, regional hydrology, the carbon cycle, coastal erosion, volcanic activity, and glaciology.

The Bureau of Land Management's (BLM) Initial Attack Management System (IAMS) provides real-time data access and modeling for the fire management organization. The system enables rapid evaluation, assessment, and decision making capabilities for the BLM's wildfire responsibilities. The principal inputs are Remote Automatic Weather Station (RAWS) meteorological data, Automatic Lightning Detection System (ALDS) information, vegetation, slope, elevation, and terrain data. These real-time data sources are coupled to advanced fire modeling capabilities to facilitate the BLM's fire and resource management objectives.

The BLM's RAWS Program collects meteorological data from a network of stations located throughout the eleven western states and Alaska. This network is comprised of three classes of systems placed at strategic remote locations. All data are recovered via the GOES system by the BLM's Direct Readout Ground Station (DRGS) located at the Boise Interagency Fire Center (BIFC) in Boise, Idaho. The Bureau presently owns 339 systems with 191 of these being fielded and another 20 scheduled for purchase in FY 1991. The network is planned to ultimately reach 359 fielded systems. Completion of the network as planned is based on acquiring the personnel (FTE) to implement and maintain the total number of planned systems.

The BLM's RAWS Support Facility at BIFC provides a full range of management, maintenance, data, and support services for the BLM and numerous other Government agencies. This work is performed under long-term interagency agreements with those agencies having similar equipment and requirements.

The BLM's ALDS covers the eleven western states and Alaska. The western U.S. ALDS is comprised of 36 direction finders (DF) providing high detection efficiency coverage of cloud-to-ground activity for 95 percent of the western United States. The system provides data via a satellite telecommunications system for the BLM's IAMS. Data are also supplied to the National Weather Service, State University of New York (SUNY), New Mexico Institute of Mining and Technology, and several Department of Defense installations. The Alaska ALDS is comprised of nine DFs providing the required coverage for Alaska Fire Service's needs.

In addition to the meteorological monitoring BLM conducts primarily to support fire management activities, the BLM also conducts site-specific climate monitoring at over 200 locations on the Public Lands in the eleven western states and Alaska. The operation of these sites ranges from seasonal to annual measurements of precipitation, temperature, soil moisture and other meteorological parameters necessary to assess local climatic influences. These data are primarily used for natural resources management and planning at the local level.

The Minerals Management Service's Environmental Studies Program gathers offshore environmental data in support of mineral leasing responsibilities. Currently, the Service supports eight data buoys which transmit via NOAA satellites from off the Pacific Coast. Wind data is used in the Service's Oil Spill Risk Analysis Model to predict effects of potential spills.

The National Park Service monitors air quality in several national parks and monuments. Approximately 20 GOES DCPs are used to collect these data. The Service has contracted research to develop and test models to assess long-range transport of anthropogenic pollutants including sulfur dioxide and sulfur deposition.

The Bureau of Indian Affairs collects atmospheric data to evaluate potentially irrigable Indian Trust lands in the Southwest. The Bureau also shares fire weather data with other Federal agencies while participating in fire weather forecasting at the Boise Interagency Fire Center.

DEPARTMENT OF STATE

The Department of State is assuming a much more active role in international climate/meteorological policy making as a result of growing public concern with possible substantial warming of the global atmosphere due to the "greenhouse gas effect." The Assistant Secretary of State for Oceans, International Environmental and Scientific Affairs, chairs the U.S. Delegation to the Intergovernmental Panel on Climate Change (IPCC) which held its first meeting at Geneva in November 1988. The purpose of the IPCC is to serve as a government forum to call for scientific examination and assessment of future global climate change due to atmospheric warming from the greenhouse effect. It is anticipated that the IPCC will draw upon scientific assessment support from the World Meteorological Organization (WMO), the United Nations Environmental Program (UNEP), the International Council of Scientific Unions (ICSU) and their various international climate assessment programs.

The Department of State is also active on the Committee on Earth and Environmental Sciences (CEES) of the Federal Coordinating Committee on Science, Engineering and Technology (FCCSET). The CEES was established in 1987 by the President's Science Advisor to coordinate all domestic programs dealing with global change, including global climate change assessments. The CEES is the chief Federal interface with the National Research Council's global change program which is a part of the ICSU's emerging International Gesophere/ Biosphere Program (IGBP) which is charged with assessing and analyzing Earth systems science and changes in the Earth systems as a whole. Through the CEES, the State Department is able to help shape and define U.S. international science policies regarding global change, including global climate change.

These new responsibilities are in addition to, but do not replace, traditional Department responsibilities set forth in earlier annual Federal Plans, i.e., international aspects of global food policies, disaster warnings and assistance, WMO activities, international meteorological programs, and concern with some programs which start as operating programs but develop international interest and concern such as the possibility of seeding Pacific storms.

Finally, the Department is monitoring and implementing international actions to enforce the provisions of the 1985 Vienna Convention on the Preservation of the Ozone and the subsequent Montreal Convention Protocols on enforcement of chloroflourocarbon (CFC) reduction.

All of the above activities -- especially IPCC, IGBP and CEES responsibilities, and the ozone monitoring and implementation actions will be continued for many years.

ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) is responsible for working with state, local, and other Federal Government agencies to ensure adequate air quality meteorological programs to support regulatory applications. Applied research and meteorological support is provided by EPA's Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC. Meteorological support to the EPA Office of Air and Radiation, the EPA Regional Offices, and to state and local agencies includes: review of the meteorological aspects of environmental impact statements, state implementation plans, and variance requests; development and application of air quality dispersion models for pollution control and exposure assessment strategies; and preparation of dispersion studies and model evaluations. Meteorological expertise and guidance is also provided for the air quality standard, modeling guideline, and policy development activities of EPA.

