The Federal Plan for Meteorological Services and Supporting Research

FISCAL YEAR 1997

OFCM
OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGY

FCM P1-1996

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

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FEDERAL COORDINATOR
FOR
METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

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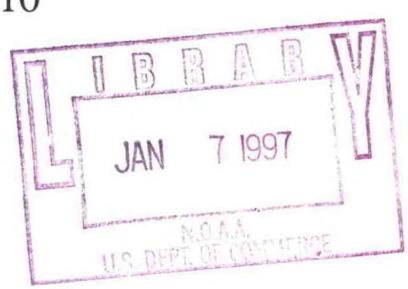

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PREFACE

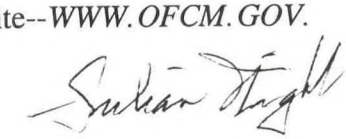
Since 1965, the Office of the Federal Coordinator has developed a federal plan which articulates the meteorological services provided and supporting research conducted by agencies of the federal government. As in the past, it provides Congress and the Executive Branch a comprehensive plan for meteorological services and supporting research within the federal meteorological community. "Supporting" research is defined as those research and development (R&D) programs that directly support and improve meteorological services. The plan reviews agency programs for FY 1996 and documents proposed programs for FY 1997.

Section 1 provides an overview and general summary of the entire document. Section 2 highlights interagency cooperation that is essential to meet the federal government's requirements for meteorological services. Section 3 contains a discussion of resources requested in the President's budget for FY 1997 as compared to those resources that Congress appropriated for FY 1996. This budget information along with other significant aspects are summarized in graphical format throughout this section and are current as of the end of June 1996. The emphasis is on changes in resources and the related changes in programs. Section 4 is a review article entitled *Space Weather--A Challenge for Meteorologists*. Appendices A through D describe individual agency weather activities and programs; Appendix E describes the World Weather Program; and Appendix F contains a list of acronyms.

The policy and program guidance for coordinating weather activities and programs is provided by the interagency committees shown on the inside front cover. These committees and the supporting organizational structure shown on the inside of the back cover conduct systematic and continuous reviews of federal programs and requirements for meteorological services and supporting research according to guidelines initially set forth in the Office of Management and Budget Circular A-62.

This edition of the Federal Plan contains some modifications to format and presentation of information. For example, the focus of Section 2 is now on OFCM's coordination and planning activities for the past year rather than descriptive, historical program information.

Lastly, the FY 1997 Federal Plan will be the first edition available on the Internet. In the near future, other OFCM publications will be converted to HTML format and available for viewing and distribution via our Web site--*WWW.OFCM.GOV*.



Julian M. Wright, Jr.
Federal Coordinator for Meteorological
Services and Supporting Research

THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH, FISCAL YEAR 1997

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SECTION 1

EXECUTIVE SUMMARY

The President's FY 1997 Budget requests $2.50 billion for meteorological services and supporting research. This request represents an increase of 0.4 percent from the $2.42 billion appropriated for FY 1996. Of the total, $2.132 billion will be for operations and $370 million for supporting research. The FY 1997 budget proposal, by agency, is shown in Table 1.1.

The Departments of Commerce (DOC), Defense (DOD), and Transportation (DOT) are projected to receive approximately 92 percent of the funds. In FY 1997, funding levels required to support major systems acquisitions of automated surface observing systems and Doppler weather radars are decreasing in the three Departments. DOT's budget request decreases almost 18 percent. Overall, DOC realizes nearly a 14 percent increase principally for operating its satellite programs and support to Advanced Weather Interactive Processing Systems (AWIPS) system development. Funding levels for the DOD continue to decline as "downsizing" activities linger. The Air Force's budget request decreases by 5.3 percent while the Army's decreases by 20.6 percent. The Navy receives a small 4.2 percent increase.

The National Aeronautics and Space Administration (NASA) realizes a small increase of 1.9 percent in supporting research but incurs a decrease of nearly 20 percent in operations. Also, the operations budget for the Bureau of Land Management within the Department of Interior is reduced by 31.6 percent.

Notwithstanding these reductions in several of the agencies and the overall reduction-oriented budget environment, the federal meteorological community has requested an increase of 8.4 percent from the FY 1996 funding levels appropriated for meteorological services and supporting research.

Table 1.1. Federal Budget for Meteorological Operations and Supporting Research, FY 1997 (in thousands of dollars)

Agency	Operations	% of TOTAL	Supporting Research	% of TOTAL	TOTAL	% of TOTAL
Agriculture	$12,105	0.6	$15,467	4.2	$27,572	1.1
Commerce	1,230,276	57.7	84,498	22.8	1,314,774	52.6
Defense	425,141	19.9	93,729	25.3	518,870	20.7
Interior	800	0.0	0	0.0	800	0.0
Transportation	459,777	21.6	5,873	1.6	465,650	18.6
EPA	0	0.0	6,700	1.8	6,700	0.3
NASA	3,453	0.2	163,800	44.3	167,253	6.7
NRC	289	0.0	0	0.0	289	0.0
TOTAL	2,131,841	100.0	370,067	100.0	2,501,908	100.0

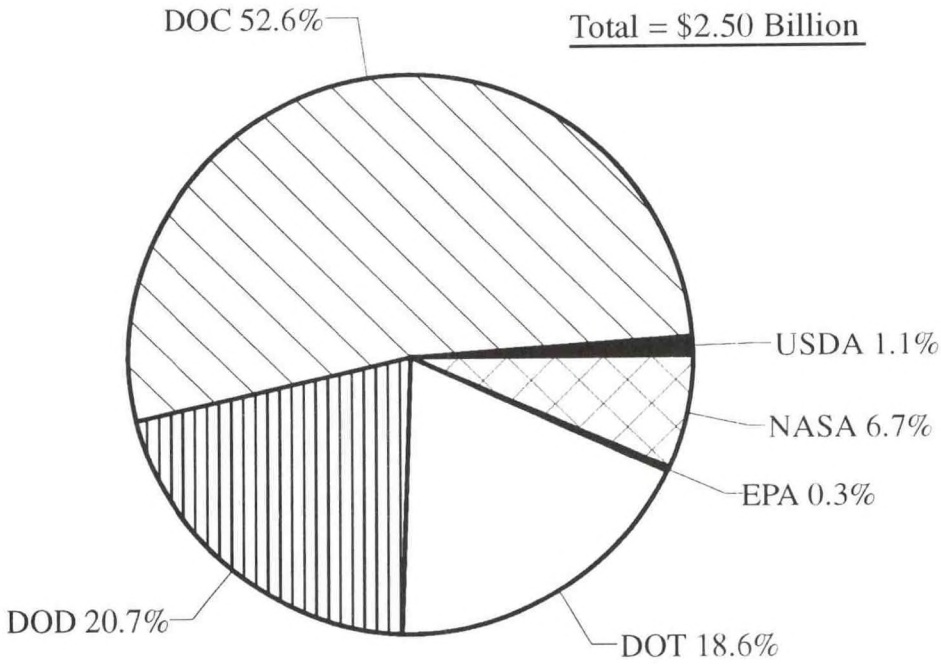


Figure 1.1 Agency Percent of Total Federal Budget for Meteorological Operations and Supporting Research, FY 1997

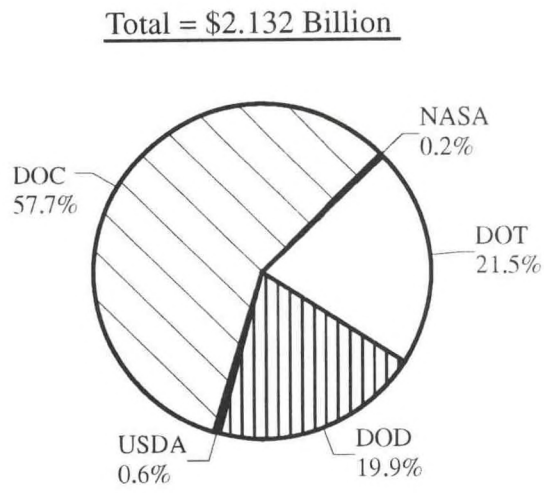


Figure 1.2 Agency Percent of Federal Budget for Meteorological Operations, FY 1997

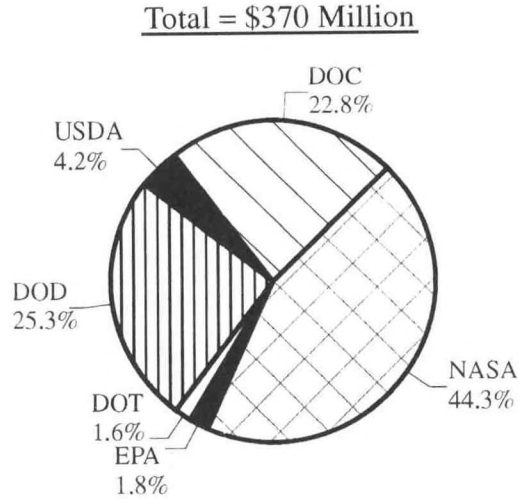


Figure 1.3 Agency Percent of Federal Budget for Supporting Research, FY 1997

Figure 1.1 depicts each agency's proportion of the proposed FY 1997 federal budget for meteorological operations and supporting research. As in previous years, the DOC budget accounts for 52.6 percent of the total, DOD--20.7 percent, DOT--18.6 percent, and the remaining federal agencies 8.1 percent. Each agency's portion of the proposed funding for meteorological operations is shown in Figure 1.2. Nearly 99 percent of the federal budget for operations is allocated for spending within DOC, DOD, and DOT. Figure 1.3 depicts each agency's portion of the proposed federal supporting research budget. Unlike operations, the majority of the supporting research budget is directed to NASA, DOD, and DOC.

The agencies project a total of 16,214 full-time equivalent (FTE) personnel to be employed in federal meteorological operations in FY 1997. This figure represents a decrease of 2.7 percent from the 16,662 FTE personnel employed in FY 1996.

Major Programs of DOC, DOD, and DOT

The required funding for major weather system acquisition programs for DOC, DOD, and DOT is lower than the previous year's level. However, the President's Budget still provides sufficient funding support to continue modernization efforts in FY 1997.