EPA applied research is in such areas as: air quality dispersion model development, evaluation, and application; construction and application of air pollution climatologies; determination and description of pollutant effects on atmospheric parameters; and determination of meteorological effects on air quality. Dispersion models for inert, reactive, and toxic pollutants are under development and evaluation on all temporal and spatial scales; e.g., indoor, urban, mesoscale, and regional. Particular emphasis is being given to the development of dispersion models for inhalable particulate matter, photochemical pollutants, and acid deposition on several spatial scales. Measurement data obtained during field programs and from wind tunnel and water channel/towing tank experiments will be used to continue development and evaluation of models in the FY 1990-91 period. Examination of the relationship between meteorology and air quality continues with emphasis on ozone, sulfates, acid deposition, particulate matter, and toxic air pollutants. Also, specialized studies have been initiated to support stratospheric ozone, global climate change, and acid aerosol research.

FEDERAL EMERGENCY MANAGEMENT AGENCY

Under direction of the President, the mission of the Federal Emergency Management Agency (FEMA) is to plan for and coordinate the protection of the civilian population and resources of the Nation, and to include planning for the continuity of constitutional government in time of emergency. FEMA replaced five former agencies, integrating a number of emergency activities which include development of community awareness for meteorological emergencies and coordination of all emergency warnings to the public.

FEMA's principal involvement with meteorology results from the coordinating role of FEMA in support of preparedness for national security emergencies, and for carrying out statutory disaster relief responsibilities involved with the extremes of meteorologically-related phenomena. These responsibilities have been listed in Executive Order 12656 which forms the basis for FEMAs continuing relationship with the Executive line agencies.

In carrying out its role, FEMA works with all of the agencies to assure that the delivery of meteorological and climatological-related information is conducted in keeping with established preparedness goals and objectives. As administrator of the National Flood Insurance Program, FEMA publishes a system of Flood Insurance Rate Maps (FIRM) which serve as the official demarcation for flood insurance risk. Recently, FEMA was given responsibility by the 100th Congress for coordinating the preparation of a national coastal erosion and flood plain database.

FEMA's priority interests with the Office of the Federal Coordinator are in promoting standards and procedures which will enhance the ability of the Nation to mitigate and recover from national security emergencies, and to coordinate its statutory responsibilities by enhancing integrated services under off-standard conditions. These interests extend to national standards for geographic information systems which serve as vehicles for delivery of meteorological services by other agencies.

For meteorologically-related matters, the National Preparedness Directorate is the principal contact point within FEMA. Developments involving flooding and erosion impacts are coordinated within the Insurance Administration offices of FEMA.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Operations

The National Aeronautics and Space Administration (NASA) Headquarters Weather Support Office, through its Weather Working Group, has continued to improve NASA's weather support capabilities for both manned and unmanned launch vehicles. It is expected that these improvements will strengthen and enhance the information provided to the ground-based decision makers and astronaut observers to insure that NASA achieves the best operational posture for the space shuttle launches and landing. Improved weather information begins with improved observing systems and includes efforts to provide better communications, integrated data management systems and displays, an automated network of observing stations/systems, and improved forecasting techniques and methods.

The elements comprising the operations program are intended to provide the specialized meteorological data that are needed for the support of both manned and unmanned launch vehicles. The upgraded lightning sensors network to monitor and aid in predicting the occurrences of lightning in the Kennedy Space Center (KSC) area has been completed.

NASA has upgraded weather observing capabilities at the Shuttle landing and alternate landing sites. This includes completion of the Meteorological Interactive Data Display System (MIDDS) that facilitates the transfer of meteorological data and reduces the time required to evaluate weather situations and increase the forecaster's confidence in their recommendations for launches, landings, and operations of both manned and unmanned space vechicles. This technology also provides for operational redundancy and increases safety.

NASA has also installed a Doppler radar vertical wind profiler at the Kennedy Space Center to monitor the variation of winds aloft. The unit, located near the Shuttle Landing Field, is currently under test and evaluation. The goal of this system is to aid in the prediction of an avoidance of those weather impacts associated with adverse weather phenomena in a subtropical coastal environment.

NASA plans to conduct a special Jimsphere wind profile data acquisition and analysis project to support launch and post-launch requirements. To support enhanced vertical wind data acquisition processing, and transfer capabilities, the winds ingest computer has been upgraded.

None of these improvements are intended to depart from NASA's adherence to traditional operational principles. These improvements are designed to strengthen this approach and enhance information available to the launch/operations control decision makers, astronaut observers and management team for space vehicle launches, flight, and landings.

Supporting Research

In July 1989, President Bush tasked NASA to develop a program to observe and improve our understanding of global change. This task is called "Mission to Planet Earth," and is intended to provide a scientific basis to decision makers regarding man's impact on climate. NASA has received the President's approval to initiate the Earth Observing System, or EOS, as part of this plan. It will consist of a series of large polar orbiting platforms launched by the U.S., Europe, and Japan, all designed to make long-term, important global Earth science and climatological measurements. This program will also include a data and information system to retrieve, process, archive, and distribute information, and an ongoing research program to analyze, understand, and

model the Earth as a system in order to understand and predict climate. NASA has been joined in this activity by a number of other Federal agencies, including NOAA and the National Science Foundation.

The NASA Atmospheric Sciences Research Program conducts research using space technology to increase our knowledge and understanding of atmospheric behavior. This knowledge and understanding is obtained by utilizing satellite sensors to obtain global observations, together with an information system, to make the data accessible to investigators, and a research and analysis program to understand the observations.

The NASA program includes the following major components:

- Development of space-borne observing systems and supporting ground-based systems to observe the state of the atmosphere, and important atmospheric and surface parameters such as temperature, moisture, winds, albedo, clouds, etc.
- Development of algorithms and inversion techniques to derive useful atmospheric parameters from remote observations.
- Development of data processing and data assimilation techniques to address the problems peculiar to the use of satellite data in atmospheric analyses and modeling.
- Analysis of satellite data to improve our understanding of atmospheric processes on temporal and spatial scales consistent with satellite observing capabilities.
- Development of models to exploit the spatial densities and temporal frequencies inherent in satellite data to initialize and verify models and assess their predictive value.
- Development of parameterization schemes which permit the representation of space observations of sub-grid scale phenomena in atmospheric models.
- Assessment of the performance of satellite sensors through numerical simulation experiments which compare model output with and without satellite sensor data.

Development of the Upper Atmosphere Research Satellite (UARS) is nearing completion. The UARS will address the coupling of chemical, radiative, and dynamic processes in the stratosphere and the mesosphere. NASA's Scatterometer (NSCAT), which continues in development, will measure surface wind velocity over the oceans with high accuracy and has been selected to fly on a Japanese mission called the Advanced Earth Observations Satellite (ADEOS).

In studying atmospheric phenomena, NASA uses geosynchronous satellite data (especially, NASA-developed temperature soundings), aircraft instrumentation (e.g., Doppler lidar wind measurements), and ground-based techniques, in addition to conventional observations, to obtain data that will improve our understanding of the processes involved in the generation, propagation, and decay of mesoscale weather phenomena. Models have been developed to use the quantitative information provided by these remote sensors.

NASA continues to support research and development activities to improve our remote sensing capabilities for possible future deployment on satellites. Studies involve remote sensing of atmospheric temperature, pressure, moisture, and winds using passive and active techniques. Successful flights of remote sensing instruments on several aircraft have been made using sensors to study the dynamics and radiative properties of cloud tops, and the fluxes of heat, moisture, and momentum between land and ocean surfaces and the atmosphere.

NASA has as one of its goals to understand the Earth Climate System and the impact of man's activities on it. This program is called "Global Change" and is being conducted with the cooperation of many institutions including both Federal agencies and foreign government agencies.

NASA issued an EOS Announcement of Opportunity and has completed its preliminary selection of instruments and investigators in four key Earth system science categories: geophysical processes, biogeochemical cycles, climatological processes, and the hydrologic cycle. In all, NASA selected 7 facility instruments, 25 instrument investigations, and 28 interdisciplinary investigations. The selected instruments are presently undergoing feasibility and definition studies.

NASA will complete instrument concept, design, and cost reviews, and then make its final selection of instruments for the first platform in 1990. It will also confirm other definition-phase selections. Payload execution will begin in October 1990. Launch of the first NASA polar platform is planned for late 1997. This will be followed by a European platform, a Japanese platform, a second NASA platform, and second European platform. The plan is to continue the observations for approximately 15 years to acquire a data set sufficient to serve as the basis for analysis and understanding.

NASA scientists recognize that EOS alone cannot address the entire range of environmental problems involved in global change. EOS does, however, represent the most significant and unifying approach ever taken to understanding the Earth sciences as a single system.

NUCLEAR REGULATORY COMMISSION

The Nuclear Regulatory Commission (NRC) licenses and regulates all nuclear facilities subject to the Atomic Energy Act of 1954, as amended. The licensing and operation of nuclear facilities require identification and evaluation of meteorological conditions that can affect the safe operation of the facility and that provide input to the assessment of the radiological impacts of any airborne releases from the facility.

Within the NRC, the Offices of Nuclear Reactor Regulation and Nuclear Material Safety and Safeguards review facility siting, design, construction, and operation. These reviews include consideration of meteorological factors. The Office for Analysis and Evaluation of Operational Data and the Regional Offices assure that commitments by NRC applicants, permittees and licensees are carried out, and conduct NRC responses to nuclear facility emergencies. The Office of Nuclear Regulatory Research develops regulations, guides, criteria, and other standards relating to the protection of public health and safety and the environment in the licensing of nuclear facilities. This Office also develops and conducts confirmatory research programs in support of activities of the other offices and in support of rule-making and standards activities.

There are several meteorological areas in which the NRC will have an interest during FY 1991 and beyond. Paleoclimatic reconstruction and climatic change models for high-level radioactive waste repositories will continue to be evaluated. Improvements in the meteorological capabilities of the NRC and the operators of nuclear facilities to cope with emergencies involving unplanned releases of radioactive material are expected to continue. Updated guidance on meteorological measurement programs is in preparation. The NRC is also concerned with the dispersion of hazardous non-radioactive materials and their potential effects on the safe operation of nuclear facilities.

APPENDIX E

WORLD WEATHER PROGRAM

The Department of Commerce (DOC) was designated by the President, following Senate Concurrent Resolution 67 (1968), to be the lead agency in coordinating the U. S. participation in the World Weather Program (WWP). Previous to 1983, DOC published a separate report on WWP Plans. Beginning with the 1983 edition of the Federal Plan for Meteorological Services and Supporting Research, a section on the WWP has been included and has obviated the need for a separate report. Included at the end of this Appendix are bilateral and regional international cooperative activities not under the WWP. While not exhaustive, most government programs are included. This Appendix was prepared by the Working Group for World Weather Program (WG/WWP) of the Committee for Basic Services within the Federal meteorological coordination mechanism.

GOALS AND ORGANIZATION OF THE WORLD WEATHER PROGRAM

The goals of the World Weather Program (WWP) are to extend the time, accuracy, range, and scope of weather prediction and to understand the physical basis of climate and of climatic changes. The ability of the United States and other nations to use their existing scientific capability to understand the climate and to increase their weather predicting skills is limited by the lack of global weather data. Available weather data is barely adequate over 20 percent of the Earth while the remaining 80 percent, mostly over the oceans, remains inadequately observed.

Development of the technology and the systems to obtain these observations, especially over the oceans, presents formidable problems. However, with the use of satellites, aircraft, ships, radar, anchored and drifting buoys, and balloons, a system can be developed that will be able to observe and collect comprehensive daily data about the atmosphere of the entire globe. This system is too complex to be implemented by a single nation. This has been clearly recognized by the leaders of many nations whose international cooperation in meteorology has been a tradition for more than a century. The continuing need for international cooperation prompted the President of the United States to propose to the United Nations (UN) in 1961 the establishment of an international effort in weather prediction. The United Nations responded by calling upon the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) to develop measures to improve weather forecasting capabilities and to advance knowledge of the basic physical forces that determine climate.

The WMO, with 160 members, is a specialized agency created by the UN to facilitate international cooperation in the fields of meteorology and hydrology. The WMO responded to the UN request with the concept of the World Weather Watch (WWW), an operational system to bring the global atmosphere under improved surveillance and to provide for the rapid collection and exchange of weather data as well as for the dissemination of weather products from centralized processing centers.