Next Generation Weather Radar (NEXRAD). The NEXRAD Program which began in FY 1981 was responsible for procurement, installation, and operation of the Weather Surveillance Radar-1988 Doppler (WSR-88D). The first limited production WSR-88D system was installed at Oklahoma City, Oklahoma in May 1990. Four years later, in February 1994, the Oklahoma City NEXRAD became the first WSR-88D to be officially commissioned. In July 1996, the WSR-88D program achieved a major milestone when the last unit from the original order was installed atop the Santa Ana Mountains to cover the areas surrounding San Francisco and Monterey Bay in California.

As of August 1996, 106 WSR-88D units have been commissioned as an official site on the national network of weather radars. The WSR-88D was developed to meet the requirements of DOC, DOD, and DOT for improved capability to detect and maintain surveillance of hazardous weather.

Automated Surface Observing System (ASOS). The ASOS program, began in 1983, as a joint development effort between the DOC, DOD, and DOT/FAA. Installation of ASOS units started in 1991. As of August 1996, a total of 868 units have been purchased. The NWS has purchased, installed, and accepted 245 units. The FAA has purchased 537 units, installed 421 units, and accepted 413 units. The Navy has purchased 86 units, installed 59 units, and accepted 48 units. Collectively, the NWS and FAA have commissioned 297 units--NWS 205 and FAA 92.

In July 1996, the ASOS Program Office successfully implemented software modifications to change the observation code format from Surface Aviation Observation (SAO) or Airways to METAR.

Automated Weather Information Systems (AWIS). The DOC, DOD, and DOT require AWISs to facilitate the collection, processing, and interpretation of meteorological data. AWISs are being procured to provide an automated, high-speed, user-friendly man/machine interface to access and process large volumes of sophisticated meteorological data. AWIS supports the timely production of accurate and geographically precise warnings, forecasts, and special tailored products. They also provide the communications capability for expeditious product dissemination.

Major agency systems classified as AWISs are: NOAA's Advanced Weather Interactive Processing System (AWIPS), the FAA's Weather and Radar Processor (WARP), the Air Force's Automated Weather Distribution System (AWDS), and the Navy's Naval Oceanographic Data Distribution and Expansion System (NODDES) and Navy Integrated Tactical Environmental Subsystem (NITES).

Other Agency Programs

For FY 1997, the Department of Agriculture's (USDA) budget request for meteorological operations and supporting research is $27.57 million. Operationally, the USDA supports specialized weather observation networks and also conducts an active supporting research program to ensure an abundance of high-quality agricultural commodities while minimizing the adverse effects of agriculture on the environment.

The Department of Interior (DOI) is requesting $800,000 primarily to support the Bureau of Land Management's remote automatic weather station (RAWS) program.

The budget request for the Environmental Protection Agency (EPA) decreases to $6.7 million to provide user-appropriate and scientifically credible air-

quality meteorological programs to support regulatory applications.

NASA's total funding request of $167.3 million is primarily for supporting research focused within the Mission to Planet Earth (MTPE) program. These funding levels are composed of the estimated meteorology share of the supporting research and analysis programs, to include the Earth Observing System (EOS) and Earth Probe instruments, EOS science, and the EOS Data and Information Systems (EOSDIS).

The Nuclear Regulatory Commission's (NRC) request of $289,000 is mainly for operations. The NRC will dedicate these funds to obtain and analyze meteorological data and information related to the safe operation of nuclear facilities, and the protection of the environment, public health, and safety.

Federal Coordination Activities

The National Space Weather Program (NSWP) published (August 1995) ***The National Space Weather Program: Strategic Plan***. The Working Group for Space Environmental Forecasting is finalizing a draft of a NSWP Implementation Plan which will cover research, modeling, and observation requirements, and provide guidance on priorities, agency roles and responsibilities, and program management. The projected publication date for the Implementation Plan is late 1996.

In November 1995, the Ad Hoc Group for FMH-1 (AHG/FMH-1) finalized the fifth edition of Federal Meteorological Handbook No. 1, ***Surface Weather Observations and Reports***. The latest edition, published in December 1995, reflects the United States implementation of the World Meteorological Organization's (WMO) Aviation Routine Weather Report (METAR) and Aviation Selected Special Weather Report (SPECI) code formats for surface weather observations.

In late 1995, the Working Group for Meteorological Codes (WG/MC) finalized the list of United States exceptions to three WMO codes--METAR, SPECI, and Aerodrome Forecast (TAF). These new code formats were implemented in the United States on July 1, 1996, at 0800 Greenwich Mean Time/Coordinated Universal Time (UTC).

The Ad Hoc Group for Mobile Meteorological Equipment (AHG/MME) published (December 1995) a revised ***Federal Directory of Mobile Meteorological Equipment and Capabilities*** which catalogues both current mobile systems or capabilities and those programmed to be available in the near future.

In March 1996, the Office of the Federal Coordinator for Meteorology hosted the 50th Interdepartmental Hurricane Conference (IHC) in Miami, Florida. A combination of a near-record hurricane season, celebration of the 50th conference, and concern about certain weather reconnaissance issues made for a full agenda and unusually large attendance (134 representatives from DOC, DOD, and DOT). Special events to celebrate the 50th conference included historical presentations on hurricane forecasting and aircraft reconnaissance, a look into the future of hurricane forecasting, and former Federal Coordinator Bill Barney's review of weather and its impact over the years.

The Working Group for Cooperative Support and Backup completed and published (May 1996) section one of the totally revised ***Federal Plan for Cooperative Support and Backup Among Operational Processing Centers***. The revised plan details the mission and operations descriptions plus the general cooperative support and backup requirements of the operational processing centers.

The Working Group for Marine Environmental Services (WG/MES) published (June 1996) the ***Federal Plan for Marine Environmental Data, Services, and Supporting Research*** which defines a responsive national policy for marine environmental services. The plan will serve as a mechanism for interagency cooperation in marine data collection efforts.

SECTION 2

FEDERAL COORDINATION AND PLANNING

BASIS FOR FEDERAL COORDINATION PROCESS

In 1963, Congress and the Executive Office of the President expressed concern about the adequacy of coordination of federal meteorological activities. In response, Congress directed in Section 304 of Public Law 87-843--the Appropriations Act for State, Justice, Commerce, and Related Agencies--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 the Office of Management and Budget) issued a report entitled "Survey of Federal Meteorological Activities" (1963). The report described each agency's program in some detail, particularly its operational services, and detailed the relationship between the programs of the various agencies. The report revealed close cooperation but little evidence of systematic coordination. Based on this study, the Bureau of the Budget issued a set of ground rules to be followed in the coordination process. It established a permanent 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 Bureau of the Budget tasked the Department of Commerce (DOC) to establish the coordinating mechanism in concert with the other federal agencies. It also reaffirmed the concept of having a central agency--the DOC-- 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 these directives by DOC led to the creation of the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) which 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 accomplished by the OFCM staff with the advice and assistance of the Interdepartmental Committee for Meteorological Services and Supporting Research, and over 40 program councils, committees, and working groups.

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 the 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 has meshed its objectives with the objectives of the agencies that provide the services and perform the research. They include:

- Documenting agency programs and activities in a series of national plans and reports that enable agencies to revise/adjust their individual ongoing programs and provide a means for communicating new ideas and approaches to fulfill requirements.
- Providing structure and program to promote continuity in the development and coordination of interagency plans and procedures for meteorological services and supporting research activities.
- Preparing 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.
- Reviewing federal weather programs and federal requirements for meteorological services and supporting research. 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.

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, DOC increased the permanent professional staff from one to seven and assigned an additional professional staff member as the DOC representative. DOC also provides administrative support to the OFCM and provides approximately one-half of the OFCM's annual operating budget. The Department of Defense (DOD) currently provides two senior staff officers-- one Air Force and one Navy--and contributes approximately one-fourth of the annual budget. The Department of Transportation (DOT) Federal Aviation Administration (FAA) provides one professional staff member and also provides approximately one-fourth of the annual operating budget. These four agency representatives are designated Assistant Federal Coordinators for liaison to their respective agencies. The OFCM staff consists of 17 meteorologists, oceanographers, physical scientists, and administrative and computer-support personnel.

COORDINATION OF MULTIAGENCY PROGRAMS

The Federal Committee for Meteorological Services and Supporting Research (FCMSSR), established in 1964, provides high-level agency representation and policy guidance to the Federal Coordinator in resolving agency differences that arise during the coordination of meteorological activities and the preparation of federal plans. The Under Secretary of Commerce for Oceans and Atmosphere, who is also the Administrator of the National Oceanic and Atmospheric Administration (NOAA), serves as the FCMSSR Chair.

The 13 federal agencies that engage in meteorological activities or have a need for meteorological services are represented on FCMSSR. The FCMSSR membership includes: DOC, DOD, DOT, the Departments of Agriculture (USDA), Energy (DOE), Interior (DOI), and State (DOS), and the Environmental Protection Agency (EPA), Federal Emergency Management Agency (FEMA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), National Transportation Safety Board (NTSB), and the U.S. Nuclear Regulatory Commission (NRC). In addition, the Office of Management and Budget (OMB) is represented.

OMB and FCMSSR provide guidance at the policy level to the Federal Coordinator. At the program management level, guidance from the agencies is provided 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.

Also within the OFCM structure, there are seven program councils (PC) to coordinate specific interagency cooperative programs. There seven PCs are:

- Next Generation Weather Radar.
- Joint Automated Weather Observations.
- Automated Weather Information Systems.
- Aircraft Icing.
- Aviation Weather.
- National Space Weather.
- Improved Weather Reconnaissance.

Each of the PCs is comprised of decision-level representatives from the agencies directly concerned with the specific program area. The Federal Coordinator serves as the chairperson of each PC.

Next Generation Weather Radar (NEXRAD)

A major milestone in United States weather modernization programs was achieved during July 1996 with delivery of Weather Surveillance Radar-1988 Doppler (WSR-88D) number 161, the last system in the basic Next Generation Weather Radar (NEXRAD) procurement schedule. Five of the 161 WSR-88D systems have been allocated to support training, maintenance, and testing activities; 116 are deployed at National Weather Service (NWS) sites within the contiguous 48 states, 29 are deployed to DOD operational sites in the U.S. and overseas, and 11 were installed by the FAA in Alaska and Hawaii. As of August 1996, 106 WSR-88D units have been commissioned as the official site on the national network of weather radars--a little over two years since commissioning began during 1994.

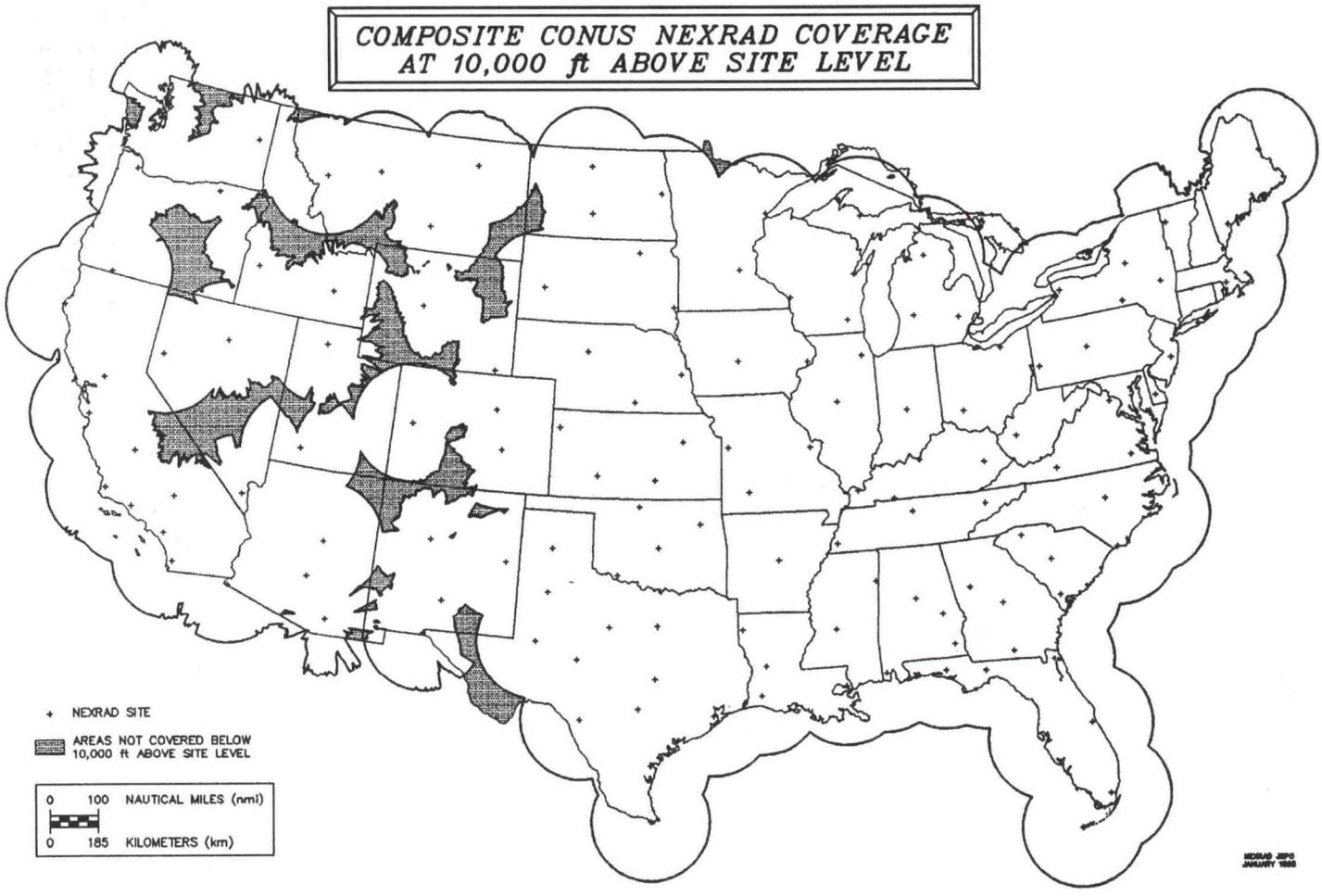


Figure 2-1 WSR-88D Continental United States Coverage

The WSR-88D is a computerized Doppler weather radar developed to meet the needs of DOC, DOD, and DOT for improved ability to detect and maintain surveillance of hazardous weather. This need was defined in an OFCM-sponsored study in the late 1970's. It led, in 1979, to the establishment of a Joint System Program Office to develop and procure the new Doppler radar under policy guidance and oversight of the triagency NEXRAD Program Council.

The WSR-88D system's advanced technology provides automated Doppler signal processing, computerized processing of data by sophisticated meteorological software algorithms, state-of-the-art ergonomically designed operator workstations, and a high-capacity, processor-driven communications capability. The system is modular in design, upgradeable, and has a long life-cycle expectancy. NEXRAD's advanced weather radar products meet the needs of the three Departments for accurate information on the location, severity, and movement of hazardous weather.

The NWS uses the WSR-88D for more than forecasts and warnings of severe weather. The WSR-88D also provides rainfall analysis capability for improved river stage and flood forecasts and for data to support effective management of water resources. This advance in water resources management reaches beyond flood control to impact areas, such as river navigation, drinking water supplies, pollution management, and water-based recreation--all with beneficial economic consequences. The DOD will use WSR-88D data to support military operations and protect defense assets in the United States, the Azores, and at key Pacific locations. The FAA uses the data to improve flight safety and to manage traffic more efficiently within the National Airspace System. The National Climatic Data Center provides historical archiving of the WSR-88D data.