In addition to WWW, DOC through the National Oceanic and Atmospheric Administration (NOAA) was also involved in another major cooperative international program. This is the Sahel Agrometeorological and Hydrological Program. Funds for NOAA's participation and support of this program was provided by the Department of State's Agency for International Development.

The responsibilities of U. S. Federal agencies in the WWP follow:

Department of Commerce (DOC): Represents the U. S. at WMO and provides the focal point (NOAA) to coordinate our Nation's efforts in these international programs, implements those

service improvements in the existing international weather system for which the U. S. accepts responsibility, and develops new technology as related to its responsibilities.

Department of State (DOS): Maintains relations with developing nations and through the WMO assists developing nations in improving their national weather services; and develops appropriate multilateral and bilateral arrangements to further international participation.

National Science Foundation (NSF): Stimulates and supports basic research by non-government scientists on atmospheric and ocean circulations and modeling. It also promotes the education and training of atmospheric and ocean scientists at universities.

Department of Defense (DOD): Although the mission of the Department of Defense (DOD) weather services is basically internal, the nature of DOD's operations is global. As such, the observation, telecommunication and data processing programs of the military weather services provide significant indirect support to the WWW through DOD's interface with NOAA's National Weather Service (NWS). Information from the research and development activities of these services is exchanged routinely with other similar national agencies and is often presented at national forums.

Department of Transportation (DOT): Through the U. S. Coast Guard, provides personnel to support NOAA's National Data Buoy Center (NDBC) in developing, operating, and evaluating data buoy systems. Coast Guard cutters and aircraft provide operational support to deploy, service, and retrieve buoys built for test or operational purposes. The observation and telecommunication programs of the Department of Transportation (DOT) also provide significant indirect support to the World Weather Watch through DOT's interface with NOAA's National Weather Service.

National Aeronautics and Space Administration (NASA): Performs research and develops space technology required for an effective global weather system.

THE WORLD WEATHER WATCH

The World Weather Watch (WWW) is an integrated system which functions on three levels global, regional, and national. The WWW is divided into three essential elements that are closely linked and interdependent: Global Observing System (GOS), Global Data Processing System (GDPS), and Global Telecommunication System (GTS).

These elements are coordinated and closely integrated through three WWW support functions. The Data Management function coordinates, monitors, and manages the flow of data and products within the WWW system to assure their quality and timely delivery. It also includes the definition and use of code forms for data exchange. The Implementation Support Activity provides guidance, technical and scientific information, and training to those involved in the planning, development, and operation of WWW components. The Implementation Coordination function assures the timely completion of the WWW implementation and effective support and maintenance of the WWW system.

Global Observing System (GOS)

The GOS is a coordinated system of methods, techniques, and facilities for making weather observations on a worldwide scale. It is a composite system containing surface-based and space-based (satellite) subsystems. The main elements of the surface-based subsystem are:

- Regional basic synoptic networks, manned and automatic, for both surface and upper-air observations.

- Fixed sea stations, composed of ocean weather stations, fixed and anchored platform stations, island and coastal stations.
- Mobile sea stations, including moving ships and drifting buoys.
- Aircraft Meteorological Stations, including automated aircraft reporting systems.

Other elements are:

Aeronautical Meteorological Stations	Solar Radiation Stations
Research and Special Purpose Vessels	Atmospheric Detection Stations
Climatological Stations	Meteorological Rocket Stations
Agricultural Meteorological Stations	Ozone Stations
Weather Radar Stations	Background Pollution Stations
Meteorological Reconnaissance Aircraft	Tide Gage Stations

The space-based satellite subsystem has become increasingly important in supporting meteorological and hydrological predictions and warnings. The types of satellites which constitute the space-based subsystem and their functions are described below.

Meteorological satellites are divided into two groups, those in near-polar orbits and those in geostationary orbits. Those in near-polar orbits at low altitude (less than 1000km) provide global coverage (twice a day for each satellite) and customarily are used for precise radiance measurements needed for temperature and water vapor soundings, sea surface temperature and radiation fluxes. Those in goestationary orbit (36,000 km above the equator) provide a continuous view of a large portion of the Earth (except the polar areas). They are used primarily for a "continuous weather watch" to produce wind estimates by measuring the motion of clouds viewed over a period of one to two hours, to monitor mesoscale cloud growth and for communications functions.

The present operational meteorological satellites in near-polar orbit are the METEOR-2 series of the Union of Soviet Socialist Republics and the NOAA series of the United States of America (USA). NOAA launches satellites every 15 1/2 months alternately into morning and afternoon orbits. The current operational polar satellites are NOAA-10 (launched in September 1986) and NOAA-11 (launched in September 1988). These two satellites provide global observations in their early morning and early afternoon orbits respectively. One earlier satellite, NOAA-9, launched in December 1984, is technically in a standby mode, but data are still being acquired from instruments on-board for ozone and earth radiation budget measurements. The next in this series of satellites (NOAA-D, which will become NOAA-12 upon successful launch) is scheduled for launch into an afternoon orbit in November 1990.

The operational meteorological geostationary satellites at present are the Geostationary Meteorological Satellite (GMS) series of Japan at 140°E, the Geostationary Operational Environmental Satellite (GOES) of the U.S. switching between 98°W and 108°W, the Indian National Satellite (INSAT) at 74°E, and the METEOSAT series of Europe at 0°. The U.S. normally operates a two-GOES system, with the satellites stationed at 75°W and 135°W. With the demise of GOES-6 in January 1989, GOES-7 (which was launched in February 1987) became the sole remaining U.S. GOES satellite with imaging capability. It is alternately positioned at 108°W for the winter season from November to May and moved back to 98°W for the hurricane season from June through October. NOAA currently plans to launch the next in this series (GOES-I to become GOES-8) no earlier than mid-1991. The launch of GOES-8 will restore the U.S. two-2GOES system.