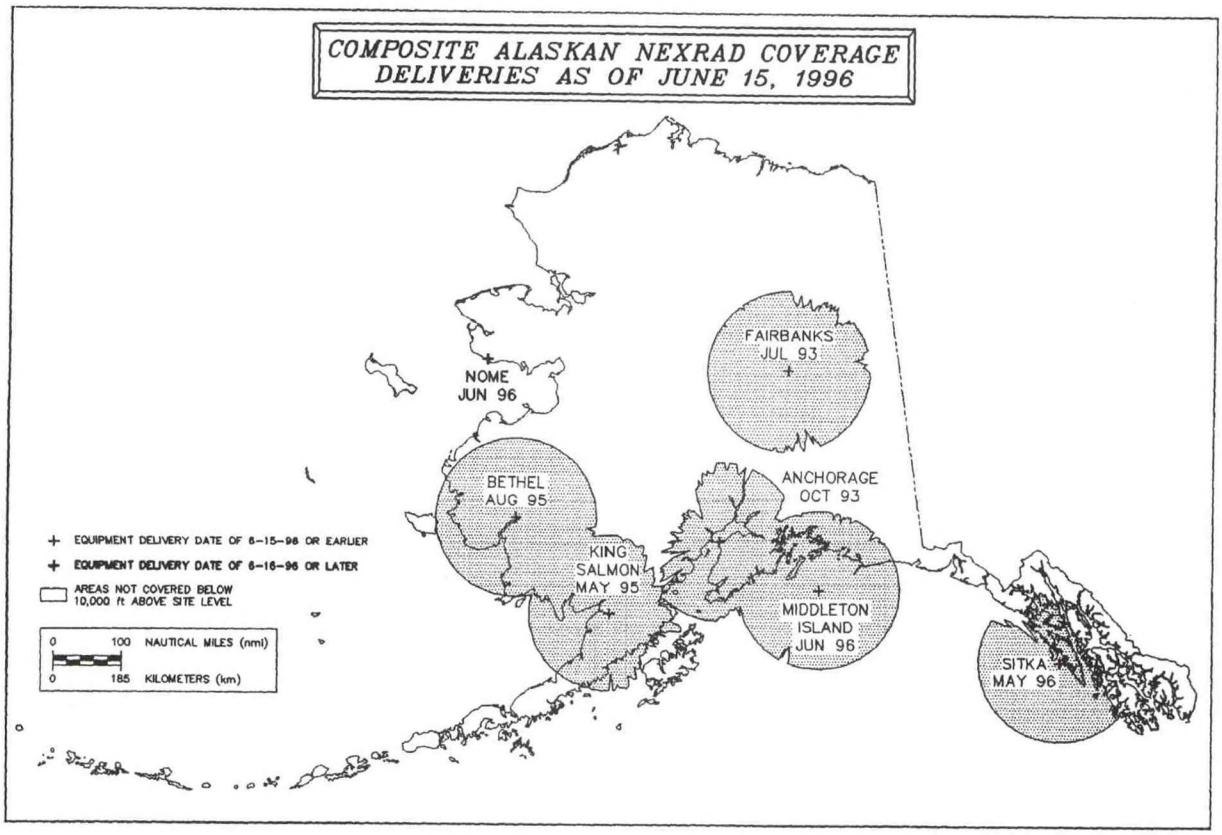


Figure 2-2 WSR-88D Alaskan Coverage

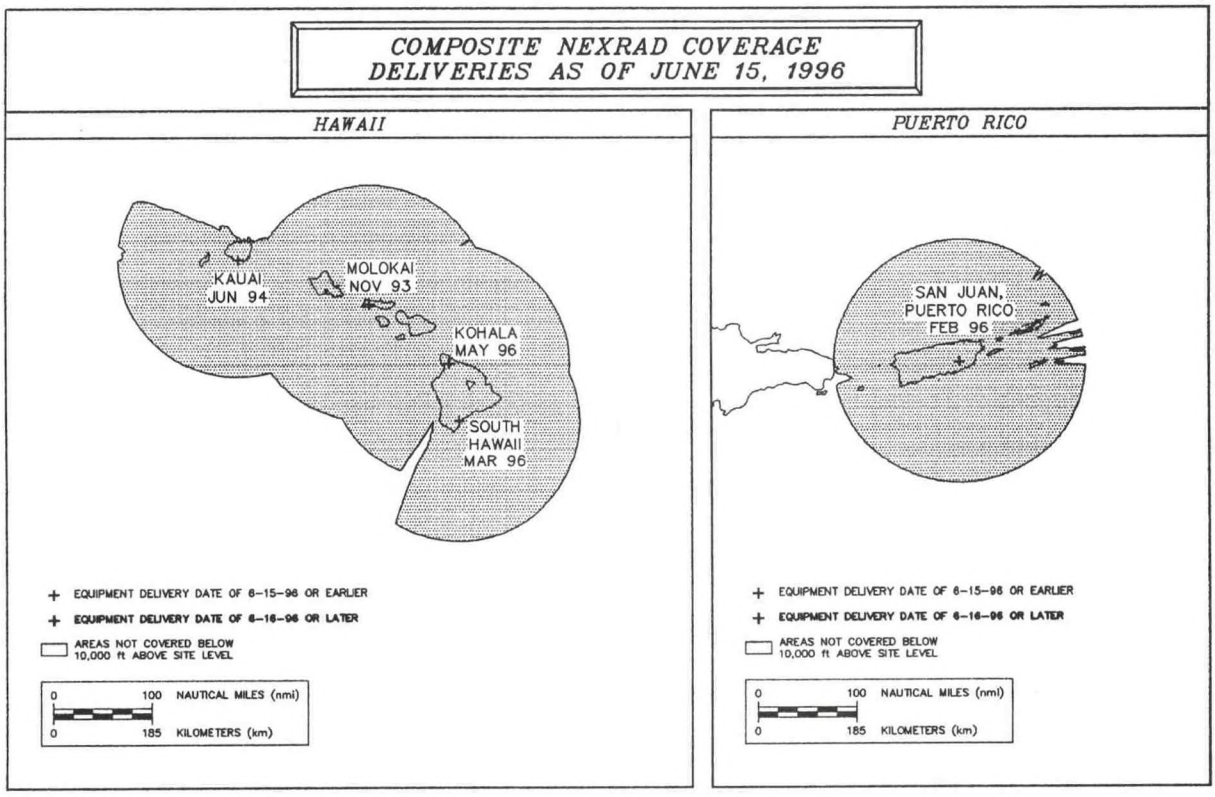


Figure 2-3 WSR-88D Hawaiian and Puerto Rican Coverage

Planned activities for FY 1996 and 1997 include procurement and implementation of 3 additional WSR-88D systems in response to recommendations made the the National Research Council Report on the NWS Modernization and Restructuring. In addition, major initiatives in hardware and software capabilities refinement are underway for WSR-88D product improvement. These pre-planned product improvements include the evolution to an open-architecture environment to ensure compatibility with the automated weather information systems of NWS, DOD, and the FAA.

Automated Surface Weather Observations

As of August 1996, a total of 868 units have been purchased as part of the base program. The NWS has purchased, installed, and accepted 245 units. The FAA has purchased 537 units, installed 421 units, and accepted 413 units. The Navy has purchased 86 units, installed 59 units, and accepted 48 units. Collectively, the NWS and FAA have commissioned 297 units--NWS 205 and FAA 92. In FY 1995-1996, the average ASOS commissionings for the NWS and FAA were 10 and 7 units per month, respectively. The rate of commissionings for the FAA is expected to increase in the coming year.

In July 1996, the ASOS Program Office successfully implemented software modifications to change the observation code format from Airways (SAO) to METAR. This change was part of the overall United States effort to join the world aviation and meteorological communities in the use of a common code for surface aviation weather observations. The conversion required close coordination between the users of ASOS (NWS, FAA, AF, and Navy) and represented a major program accomplishment.

Historically, each agency has independently developed an operational weather system capability in pursuit of its mission. In 1983, the Joint Automated Weather Observations Program (JAWOP) was established with membership from DOC, DOD, and DOT/FAA. Concurrently, the JAWOP Council was established to provide policy guidance and oversight for automated surface observation program development efforts.

In 1986, the JAWOP Council agreed to use the NWS Automated Surface Observing System (ASOS) at the FAA's towered airport locations. The Administrators of NOAA and FAA agreed that NOAA would procure, install, operate, and maintain the ASOS to meet FAA requirements for both the towered and most of the non-towered (smaller) airports. This action would make ASOS the primary federal surface observing system. Immediate needs of the FAA for limited weather observations at small non-towered airports was satisfied by 200 off-the-shelf automated weather observing systems (AWOS) as an interim capability system until the fielding of ASOS.

In February 1991, based on the recommendations of an independent interagency Test Review Board (TRB), the ASOS production and implementation contract was awarded to AAI Corporation for as many as 1700 units over the next 5 years. The early systems were fielded in the central United States during the summer of 1991. In March 1992, the TRB concluded that the risks of proceeding with full system acceptance and commissioning during the summer of 1992 were small and manageable. Commissioning of NWS-sponsored ASOS units began in September 1992; FAA commissionings began in November 1993.

The Navy is replacing obsolete equipment with ASOS at Navy and Marine Corps Air Stations. The Navy does not plan to use ASOS as a fully automated station except at remote sites, such as bombing ranges, where surface observations are not presently taken due to manpower limitations. The Navy requires 86 ASOS units--85 operational and one for research and development (R&D)--at 70 continental U.S. sites and 15 overseas sites. In 1992, the R&D unit was installed at the Naval Electronics Engineering Center, Charleston, SC.

The Air Force is acquiring and installing ASOS units at towered and non-towered facilities to meet requirements not currently satified by existing Air Force equipment and manpower. The Air Force does not plan to use ASOS as a fully automated station except at remote sites, such as training ranges, where surface observations are not presently taken due to equipment or manpower limitations. The Air Force purchased 23 ASOS units in FY 1994 and 1995, and will continue to fill ASOS requirements as funding becomes available in FY 1997 and beyond.

The U.S. Army Research Laboratory (ARL) 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. Each data collection package (DCP) measures: solar radiation, air temperature, humidity, wind direction and speed, barometric pressure, and soil temperature. 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 ASOS activities for FY 1996-1997 include continuing with ASOS full-scale production, fielding as many as 12 or more systems per month, and commissioning of NWS and FAA ASOS units. In addition, NWS, FAA, and DOD (under the auspices of the JAWOP) will continue with selected future sensor enhancement, development, and testing.

Automated Weather Information Systems

Automated Weather Information Systems (AWIS) are required by a number of federal agencies. AWISs are being procured to provide an automated, high-speed, user-friendly man/machine interface to access and process large volumes of sophisticated meteorological data. They support the timely production of accurate and geographically precise warnings, forecasts, and special tailored products. They also provide the communications capability for expeditious product dissemination.

Major agency systems classified as AWISs are: NOAA's Advanced Weather Interactive Processing System (AWIPS), FAA's Central Weather Processor (CWP), Air Force's Automated Weather Distribution System (AWDS), and Navy's Naval Oceanographic Data Distribution and Expansion System (NODDES) and Navy Integrated Tactical Environmental Subsystem (NITES). These systems include communications to collect and distribute raw data, information and processed products but exclude observation subsystems and the supercomputers at the major centers.

The AWIS Program Council which consists of high-level representatives from DOC, DOD, and DOT, was established in 1986 in response to a 1985 recommendation by the Inspectors General of these agencies. The goals of the council were to: (1) identify major items that needed coordination, (2) determine what commonalities existed among the systems, and (3) produce a federal plan for the coordination of AWIS programs. To pursue these goals, the Council uses the Committee for Automated Weather Information Systems (CAWIS) and its Working Groups for Communications Interfaces and Data Exchange (WG/CIDE), AWIS Meteorological Applications (WG/AMA), and NOAAPORT Liaison (WG/NPL).

National Aviation Weather Program

The National Aviation Weather Program Council (NAWPC) was formed in 1989 and a supporting Joint Action Group (JAG) in 1990 to address aviation weather issues. Membership includes the Departments of Agriculture, Commerce, Defense, and Transportation as well as the National Transportation Safety Board and NASA. The first major undertaking of the JAG resulted in the publication of the ***National Aviation Weather Program Plan (NAWPP)*** in 1992 which outlined unmet user needs.

After some intervening time and prompted by recommendations from the National Research Council, the JAG has been reconstituted by the NAWPC and tasked with the preparation of a National Aviation Weather Strategic Plan. In spite of the NAWPP, several user forums, and individual agency activities, no single, integrated policy/strategy for a national aviation weather information system exists. The JAG will be meeting regularly over the next several months with the goal of having a draft strategic plan by the end of 1996. The emphasis will be to build upon what has been done before and to foster a unified effort to improve the overall state of the Nation's aviation weather program.

National Space Weather Program Council

Recent activity in the National Space Weather Program (NSWP) has focused on completing an Implementation Plan which builds on the Strategic Plan published in late 1995. The NSWP Implementation Plan covers research, modeling, and observation requirements, and provides guidance on priorities, agency roles and responsibilities, and program management. The projected publication date for the Implementation Plan is late 1996. In April 1996, the National Science Foundation released a letter to the scientific community requesting proposals for research to support the National Space Weather Program. The announcement generated strong

interest in the community. The 23 successful proposals will share in $1.3 million in new research money acquired from multiple agencies and identified as National Space Weather Program funding.

Improved Weather Reconnaissance System (IWRS)

The Improved Weather Reconnaissance Program Council (IWRPC) was formed to manage the acquisition of the IWRS. Currently, the Air Force Reserve's 53rd Weather Reconnaissance Squadron (53 WRS) operates ten WC-130H aircraft equipped with the IWRS, which provides an automated, accurate, high-density, data-gathering capability in support of tropical cyclone and winter storm forecasting operations. The 53 WRS has a Congressionally mandated charter to provide hurricane reconnaissance in support of the NWS's National Hurricane Center/Tropical Prediction Center. With the successful completion of the IWRS program, the IWRPC continues to meet at least annually to evaluate the operational effectiveness of the IWRS and to evaluate/approve proposals for IWRS improvements and upgrades. The IWRPC met in March 1996, in conjunction with the 50th Interdepartmental Hurricane Conference, to review the status of ongoing projects and enhancements.