The different capabilities of the two satellite groups complement each other and are necessary parts of the space-based subsystem of the GOS. In addition to the polar satellites providing the measurements listed above, they are also used to monitor volcanic eruptions, produce vegetative indices of the entire globe, monitor ozone distribution, measure the energetic particle distribution in the upper atmosphere, provide an in situ data collection and location system, and last, but not least, perform a Search and Rescue Satellite-Aided Tracking process. By processing a series of images acquired over a period of several hours, moving clouds in partly cloudy regions can be eliminated by digital filtering in a computer. The output is a single averaged image field of the surface without cloud interference. As well as taking observations directly, both types are capable of accomplishing data collection and data dissemination missions. With the launch of GOES-I, NOAA will have a new capability for acquiring simultaneous sounding and imaging data, as opposed to the shared imaging/sounding function characterized by previous GOES satellites including GOES -7.

Besides taking observations directly, both types of satellites have a ground segment. This is composed of receiving and processing stations for satellite signals and data from Data Collection Platforms (DCPs). The ground segment also provides information and products for further distribution by the Global Telecommunication System (GTS).

The WWW is a flexible system which can be adapted to changing technology and operational conditions. The latest technological and scientific developments in observations, data processing, and telecommunications are under constant review with an eye towards improving the GOS, GDPS and GTS.

During the last few years, several systems have been under development and/or have been partially deployed which will contribute to improving the GOS. Among these are the family of automated aircraft reporting systems (AMDAR) including the Aircraft to Satellite Data Relay (ASDAR) and Aeronautical Radio Inc. (ARINC) Communications Addressing and Reporting System (ACARS). Work continues to achieve certification for the first of 13 ASDAR systems that are expected to be deployed on routes over the Atlantic, Pacific and parts of the Southern Hemisphere. A cooperative effort among ARINC, NWS, and FAA is underway to provide thousands of meteorological reports from ACARS equipped aircraft flying over the U.S., Europe, and the Atlantic and Pacific Oceans. Approximately 10 Automated Shipboard Aerological Program (ASAP) systems and substantial numbers of drifting buoy systems have also been deployed in recent years. A number of nations, including the U.S., are in the process of implementing test networks of ground based doppler radars called wind profilers to provide soundings of wind on a near continuous basis. The first system of a demonstration network of 30 wind profilers being deployed in the central U.S. was installed in 1989. Implementation of the remaining systems will be completed in 1991.

The concept of the Operational World Weather Watch Systems Evaluation (OWSE) has also been developed as a framework for regional implementation. The OWSE-North Atlantic was begun in January 1987 and was completed in 1989. Data have been gathered and reports produced on the quality and reliability of the information. Data impact studies have been performed with results that are important to planning changes to the mix of observing systems. The OWSE-Africa has been initiated to evaluate the very extensive use of a geostationary meteorological satellite (operated by the European operational satellite consortium, EUMETSAT) to improve telecommunications and data availability in Africa. Equipment is currently being deployed and technical problems eliminated as experience with the systems grows. Evaluations will be carried out to gauge the improvement of observations.

In 1986 the U.S. agreed to undertake the development of a plan and evaluation of the feasibility of satellite sounding improvement techniques through the use of a baseline upper air network consisting of rawindsonde, rocketsonde and ASAP observing systems. With the cooperation of a number of foreign meteorological services, the observational phase of the project took place during the period January 15 - July 15, 1988. The final report on the project summarizing the results will be completed by early 1990.

Global Data Processing System (GDPS)

The purpose of the GDPS is to make available all processed information required for both real-time and non-real time applications. The GDPS produces products and processed information, based on recent advances in atmospheric science, using powerful numerical computer methods. Members have real-time access through the GTS to GDPS products which allow all countries to benefit from their participation in the WWW.

The GDPS is organized as a three-level system. It consists of World Meteorological Centers (WMCs), Regional/Specialized Meteorological Centers (RSMCs) together with National Meteorological Centers (NMCs) which carry out GDPS functions at the national level. In general, real-time functions of the system involve preprocessing of data, analysis and prognosis, including derivation of appropriate meteorological parameters. The non-real-time functions include data collection and archival, quality control, storage and retrieval, as well as cataloging of observational data and processed information for operational and special applications, and for research.

WMCs are located in Melbourne, Moscow and Washington; they provide products used for general short, medium and long-range weather forecasts on a global scale. Melbourne specializes in forecast products for the Southern Hemisphere.

The RSMCs are located at Algiers, Algeria; Antananarivo, Malagasy; Beijing, People's Republic of China; Bracknell, England; Brasilia, Brazil; Buenos Aires, Argentina; Cairo, Egypt; Dakar, Senegal; Darwin, Australia; Jeddah, Saudi Arabia; Khabarovsk, USSR; Lagos, Nigeria; Melbourne, Australia; Miami, USA; Montreal, Canada; Moscow, USSR; Nairobi, Kenya; New Delhi, India; Novosibirsk, USSR; Offenbach, Germany; Rome, Italy; Tashkent, USSR; Tokyo, Japan; Tunis, Tunisia; Washington, U.S.A. and Wellington, New Zealand. The European Center for Medium Range Forecasting is also an RSMC. These centers provide regional products used for short and medium-range forecasting of small, meso and large-scale meteorological systems by WMCs. Products of RSMCs can be used by Members at the national level for further processing or interpretation to provide assistance or service to users.

Further progress toward implementation of the World Area Forecast System (WAFS) was made during 1989. In this system, two centers (Washington and London) designated by the International Civil Aviation Organization (ICAO) as World Area Forecast Centers (WAFCs) issue upper wind and temperature forecasts with global coverage to associated Regional Area Forecast Centers (RAFCs). The plan has been for this information to be redistributed as required within each regional center's service area. The regional centers also prepare and distribute forecasts of weather elements defined by ICAO as significant weather. Washington and London WAFCs have both been implemented since 1984. These two centers, also designated by ICAO as RAFCs, have functioned in this role since 1984. RAFCs associated with WAFC Washington include Brasilia, Buenos Aires, Tokyo, Wellington, Melbourne, New Delhi and Washington. RAFCs associated with WAFC London, are Paris, Frankfurt, London, Moscow, Nairobi, Cairo, Las Palmas and Dakar. As of September 1988, the RAFCs implemented were London, Paris, Frankfurt, Moscow, Washington, Tokyo, Wellington and Melbourne.