The Air Force and the IWRPC are actively pursuing the acquisition of the Global Positioning System (GPS)-based Atmospheric Vertical Profiling System (AVAPS) to replace the Lightweight Omega Digital Dropwindsonde System (LOD2), which will become obsolete with the demise of the Omega radionavigation system on September 30, 1997. AVAPS is being developed by the National Center for Atmospheric Research (NCAR) for NOAA's WP-3Ds and for the new Gulfstream IV-SP aircraft. The result will be the standardization of atmospheric sounding systems used by the Nation's weather reconnaissance aircraft. The 53 WRS briefed on the new C-130J--the likely successor to the WC-130H. The C-130J sports a "glass cockpit," is GPS equipped, and promises significantly enhanced performance. The 53 WRS hopes to have the first three operational aircraft by June 1998.

In August 1995, Quadrant Engineering, Inc. installed the next generation stepped frequency microwave radiometer (SFMR) on NOAA's WP-3D to provide remotely sensed surface wind speeds. Flight testing began almost immediately due to the very active hurricane season. While the system operated properly, the noise levels in the system measurements were higher than expected. Quadrant Engineering completed an analysis of the noise problem and modified the SFMR to correct the problem; final flight testing will be conducted during the 1996 hurricane season. Plans for FY 1997 will focus on completing a series of analysis tasks required to provide the data to the National Hurricane Center in real-time and on planning the transfer of technology to the operational environment of the WC-130. This project was approved and funded by the IWRPC.

PLANNING, COMMITTEE ACTIVITIES, AND PUBLICATIONS

Interdepartmental Hurricane Conference

In March 1996, the Office of the Federal Coordinator for Meteorology hosted the 50th Interdepartmental Hurricane Conference (IHC) in Miami, Florida. A combination of a near-record hurricane season, celebration of the 50th conference, and concern about certain weather reconnaissance issues made for a full agenda and unusually large attendance (134 representatives from DOC, DOD, and DOT). In addition to the normal activity of reviewing the 1995 hurricane season and incorporating plans for 1996 into the National Hurricane Operations Plan (NHOP), representatives participated in several activities unique to this particular conference. A groundswell of interest in hurricane research necessitated extending the research portion of the conference.

Special events to celebrate the 50th conference included historical presentations on hurricane forecasting and aircraft reconnaissance, a look into the future of hurricane forecasting, and former Federal Coordinator Bill Barney's review of weather and its impacts over the years. A special session was convened to review issues regarding the most effective use of limited aerial weather reconnaissance resources.

The 1996 NHOP was published in May. The 51st Interdepartmental Hurricane Conference is scheduled for March 4-7, 1997 in Miami, Florida.

Climate Services

In 1994, the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) formed the Working Group for Climate

Services (WG/CS) in an effort to provide a focal point for federal involvement in climate change, ozone depletion, seasonal to interannual forecasting, and climatological applications. The WG/CS has provided a unique forum, bringing together an extremely diverse group of agencies which conduct a very broad scope of activities related to climatology. The exchange of information at working group meetings has been invaluable, and the WG/CS is looking into methodologies for providing some unity to their various climate services efforts.

Federal Meteorological Handbooks

At the direction of the ICMSSR, the OFCM maintains a continuing program to revitalize the Federal Meteorological Handbooks (FMH). Responsibility for review and revisions, if necessary, of each handbook is assigned to the approriate committee and/or working group within the existing interdepartmental coordinating infrastructure. The FMH series includes observing and reporting practices for surface, upper air, radar, and meteorological rocket observations. The titles of nine existing handbooks are: ***Surface Weather Observations and Reports***, ***Surface Synoptic Codes***, ***Radiosonde Observations***, ***Radiosonde Code***, ***Winds-Aloft Observations***, ***Upper Wind Code***, ***Weather Radar Observations***, ***Meteorological Rocket Observations***, and ***Doppler Radar Meteorological Observations***.

To date, revisions have been completed for the ***Surface Weather Observations and Reports*** (FMH-1), ***Surface Synoptic Codes*** (FMH-2), ***Meteorological Rocket Observations*** (FMH-10), and ***Doppler Radar Meteorological Observations*** (FMH-11) handbooks. In November 1995, the Ad Hoc Group for FMH-1 finalized and recommended publication of the fifth edition of FMH-1. The latest edition reflects the U.S. implementation of METAR code for surface weather observations. Federal agencies are reviewing a preliminary draft of the ***Manual on Codes--U.S. Supplement*** (FMH-12). This new handbook will include, along with other codes to be determined, the Pilot Report (PIREP) code form that had been included in earlier versions of FMH-1; the projected publication date is the fall 1996. Federal agencies are also reviewing the latest draft of ***Upper Air Observations*** (FMH-3).

New versions of all handbooks are available to private-sector users through the Customer Services at the National Climatic Data Center, Asheville, North Carolina. Federal agencies may request copies from the OFCM.

Meteorological Codes

The use of meteorological codes is of fundamental importance for the collection, exchange, and distribution of meteorological information. Within the OFCM, the Working Group for Meteorological Codes (WG/MC) is the principal means for coordinating the employment of these codes by concerned federal agencies.

The major WG/MC effort during 1995-1996 was the coordination and formulation of exceptions to three WMO codes--Aviation Routine Weather Report (METAR), Aviation Selected Special Weather Report (SPECI), and Aerodrome Forecast (TAF). These new code formats were implemented in the U.S. on July 1, 1996, at 0800 UTC. The WG/MC is also considering updates to several code formats, such as Gridded Binary (GRIB) and Binary Universal Form (BUFR), that are being discussed and proposed within the WMO. The WG/MC is continuing coordination and review of the initial chapters of FMH-12.

Satellite Telemetry

The Satellite Telemetry Interagency Working Group (STIWG) is co-chartered by the Federal Coordinator for Meteorology and the Chief, Office of Water Data Coordination. The STIWG reports to the coordinators through the Committee for Basic Services and the Hydrology Subcommittee in their respective coordinating infrastructures. The STIWG agencies collect data from remote Data Collection Platforms (DCP) through the GOES Data Collection System (DCS). DCPs owned by the user agencies sense and collect a variety of data at remotely located positions. Among those types of data are rainfall, stream flow, water levels in lakes and reservoirs, seismic stress and vibration, wind direction and speed, atmospheric pressure, soil moisture, air/soil temperature, sea surface temperatures, and relative humidity.

A major concern of the STIWG and NESDIS has been the growing numbers of DCPs and the possibility of system saturation. Several international users are coming on-line with a growing number of DCPs. In response to this growing concern, NESDIS has taken steps to increase the efficiency of bandwidth use in the satellite and to increase the throughput at the ground processing system at the Command and Data

Acquisition Station. The STIWG member agencies have funded additional demodulators for the ground receiving system and a domestic communications satellite channel to disseminate the collected data to users. They have also funded studies to evaluate the advantages and impacts of higher baud-rate equipment. Based on these results, STIWG agencies have jointly funded the development of 300 and 1200 baud transmitters, demodulators, and test sets. Prototypes are expected in late 1996.

Post-Storm Data Acquisition

A Working Group for Post-Storm Data Acquisition (WG/PSDA) was established by ICMSSR to prepare an interagency plan for scientific and engineering data acquisition, especially highly perishable data, after coastal storms, tornadoes, tsunamis, and lake storms. Active participants are from the U.S. Army Corps of Engineers, NWS, FEMA, USGS, NOAA Coastal Oceans Program, National Institute for Standards and Technology, and the USDA's Soil Conservation Service.

In March 1995, a draft of the federal plan, which is designed to improve coordination among the federal agencies and reduce duplication of effort, was distributed for review.

Volcanic Ash Reporting and Warning

At the request of the federal agencies in 1993, the ICMSSR established the Ad Hoc Group for Volcanic Ash (AHG/VA) to develop a "National Plan for Volcanic Ash Reporting and Warning." The Plan will identify responsibilities of the federal agencies to report and collect data on volcanic disturbances and eruptions, and to develop forecasts and warnings of locations and movement of ash plumes or clouds. A draft plan is under review.

An International Workshop on Volcanic Ash Hazards to Aviation was held in Anchorage, Alaska in May 1996. Representatives included pilots, airport managers, dispatchers, volcanologists, as well as representatives from the airline industry and FAA's Air Traffic Control management. The participants exchanged concerns and capabilities, highlighted issues, and conducted a desktop exercise. The findings derived from this exercise will provide direction for new work to improve the volcanic ash alerting system.

Operational Processing Centers

The principals of the OFCM-sponsored Committee for Operational Processing Centers (COPC) and the Shared Processing Program Operations Steering Committee (SPOSC) meet twice a year to discuss data issues, modeling activities and algorithm development, and other cooperative efforts. During FY 1995, joint meetings of the COPC and SPOSC were held, and it was concluded that the two committees should meet consecutively rather than jointly, followed by a joint executive session. The November 1995 meeting, hosted by Air Force Global Weather Center (AFGWC), and the May 1996 meeting, hosted by the NESDIS Office of Satellite Data Processing and Distribution (OSDPD), were successfully conducted in this format. At the November meeting, NESDIS/OSDPD was added as the fifth principal of the COPC, joining AFGWC, Fleet Numerical Meteorology and Oceanography Center (FNMOC), the Naval Oceanographic Office (NAVOCEANO), and the National Centers for Environmental Prediction (NCEP). Concern over the declining number of observations and the variability in terms of data counts and data types in the databases of the OPCs led to the formation of an Ad Hoc Group for Observations (AHG/OBS). At the May COPC meeting, the Chairman, AHG/OBS, briefed on the group's plans to review master station libraries, data counts, and observation processing/quality control procedures, and to begin working towards common, quality observational databases among the OPCs. AFGWC briefed that the FNMOC-AFGWC Asynchronous Transfer Mode (ATM) communications link was operational in February 1996. Plans are underway to tie all the centers together using ATM, significantly upgrading the landline and satellite communications that currently link the OPCs. The October 1996 meeting will be hosted by NAVOCEANO at Stennis Space Center, Mississippi.

The Working Group for Cooperative Support and Backup, under the auspices of the COPC, completed and published section one of the totally revised ***Federal Plan for Cooperative Support and Backup Among Operational Processing Centers.*** The revised plan details the mission and operations descriptions plus the general cooperative support and backup requirements of the OPCs. In section two, each of the OPCs has a separate annex to document their detailed cooperative support and backup requirements with the other OPCs. Work in the coming year will focus on the preparation of these annexes.