The preceding paragraph deals with efforts towards implementation of the interim phase of the WAFS. In the planned implementation of the final phase, the two world centers would prepare and issue computer-based wind and temperature forecasts as they now do. In addition, those centers will automate all of the significant weather elements. While some of these elements are now prepared automatically, others may begin to be realized in the early 1990's through forecaster initiated graphic interaction.

Global Telecommunication System (GTS)

The GTS provides communication services for the collection, exchange and distribution of observational data and processed information from the WMCs, RSMCs and NMCs operating within the GDPS of the WWW, to meet the needs of Members for operational and research purposes which involve real-time or quasi-real-time exchange of information. The GTS also supports other WMO programs, joint programs with other international organizations, and environmental programs as decided by the WMO Congress.

The GTS is organized on three levels:

- The Main Telecommunication Network (MTN);
- The Regional Meteorological Telecommunication Networks (RMTN);
- The National Meteorological Telecommunication Networks (NMTN).

The GTS is supported by telecommunication functions of the WMCs, Regional Telecommunications Hubs (RTHs), RSMCs, and NMCs.

The MTN links the WMCs at Melbourne, Moscow, and Washington with the RTHs at Beijing, Bracknell, Brasilia, Buenos Aires, Cairo, Dakar, Nairobi, New Delhi, Offenbach, Paris, Prague, Sofia, Tokyo, and Jeddah. It ensures the rapid and reliable exchange of observational data and processed information required by the Members.

The RMTNs consist of an integrated system of links which interconnects RTHs, NMCs, and RSMCs to WMCs. The RMTNs provide for the collection of observational data and the selective distribution of meteorological information to Members.

In summary, the GTS enables the NMCs to receive and distribute observational data and meteorological information to meet the requirements of Members.

Planned WWW activities for FY 1990 include:

- Improvement of the capacity of MTN links and inclusion of graphics (e.g. Washington-Bracknell, Washington-Brasilia, Washington-Buenos Aires);
- Implementation of upgraded regional networks;
- Continued implementation of data collection platforms to enhance the collection of meteorological data from upper air and surface observing sites;
- Continued implementation of satellite direct readout stations that are compatible with polar orbiting satellites and the WEFAX (weather facsimile) component of the geostationary satellites.

Voluntary Co-operation Program (VCP)

From the beginning of WWW, it was clear that all countries need better weather observations and improved communication systems. To help remedy deficiencies and to fully implement the

WWW, the WMO established a Voluntary Assistance Program (VAP) in 1967. The name of the program was changed to Voluntary Co-operation Program (VCP) in 1979.

The WMO-VCP Program helps the developing countries to implement the WWW program by providing equipment, services, and long and short-term study fellowships. Since the inception of the VCP, the U.S. has provided short-term fellowships in electronics, communications, operation and maintenance of weather data collection systems, electrolytic hydrogen generators, tropical meteorology, and river flood forecasting to students from more than 50 countries. Long-term fellowships, through which the students receive baccalaureate or advanced degrees, have been completed by candidates from over 38 countries. Highest priorities are given to those facilities needed to support the global aspects of WWW. The goal of VCP is to eliminate deficiencies in global observations and communications and to establish ground-readout stations for Automatic Picture Transmission (APT) reception so that the countries may benefit more fully from weather satellite services.

The U.S. has contributed annually from $1.5 million to $2.3 million to VCP since 1969. Other nations contribute a total of approximately $2.0 million annually and this continues to increase. Contributions are in three categories; equipment and services (80 percent), financial contributions (about 10 percent), education and training (about 10 percent).

The Department of State (DOS) provides funding for VCP projects with NOAA administering and carrying out programs designed to aid meteorological/hydrological and climate projects in recipient countries. In FY 1989, DOS funding for WWW/VCF programs was $2.00 million. In FY 1990, $2.00 million was approved and in FY 1991, $2.30 million has been requested.

The Climate Computing (CLICOM) project of the WMO's World Climate Program has become a major and very successful WMO project in which the U.S. has played a leading role. Each CLICOM unit consists of a small network of 1 to 6 personal computers, peripherals and resident data management software which together provides developing countries with the capability to digitize and better use their climatological data. The resulting climate information can be used for better management of each country's agricultural, hydrologic and other natural resources. It is also important in determining the potential impact of the changing global climate. The U.S. VCP has provided major funding for the original development of the data management software and also funded hardware and training for installation of CLICOM in countries in Africa, Central and South America. The system has been installed in 75 countries with funding coming from France, Finland, the United Kingdom, the United States and the United Nations Development Program. Fifteen instructors have been trained and nearly 150 systems are in use.

Planned VCP activities for FY 1990 include:

- Continued support for data collection and telecommunications capabilities in Africa;
- Implementation and updating of surface and upper-air observational programs in the tropics, the Southern Hemisphere, and Africa as resources and priorities permit;
- Continued support for the implementation of VCP projects in Latin America and the Caribbean areas in support of the hurricane and tropical storm programs;
- Installation and training on the CLICOM climate data management system for countries in Africa, Central and South America, and development of enhanced graphic output capabilities.

BILATERAL AND REGIONAL INTERNATIONAL COOPERATIVE PROGRAMS

Sahel Agrometeorological and Hydrological Program (AGRHYMET)

Subsequent to the severe drought which began in 1969 in the Sudano-Sahelian area of West Africa, which reached catastrophic proportions in 1972 and 1973, six countries (Chad, Mali, Mauritania, Niger, Senegal, and Burkina Faso) established a Permanent Inter-State Committee for Drought Control in the Sahel. Gambia and Cape Verde joined the Committee in 1974. The Ministers of these countries requested assistance of international organizations specializing in the study of problems relating to drought, including certain meteorological problems. The UN responded by directing its agencies to organize the necessary assistance. For this purpose, a mission (1974) involving the United Nations Development Program (UNDP), the Food and Agriculture Organization, and the WMO, defined in detail the needs of the eight countries and prepared a "Program for the Strengthening of the Agrometeorological and Hydrological Services of the Sahelian Countries and for the Establishment of a Center for Training and Applications of Agrometeorology/Operational Hydrology."

The objectives of the Program are to contribute to the social and economic development of the Sahel by:

- Monitoring continuously and adequately the meteorological and hydrological conditions by means of modern observing networks;
- Improving the understanding of these conditions and their variations in order to forecast them;
- Applying this monitoring and understanding to human activities, and more particularly to agriculture and livestock rearing, with a view to increasing and regulating the production of the resources.

The program was developed to span 15 years and was divided into three phases of approximately five years each. It is now in Phase III. During the first phase (1976-1981) a regional training and data processing center was established at Niamey, Niger. In the second phase a regional agrometeorological and hydrological observing and reporting network was completed and made operational throughout the Sahel. Data processing and analysis equipment has been implemented in all national services. Sahelians have been trained in equipment technology, data processing, agrometeorology, hydrology and administration. NOAA was responsible for much of the technology implementation in the first two phases. That work has been completed and NOAA's activities have concluded.

APPENDIX F

SELECTED ACRONYMS AND ABBREVIATIONS

AAODL	Atmospheric Aerosols and Optics Data Library
ADAS	AWOS/ASOS Data Acquisition System
AF	Air Force (USAF)
AFB	Air Force Base
AFCC	Air Force Communications Command
AFGWC	Air Force Global Weather Central
AFOS	Automation of Field Operations and Services
AFRES	Air Force Reserve
AFS	Air Force Station
AHOS	Automated Hydrologic Observing System
AI	Artificial Intelligence
AID	Agency for International Development
AIP	Airport Improvement Program
ALBE	AirLand Battlefield Environment
AMR	Aircraft Microwave Refractometer
APT	Automatic Picture Transmission
ARGOS	French Data Collection System
ARSR	Air Route Surveillance Radar (FAA)
ARTCC	Air Route Traffic Control Center
ASL	U.S. Army Atmospheric Sciences Laboratory
ASOS	Automated Surface Observing System (NOAA)
ASR	Airport Surveillance Radar (FAA)
ATC	Air Traffic Control
AVHRR	Advanced Very High Resolution Radiometer
AWDS	Automated Weather Distribution System
AWIPS	Advanced Weather Interactive Processing Systems
AWIS	Automated Weather Information Systems
AWOS	Automated Weather Observing System (FAA)
AWN	Automated Weather Network
AWS	Air Weather Service
CAC	Climate Analysis Center
CAS	Committee for Aviation Services (OFCM)
CAT	Clear Air Turbulence
CAWIS	Committee for Automated Weather Information Systems (OFCM)
CBS	Committee for Basic Services (OFCM)
CDA	Command and Data Acquisition
CDAS	Command and Data Acquisition Station
CDDF	Central Data Distribution Facility
COES	Committee for Operational Environmental Satellites (OFCM)
CONUS	Continental United States
CSEF	Committee for Space Environment Forecasting (OFCM)
CWP	Central Weather Processor (FAA)
CWSU	Center Weather Service Unit (FAA)
DACS	Data Acquisition and Control Subsystem
DCPLS	Data Collection and Platform Location System
DCS	Data Collection System (NOAA/NESDIS)
DMSP	Defense Meteorological Satellite Program
DLC	Data Link Processor

DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOS	Department of State
DOT	Department of Transportation
DPSS	Data Processing and Services Subsystem
DUAT	Direct User Access Terminal
EO	Electro-Optical
EOSAEL	Electro-Optical Systems Atmospheric Effects Library
EPA	Environmental Protection Agency
ERBE	Earth Radiation Budget Experiment
ERBSS	Earth Radiation Budget Satellite System
ERL	Environmental Research Laboratories
FAA	Federal Aviation Administration
FCMSSR	Federal Committee for Meteorological Services and Supporting Research
FEMA	Federal Emergency Management Agency
FNOC	Fleet Numerical Oceanography Center
FSAS	Flight Service Automation System
FSS	Flight Service Station
FY	Fiscal Year
GAO	General Accounting Office
GARP	Global Atmospheric Research Program
GDPS	Global Data Processing System
GL	Geophysics Laboratory (AFSC)
GOES	Geostationary Operational Environmental Satellite
GOS	Global Observing System
GSFC	Goddard Space Flight Center
GTS	Global Telecommunications System
HRIS/2	Modified High Resolution Infrared Sounder
HRPT	High Resolution Picture Transmission
ICMSSR	Interdepartmental Committee for Meteorological Services and Supporting Research
ICSU	International Council of Scientific Unions
IMETS	Integrated Meteorological System
IR	Infrared
ITOS	Improved TIROS Operational Satellite
IWRS	Improved Weather Reconnaissance Systems
JAWOP	Joint Automated Weather Observation Program (OFCM)
JSPO	Joint System Program Office (NEXRAD)
LLWAS	Low Level Wind Shear Alert System
M	Million
MAC	Military Airlift Command
McIDAS	Man-computer Interactive Data Access System
MMS	Meteorological Measuring System
MOPP	Mission Oriented Protective Posture
MOS	Model Output Statistics

MSU	Microwave Sounding Unit
MWP	Meteorological Weather Processor (FAA)
NADIN	National Airspace Data Interchange Network (FAA)
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NBC	Nuclear, Biological, and Chemical
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center
NCP	National Climate Program
NCPO	National Climate Program Office
NDBC	NOAA Data Buoy Center
NEDN	Naval Environmental Data Network
NEDS	Naval Environmental Display Station
NESDIS	National Environmental Satellite, Data, and Information Service
NEXRAD	Next Generation Weather Radar (WSR-88D)
NGDC	National Geophysical Data Center
NHC	National Hurricane Center
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center (NOAA)
NOMSS	Naval Oceanographic and Meteorological Support System (NAVY)
NOTAM	Notice to Airmen
NRC	Nuclear Regulatory Commission
NSF	National Science Foundation
NSSFC	National Severe Storms Forecast Center
NSSL	National Severe Storms Laboratory
NTSB	National Transportation Safety Board
NWR	NOAA Weather Radio
NWS	National Weather Service
OFCM	Office of the Federal Coordinator for Meteorology
OMB	Office of Management and Budget
PATWAS	Pilot Automatic Telephone Weather Service
PROFS	Prototype Regional Observing and Forecasting Service
RAMOS	Remote Automatic Meteorological Observing System
R&D	Research and Development
RD/T&E	Research and Development, Test and Evaluation
RFC	River Forecast Center
ROMS	Remote Ocean Surface Measuring System
RWP	Real-time Weather Processor (FAA)
SATCOM	Satellite Communications System (NOAA)
SBUV	Solar Backscatter Ultraviolet Instrument
SDHS	Satellite Data Handling System (DOD)
SEL	Space Environment Laboratory (NOAA)
SEM	Space Environment Monitor
SFSS	Satellite Field Services Station (NOAA)
SIO	Scripps Institution of Oceanography
SMCC	Systems Monitoring and Coordination Center
SOCC	Satellite Operations Control Center (NOAA)
SSU	Stratospheric Sounding Unit
STIWG	Satellite Telemetry Interagency Working Group (OFCM)