National Program for Lightning Detection Systems

The Working Group for Lightning Detection Systems (WG/LDS) has compiled agency requirements

for lightning detection and developed a set of standards for lightning detection systems. These documents formed the foundation for a NWS procurement of operational lightning data from a commercial source. A Request for Proposals (RFP) was issued in February 1991. Proposals were received and evaluated. Contract award took place in August 1992. The data are used routinely in NWS field operations. Meanwhile, various other agencies have arranged to make use of lightning data to meet their requirements.

Federal agencies are collectively making plans for another procurement of lightning data, now that the original NWS contract is approaching its end (September 1996). A draft statement of work was reviewed by the agencies and provided to NWS for further action. The NWS issued the RFP for the next contract in April 1996; these responses are being evaluated.

Hydrometeorology

The Working Group for Hydrometeorology (WG/HM) has been addressing areas for mutual cooperation and coordination in hydrometeorology. One of its first tasks has been the development of a handbook for automated flood warning systems. The "Handbook on Automated Local Flood Warning Systems" describes local flood warning systems in terms of types, standards, requirements, implementation, and maintenance. The document is currently being prepared for publication by the NWS.

Marine Environmental Services

The Working Group for Marine Environmental Services (WG/MES) published the ***Federal Plan for Marine Environmental Data, Services, and Supporting Research*** with the objective to define a responsive national policy for marine environmental services. In support of this policy development, existing and planned programs are documented, and critical deficiencies in operational capabilities that can be addressed through research and development are defined. The plan will serve as a mechanism for interagency cooperation in marine data collection efforts.

Mobile Meteorological Equipment

ICMSSR tasked the Ad Hoc Group for Mobile Meteorological Equipment (AHG/MME) to provide a forum for coordinating information on mobile observing and forecasting systems within the federal meteorological community. In December 1995, AHG/MME published a revised ***Federal Directory of Mobile Meteorological Equipment and Capabilities*** to catalogue both current mobile systems and capabilities and those programmed to be available in the near future.

Committee and Working Group Structure

A schematic of the federal committee and working group structure for meteorological coordination is found on the back inside cover of this Plan.

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. The federal coordinating committees and working groups compile information from the involved agencies and propose a unified plan for consideration. Current publications of the Federal Coordinator for Meteorology are listed in Table 2.1. With the exception of FMH's, copies of OFCM publications are available upon request.

RELATED FEDERAL METEOROLOGICAL COORDINATION

The focus of OFCM and of this report is on federal operational meteorological programs and supporting research that directly supports the operational programs. Brief descriptions are given below of federal coordination activities that are not specifically a part of OFCM activities.

Omega Radionavigation System

The 1994 *Federal Radionavigation Plan* stated that the Omega radionavigation system would be phased out by September 30, 1997, in the absence of continuing requirements for the system. The phase-out date was based on the fact that current marine and aviation systems using Omega were quickly transitioning to GPS-based systems. Currently, over 220 stations around the world use Omega-based systems for upper-air observations. On March 18, 1996, the DOT Positioning and Navigation Executive Committee was briefed on the meteorological community's use of Omega and on the potential

impacts should Omega be prematurely terminated. The issue, however, went beyond use and requirements to responsibility for the continued funding of U.S. participation in the worldwide Omega network. The FAA will fund the network through FY 1997 based on civil aviation requirements, but there is no programmed funding beyond that point. On April 26, 1996, the OFCM hosted a strategy session to revalidate continuing requirements for Omega within the federal meteorological community, and then, based on those requirements, investigate possible funding arrangements. The outcome of the meeting was that, until the community can quantify the impact of losing these data, it would be impossible to justify to any agency the continuing need to fund U.S. participation in the Omega network.

In response to this need, the NWS's NCEP completed a study on the impact of the anticipated demise of Omega wind-finding capability. The study results were briefed to the ICMSSR on July 2, 1996. The conclusion of the study was that, on a global basis, removing Omega-based upper-air observational data results in a degradation of forecast error statistics equivalent to 5 years of numerical weather prediction progress in forecast error reduction. The study went on to show that, without the Omega observations, the variabilitiy of analyses and forecasts about a mean error value was greater, implying some forecasts are much worse and others are about the same. Also, if a key station for a particular forecast is missing, local error growth (downstream) will likely be large.

In a letter to the Assistant Secretary for Transportation Policy, the OFCM, on behalf of the federal meteorological community, stated that while the impacts are of concern, they are not devastating. And, given the costs of the Omega system and the community's need for a concerted effort to implement new systems, the continued funding of the Omega radionavigation system beyond September 30, 1997, would not be pursued. In the near term, the efforts of both the U.S. and international meteorological communities will be directed at finding alternative wind-finding solutions to Omega, such as GPS, for key stations impacted by the Omega phaseout.

World Weather Program

Some federal agencies participate in international activities relating to meteorological services and data exchange. These activities 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.

Table 2.1 Current OFCM Publications

Publication Title	Date	Number
Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 1996	June 1995	FCM-P1-1995
National Plan for Space Environment Services and Supporting Research: 1993-1997	August 1993	FCM-P10-1993
National Severe Local Storms Operations Plan	April 1996	FCM-P11-1996
National Hurricane Operations Plan	May 1996	FCM-P12-1996
National Winter Storms Operations Plan	September 1995	FCM-P13-1995
Federal Plan for Cooperative Support and Backup Among Operational Processing Centers	May 1996	FCM-P14-1996
National Plan for Stratospheric Monitoring, 1988-1997	July 1989	FCM-P17-1989
National Aircraft Icing Technology Plan	April 1986	FCM-P20-1986
National Plan to Improve Aircraft Icing Forecasts	July 1986	FCM-P21-1986
Federal Plan for the Coordination of Automated Weather Information System Programs	May 1988	FCM-P23-1988
Federal Plan for Meteorological Information Management	July 1991	FCM-P24-1991
National Plan for Tropical Cyclone Research (under revision) Change 1 (update inserts)	July 1992 March 1993	FCM-P25-1992
National Aviation Weather Program Plan	September 1992	FCM-P27-1992
Federal Plan for Marine Environmental Data, Services, and Supporting Research	June 1996	FCM-P29-1996
The National Space Weather Program: Strategic Plan	August 1995	FCM-P30-1995
Federal Meteorological Handbook No. 1 - Surface Weather Observations and Reports	December 1995	FCM-H1-1995
Federal Meteorological Handbook No. 2 - Surface Synoptic Codes Surface Synoptic Code Tables (Update)	December 1988 July 1990	FCM-H2-1988 FCM-T1-1990
Federal Meteorological Handbook No. 10 - Rocketsonde Observations	December 1988	FCM-H10-1988
Federal Meteorological Handbook No. 11 - Doppler Radar Meteorological Observations		
Part A - System Concepts, Responsibilities and Procedures	June 1991	FCM-H11A-1991
Part B - Doppler Radar Theory and Meteorology	June 1990	FCM-H11B-1990
Part C - WSR-88D Products and Algorithms	February 1991	FCM-H11C-1991
Part D - WSR-88D Unit Description and Operational Analysis	April 1992	FCM-H11D-1992
Directory of Atmospheric Transport and Diffusion Models, Equipment, and Projects	April 1993	FCM-I3-1993
Federal Directory of Mobile Meteorological Equipment and Capabilities	December 1995	FCM-I5-1995
A Guide to WMO Code Form FM 94 BUFR	March 1995	FCM-I6-1995
Tropical Cyclone Studies Tropical Cyclone Studies Supplement	December 1988 August 1989	FCM-R11-1988 FCM-R11-1988 S
Interdepartmental Meteorological Data Exchange System Report, IMDES (under revision)	July 1991	FCM-R12-1991
Federal Meteorological Requirements 2000	October 1990	FCM-R13-1990
Standard Formats for Weather Data Exchange Among Automated Weather Information Systems	November 1994	FCM-S2-1994
Standard Telecommunication Procedures for Weather Data Exchange (under revision)	October 1991	FCM-S3-1991
Federal Standard for Siting Meteorological Sensors at Airports	August 1994	FCM-S4-1994
50th Interdepartmental Hurricane Conference (Minutes)	October 1996 (Projected)	None

SECTION 3

RESOURCE INFORMATION AND AGENCY PROGRAM UPDATES

The tables in this section summarize fiscal information of the federal government for Fiscal Years (FY) 1996 and 1997. The funds shown are those used to provide meteorological services and associated supporting research that has as its immediate objective the improvement of these services. Fiscal data are current as of the end of June 1996 and are subject to later changes. The data for FY 1997 do not have legislative approval and do not constitute a commitment by the U.S. Government. The budget data are prepared in compliance with Section 304 of Public Law 87-843, in which Congress directed that an annual horizontal budget be prepared for meteorological programs conducted by the federal agencies.

AGENCY OBLIGATIONS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

Table 3.1 contains fiscal information, by agency, for meteorological operations and supporting research. The table shows the funding level for FY 1996 based on Congressional appropriations, the budget request for FY 1997, the percent change, and the individual agencies' percent of the total federal funding for FY 1996 and FY 1997.

DEPARTMENT OF AGRICULTURE (USDA)

The USDA budget request for FY 1997 is $27.57 million for operations and supporting research and represents a decrease from the requested FY 1996 funding level of $27.73 million. The USDA assists the Department of Commerce in determining farmers' needs for weather information and in disseminating the information to them. Major USDA activities related to weather observations include incremental modernization of the snow telemetry (SNOTEL) system operated by the Natural Resources Conservation Service (NRCS) 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 activities, the irrigation water supply estimates, and Bureau of Land Management operations. The modernization of the RAWS completed the testing phase for acceptance in operations.

For supporting research, the USDA requests $15.47 million to focus on the interactions of weather and climate with plant and animal production and water resources management. The goal of supporting research is to develop and disseminate information and techniques to ensure an abundance of high-quality agricultural commodities and products while minimizing the adverse effects of agriculture on the environment. The research budget does not include the coordinated effort with EPA on ultraviolet radiation. The Forest Service supports a research program, initiated in 1988, for a long-term monitoring network to assess potential effects of global climate change and variability on forest health and productivity. Work also continues in forestry ecological systems modeling.