TDWR	Terminal Doppler Weather Radar
TDA	Tactical Decision Aid
TESS	Tactical Environmental Support System
TIROS	Television Infrared Observation Satellite
TOGA	Tropical Ocean and Global Atmosphere
TOVS	TIROS N Operational Vertical Sounder
TRADOC	U.S. Army Training and Doctrine Command
TWEB	Transcribed Weather Broadcast
UAV	Unmanned Aerial Vehicles (Army)
UN	United Nations
USAF	U.S. Air Force
USAFETAC	USAF Environmental Technical Applications Center
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USN	U.S. Navy
UTC	Universal Coordinated Time (US usage)
VAS	VISSR Atmospheric Sounder
VHF	Very High Frequency
VHRR	Very High Resolution Radiometer
VISSR	Visible and Infrared Spin Scan Radiometer
VRS	Voice Response System
VTPR	Vertical Temperature Profile Radiometer
WEFAX	Weather Facsimile
WMC	World Meteorological Center(s)
WMO	World Meteorological Organization
WMSC	Weather Message Switching Center
WMSCR	Weather Message Switching Center Replacement
WRP	Weather Research Program (ERL)
WSCMO	Weather Service Contract Meteorological Office
WSFO	Weather Service Forecast Office
WSMO	Weather Service Meteorological Office
WSO	Weather Service Office
WSR-88D	Next Generation Weather Radar (NEXRAD)
WWP	World Weather Program
WWW	World Weather Watch

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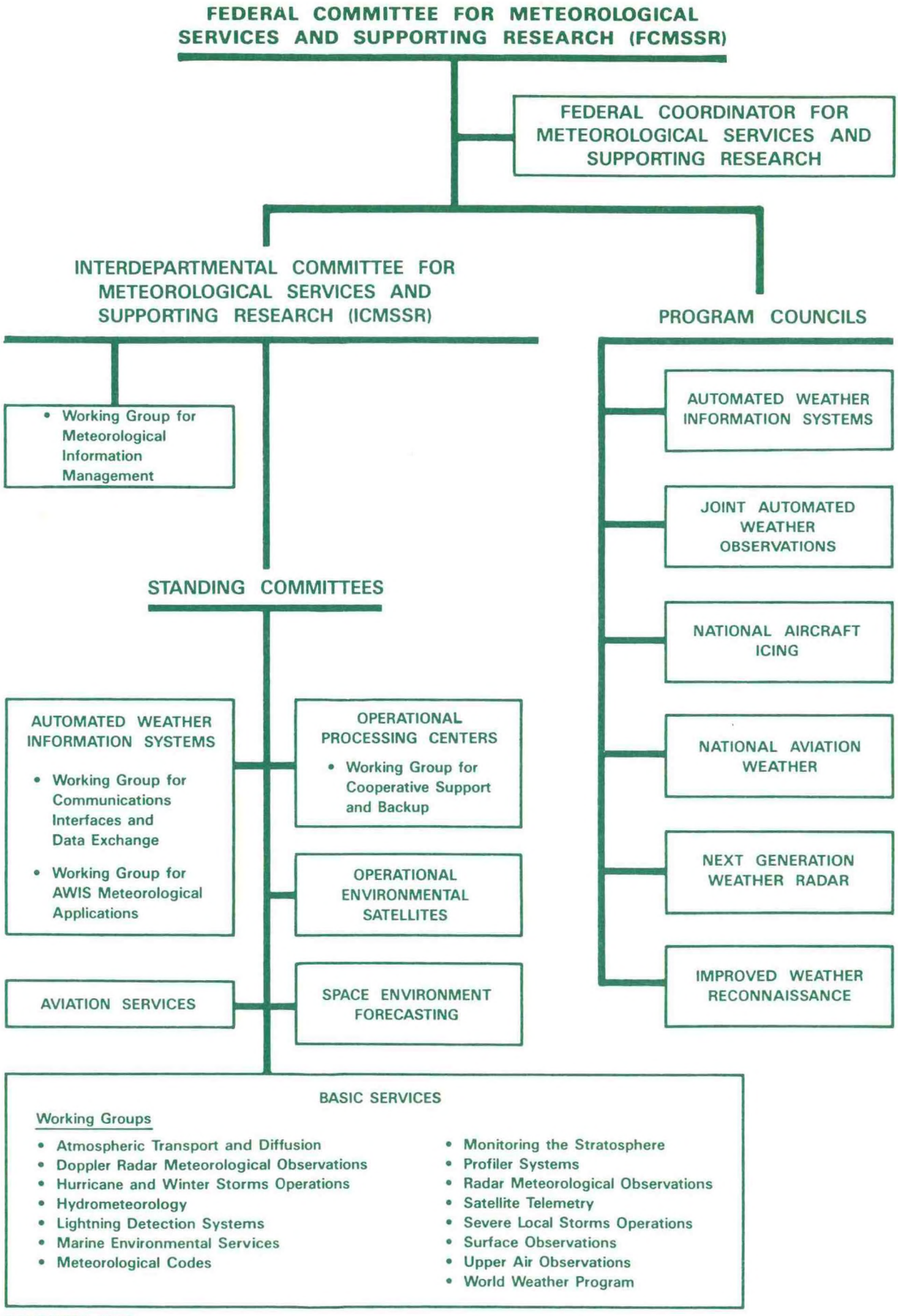

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