DEPARTMENT OF COMMERCE (DOC)

All reported DOC meteorological activities are within the National Oceanic and Atmospheric Administration (NOAA). The NOAA FY 1997 total congressional request of $1.31 billion for meteorological programs represents a 13.7 percent increase over the FY 1996 appropriated funds. NOAA's FY 1997 operations and supporting research requests for each of the major line office activities are described below:

Weather Services. Funding levels for FY 1997 will decrease by 216 positions and $17.3 million as part of the transition to the modernized office structure. Operations support funds of $471.7 million (a 4.0 percent decrease over FY 1996) are programmed to operate Next Generation Weather Radar (NEXRAD), now designated as the Weather Surveillance Radar-1988 Doppler (WSR-88D), units which significantly improve severe weather warning capabilities; to prepare for the Modernization and Associated Restructuring Demonstration (MARD); to continue Stage II staffing of Weather Forecast Offices (WFO) as the Advanced Weather Interactive Processing Systems (AWIPS) are deployed; and to provide funding in support of the certification requirements of Public Law 102-567. Included in this request is a $10 million decrease pursuant to the Administration's Reinventing Government initiative.

In FY 1997, the National Weather Service (NWS) requests a decrease of $0.2M from the FY 1996 level

TABLE 3.1 METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH COSTS*, BY AGENCY

(Thousands of Dollars)

	Operations			% of FY97	Supporting Research			% of FY97	Total			% of FY96	% of FY97
AGENCY	FY96	FY97	%CHG	TOTAL	FY96	FY97	%CHG	TOTAL	FY96	FY97	%CHG	TOTAL	TOTAL
Agriculture	12003	12105	0.8	0.6	15727	15467	-1.7	4.2	27730	27572	-0.6	1.2	1.1
Commerce/NOAA	1069760	1230276	15.0	57.7	86781	84498	-2.6	22.8	1156541	1314774	13.7	50.1	52.6
Defense(Subtot)	442846	425141	-4.0	19.9	100131	93729	-6.4	25.3	542977	518870	-4.4	23.5	20.7
Air Force	267637	259535	-3.0	12.2	50374	41691	-17.2	11.3	318011	301226	-5.3	13.8	12.0
DMSP**	42923	42424	-1.2	2.0	18213	17964	-1.4	4.9	61136	60388	-1.2	2.6	2.4
Navy	95497	99419	4.1	4.7	13946	14647	5.0	4.0	109443	114066	4.2	4.7	4.6
Army	36789	23763	-35.4	1.1	17598	19427	10.4	5.2	54387	43190	-20.6	2.4	1.7
Interior/BLM	1170	800	-31.6	0.0	0	0	0.0	0.0	1170	800	-31.6	0.1	0.0
Transportation/CG	6774	6774	0.0	0.3	0	0	0.0	0.0	6774	6774	0.0	0.3	0.3
Transportation/FAA	384460	453003	17.8	21.2	14250	5873	-58.8	1.6	398710	458876	15.1	17.3	18.3
EPA	0	0	0.0	0.0	8500	6700	-21.2	1.8	8500	6700	-21.2	0.4	0.3
NASA	4299	3453	-19.7	0.2	160800	163800	1.9	44.3	165099	167253	1.3	7.2	6.7
NRC	289	289	0.0	0.0	0	0	0.0	0.0	289	289	0.0	0.0	0.0
TOTAL	1921601	2131841	10.9	100.0	386189	370067	-4.2	100.0	2307790	2501908	8.4	100.0	100.0
% of FY TOTAL	83.3%	85.2%			16.7%	14.8%			100.0%	100.0%			

*The FY 1996 funding reflects Congressionally appropriated funds; the FY 1997 funding reflects the amount requested in the President's FY 1997 budget submission to Congress.

**DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

to operate and maintain the current WSR-88D network of 120 systems, continue the WSR-88D product improvement initiative, and begin acquisition of three additional WSR-88D systems for installation in Northern Alabama, Western Arkansas, and Northern Indiana. These systems were recommended by the Secretary of Commerce as a result of the National Research Council's study regarding WSR-88D coverage and possible degradation of weather services. Funding to begin WSR-88D Acquisition Program Office closeout activities and to continue the Systems Acquisition Office's acquisition closeout efforts is also included the FY 1997 request. The FY 1997 funding for the Automated Surface Observing System (ASOS) program decreases by $6.9 million as the full-scale production phase and product improvement activities continue.

In FY 1997, an increase of $69.2 million is required to support critical AWIPS system development activities. In addition, NWS requests a $4.0 million increase to continue the upgrade of the NOAA Central Computer Facility. These funds will allow NOAA to continue meeting operational goals in atmospheric and oceanic prediction and in processing environmental information from weather and ocean data systems through the 1990's. Further, an increase of $2.9 million is requested to continue the replacement of the NOAA radiosonde network.

Environmental Satellite, Data, and Information Services. Proposed funding for FY 1997 includes an increase in the Polar-Orbiting Satellite Program of $40.6 million and an increase in the Geostationary Satellite Program of $55.8 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 1997 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. Funding is included for NOAA's share of the converged NOAA and Department of Defense (DOD) polar-orbiting system that will replace the current NOAA series and the DOD Defense Meteorological Satellite Program (DMSP) in the year 2007.

A reduction of $2.4 million is requested to continue the Ocean Remote Sensing Program which began in FY 1995. During the next several years, NOAA will acquire data from foreign and other non-NOAA satellites that will provide measurement of ocean currents, surface winds and waves, subsurface temperature and salinity profiles, ice thickness and flows, and other marine factors.

Increases totaling $4.6 million are requested to maintain basic mission services, including maintenance and operation of satellite ground facilities, provision of satellite-derived products, and conduct of research to improve the use of satellite data. An increase of $3.5 million is requested to initiate the NOAA Virtual Data System (NVDS). This system will modernize existing data storage and retrieval systems, and vastly improve, streamline, and simplify customer access to environmental data.

Weather Research. Requested funding for FY 1997, which includes Solar Terrestrial Services and Research, is $43.4 million--the same level as FY 1996. Covering inflationary cost increases will require a programmatic cut of $0.5 M, resulting in eliminating the WSR-88D research and development (R&D) test facility, reducing WSR-88D severe weather forecast product development, and reducing other research on such weather systems as hurricanes. In addition, the Administration has determined that improved productivity resulting from staffing decreases and more efficient administration will enable a further cut in the program of $0.9 M with no programmatic impact.

DEPARTMENT OF DEFENSE (DOD)

The DOD total budget request for FY 1997 is $518.9 million. This total represents a 4.4 percent decrease in the funding level from FY 1996. Specific highlights for each of the military departments are described below:

U.S. Air Force

U.S. Air Force resources for meteorological support fall under four categories: general operations, general supporting research, DMSP operations, and DMSP and National Polar-orbiting Operational Environmental Satellite System (NPOESS) supporting research. The Air Force request (including DMSP) for FY 1997 is $361.6 million

General Operations. The operations portion of the FY 1997 budget request is $242.9 million and represents a large portion of the environmental support to the DOD. These funds will pay for weather and space environmental support to the USAF (both active

duty and reserve components), the U.S. Army, nine unified commands, and other agencies as directed by the Chief of Staff of the Air Force. Over 3,700 people conduct these activities at over 230 worldwide locations. These people include active duty military, Air Force reservists, Air National Guard weather flight personnel, weather communications and computer specialists, and civilians. General operations funds pay the salaries of these people providing weather support, and the day-to-day operations and maintenance costs for the support they provide.

The FY 1997 request includes $16.6 million for procurement of Air Force standard weather systems needed to sustain and improve current environmental support capabilities. Procurement funding goes primarily to the Air Force Combat Climatology Center (AFCCC) Replacement program. This life-cycle replacement of mainframe computers with workstations will enable AFCCC to provide climatological data to warfighters, national programs, and other DOD and government agencies in a more timely and efficient manner.

General Supporting Research. The FY 1997 budget request for Air Force supporting research is $41.7 million. The Air Force continues R&D efforts for the Cloud Depiction and Forecast System II (CDFS II) and the Global Theater Weather Analysis and Prediction System (GTWAPS), and begins R&D efforts for the Tactical Weather Radar (TWR). CDFS II will expand the computer processing capability of the current CDFS at AFGWC and will build a high resolution, worldwide cloud database by enabling the ingest and exploitation of all weather satellite and sensor data received at AFGWC. GTWAPS will provide AFGWC and the DOD a theater modeling capability to support the warfighters. A variety of other research efforts will investigate the electrodynamics of the Sun and Earth's magnetosphere, ionospheric dynamics, mesoscale meteorology, visible and infrared properties of the environment, and cloud parameterization and prediction.

DMSP Operations. Though funding for DMSP comes from the Air Force, this system is the major source of space-borne meteorological data for the military services and other high-priority DOD programs. Through the shared processing program, the DOD provides environmental data from DMSP sensors to the NWS via the network hub at the National Environmental Satellite, Data, and Information Service, and to the Navy via the network hubs at the Fleet Numerical Meteorology and Oceanography Center (FNMOC) and the Naval Oceanographic Office (NAVOCEANO).

The operations portion of the FY 1997 budget request is $43 million. The major portion of this funding is for on-orbit operations, tactical terminal procurement, and satellite sensor integration. These funds also pay operations costs for two dedicated command and control facilities. DMSP funds for 283 military and civilian personnel associated with the operation of, and to a much smaller extent, the procurement of the DMSP system.

DMSP and NPOESS Supporting Research. The FY 1997 budget for DMSP R&D is $17.9 million. The funds will be used for launch vehicle integration; system integration and testing; and mission sensor calibration, validation, and algorithm development efforts. The FY 1997 DOD R&D budget for NPOESS is $29 million. FY 1997 funds will be used for system architecture studies, independent risk reduction and technology development efforts, and to begin critical sensor and algorithm development. NPOESS is scheduled to be available in 2007 as a backup to the final launch of the NOAA polar-orbiting satellites and DMSP satellites. This system will offer improved avionics and will exploit advanced hardware and software technologies to produce a more reliable, longer-lived spacecraft with greater mission capability.

U.S. Navy

The U.S. Navy FY 1997 funding request for meteorological programs is $114.1 million. The request includes $99.4 million for operational programs and $14.6 million for supporting research. This request reflects a slight growth from the FY 1996 appropriations of $109.4 million.

Operations Support. Operational support for the Navy and Marine Corps includes the day-to-day provision of meteorological and oceanographic (METOC) products and services. Navy METOC support continues to evolve with the shift in U.S. military operational focus to expeditionary warfighting support. As Naval operations in the littoral increases, Navy METOC support is being focused on providing on-scene capabilities for warfighters that directly furnish environmental data to sensors and weapons planning and employment systems.

In addition to aviation and marine METOC support, the Navy provides a variety of unique services on demand, such as acoustic propagation models and products, METOC-sensitive tactical decision aids, and global sea ice analyses and forecasts. The primary program direction continues to be improvements in data collection and processing capabilities for on-scene METOC support in the littoral zones.

The FY 1996 operational program increase from the $89.3 million requested in the President's budget to the appropriated $95.5 million was primarily due to a realignment of funds rather than real program growth. Administrative and communications functions, originally categorized as base support, have been recategorized as mission and are now considered part of the operational program.

Systems Acquisition. Major systems undergoing procurement or upgrades in FY 1996 and FY 1997 include:

- Tactical Environmental Support System (TESS(3)).
- Naval Integrated Tactical Environmental Sub-System (NITES).
- Mobile Oceanography Support System (MOSS).
- Primary Oceanographic Prediction Systems at NAVOCEANO (POPS-I) and FNMOC (POPS-II).

Research and Development (R&D). This area is not generally system specific; instead, Navy R&D efforts typically have applications to one or more meteorological, oceanographic, or tactical systems. Navy's tabulation of these data includes R&D funding for exploratory research, demonstration, validation, and engineering and manufacturing development.

Initiatives of the Navy and Marine Corps, under sponsorship of the Oceanographer of the Navy, transition projects from exploratory development to operational Navy systems. Such efforts include advances in the Navy's numerical METOC forecasting capability, expansion in communications and data compression techniques, further development and improvement of models to better predict METOC parameters in littoral regions, and an improved understanding of the impact these parameters have on sensors, weapon systems, and platform performance.

U.S. Army

The U.S. Army is requesting $23.7 million for operational support and $19.6 million for R&D in FY 1997. Operational support decreased by about $13 million, or about 35 percent from FY 1996 funding levels. Operational manning will drop from 380 to 329, or about 13 percent from FY 1996. Much of the funding decrease is caused by ending two acquisition programs, by downsizing the numbers of Army divisions, and by the reduction in the size of artillery meteorological teams as a modern, smaller upper air sounding system completes fielding in FY 1997. Operational meteorological support at the test ranges and R&D facilities continues to decrease to account for most of the rest of the reduction in funding.

The tactical weather equipment procurement costs for the Field Artillery Meteorological Hydrogen Generator (MHG) and the Integrated Meteorological Systems (IMETS) are both scheduled to complete programmed funding for a reduced number of units. Fielding of some completed systems will continue into the next fiscal year. The MHG will complete the program in FY 1997 with funding of $7.2 million; the IMETS will be completed with funding of $3.1 million. The IMETS will be fielded to major combat units, but most aviation brigades are not programmed to receive the system because of funding reductions below the Army authorized object of one system for each Army weather team. The Communications and Electronics Command, Intelligence and Electronic Warfare (CECOM IEW) Directorate supports the CECOM Level II manager and the Project Director, Integrated Meteorological Systems with technical management of programs under their control. The total funding for IEW Directorate internal support for FY 1997 is $1.2 million.

Training and Doctrine Command (TRADOC) and U.S. Army Pacific Command (USARPAC) will have small increases in costs associated with new service or equipment for forecasting and observing at new locations. USARPAC will increase direct Staff Weather Officer (SWO) support to U.S. Army, Japan, and procure deployable weather terminals to support Joint Task Force exercises and contingencies. U.S. Army Europe (USAREUR) and Seventh Army will slightly increase funding to purchase a stand-alone satellite receiver system to access weather data from commercial satellites. Other FY 1997 USAREUR costs are for weather data transmission and leasing dial-up radar.

In operational support for Research, Development, Test, and Evaluation (RDTE), Army Matériel Command funding for the Test and Evaluation Command (TECOM) Meteorological (Met) Teams in FY 1996 was $7.02 million for basic operations supporting 11 Army test ranges and R&D sites. FY 1997 funding is $6.83 million, but is a combination of direct and reimbursable funding from users. Meteorological instrumentation will be acquired through other Army technical development resources or through direct funding from RDTE projects for test specific or unique requirements rather than mission funds.

In weather R&D, the Army Research Laboratory, Battlefield Environment Directorate has under gone mission funding decreases in the past two fiscal years. These funding decreases have resulted in personnel cuts of 25 percent from 124 to 93. FY 1995 mission funding of $12.8 million decreased to $8.3 million in FY 1996 and recovers slightly with $9.7 million requested in FY 1997. This funding level is not sufficient to cover internal labor and overhead costs, so the directorate will pursue customer funding in order to maintain R&D mission support with the current staff.

An increase in funding for the meteorological research program budget of the Army Research Office (ARO) is programmed from $920,000 in FY 1996 to $1.07 million in FY 1997 by changes in the Environmental Sciences Branch budget. The individual investigator program is dependent on the merit and relevance of proposals submitted under the ARO Broad Agency Announcement. The additional funding will permit new initiatives in stable boundary layer processes. The Augmentation Award for Science and Engineering Research and Training funds have been committed for up to 3 years at present levels. This Congressionally mandated program will continue through FY 1997 on funds provided in previous years.

DEPARTMENT OF THE INTERIOR (DOI)

The DOI funding request for FY 1997 is $970,000. This figure is for meteorological operations and support for the Bureau of Land Management's remote sensing requirements for Remote Automatic Weather Station (RAWS) and Lightning Detection programs. Normal operations and maintenance for the RAWS program is $870,000 annually (personnel, vehicles, per diem, normal procurement costs, and facilities). Starting in FY 1997, the BLM will begin a "downsizing" effort in RAWS to reduce the station number by one-third. Subsequent cost savings in operations costs will be used to replace aging equipment and upgrade sensor packages. Proposed changes in lightning detection operations will further reduce the out-year expenditures in this program. Coordination between DOI agencies and the USDA Forest Service regarding combined meteorological requirements for the National Wildfire support function is ongoing. During the coming downsizing efforts, interagency RAWS replacement coordination will continue to maximize National Fire Danger Rating System sampling points and minimize the total number of systems required in the West.

DEPARTMENT OF TRANSPORTATION (DOT)

The meteorological programs for the U.S. Coast Guard and the Federal Aviation Administration for FY 1996 and FY 1997 are described below.

U.S. Coast Guard (USCG)

All of USCG's funding for meteorological programs is for operations support. In FY 1997, the requested funding level is $6.77 million. Among the Coast Guard's activities are the collection and dissemination of meteorological and iceberg warning information for the benefit of the marine community. The Coast Guard provides coastal and marine weather observations to NOAA's NWS, radio transmission of NWS weather warnings to marine users, the use of buoy tender facilities to support the activities of the National Data Buoy Center, and the management and operation of the International Ice Patrol that provides warnings to mariners of the presence of icebergs in the North Atlantic shipping lanes.

Federal Aviation Administration (FAA)

The total FAA request for aviation weather in FY 1997 is $458.9 million for both operations and supporting research; the FAA funding for FY 1996 for aviation weather was $398.7 million. The increase in the budget is principally in operations which will rise from the appropriated $384.5 million to the requested $453.0 million. Funding for supporting research will decrease about 58 percent to $5.9 million.

The FAA is principally concerned with aviation weather. The FAA role is limited to the observation and dissemination of aviation weather information and to short-range automated warnings and forecasts. FAA's aviation weather programs are directed at improving the timeliness and accuracy of weather

information to the aviation user when and where it is needed. The FAA also supports research in those areas that involve improvements to the observation, data dissemination, and forecasting of aviation weather. The end users of the resulting products include pilots, dispatchers, and air traffic controllers.

The FY 1997 increases are in Systems Acquisition and Operational Support with system acquisition funding increasing by 39 percent to $147.7 million. Acquisition programs with significant increases are the Operational and Supportability Implementation System, the Weather and Radar Processor, and the Integrated Terminal Weather System. Lesser acquisition increases are in the Low Level Windshear Advisory System, Digital Altimeter Setting Instrument, and Next Generation Runway Visual Range. Decreases to acquisition programs are associated with completion or near completion of the programs. Appendix C contains descriptions for these systems.

Individual system acquisition and operational programs with changes greater than $2 million are listed below:

Program	Change ($ Millions)
Systems Acquisition:	
Automated Surface Observing System	- 2.8
Weather and Radar Processor	17.0
Terminal Doppler Weather Radar	- 2.7
Operational and Supportability Implementation System	23.0
Next Generation Weather Radar	-12.8
Integrated Terminal Weather System	14.6
National Airspace Data Interchange Network	- 3.9
Low Level Wind Shear Advisory System	2.4
ASR-9 Weather Systems Processor	5.6
Operations Support:	
Flight Service Stations Operations	4.7
Contract Aviation Weather Observations	16.6

The FY 1997 funding request for operational support increases by $25.3 million to $301.4 million, which reflects modest increases for leased communications and certain maintenance functions and significant increases in Flight Service Station operations and Contract Weather Observations. The large increase in operations support are associated with FAA's broadened role and responsibility for surface observations, ASOS observer augmentation, and staffing for the Aviation Weather Division.

Supporting research funding decreases from $14.3 million in FY 1996 to $5.9 million in FY 1997. This significant program decrease is associated with the movement of the Integrated Terminal Weather System to the acquisition list.

The number of personnel expected to be engaged in FAA's aviation weather program is up to 3433. This modest increase is related to: (a) increases in maintenance support and special projects and some small cuts in supporting research and (b) an increase in the percentage used to compute the weather-related duties of personnel, such as flight service specialists.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

All of the EPA's funding of meteorological programs is for supporting research. The anticipated funding level in FY 1997 for directed meteorological research is $6.7 million, which is 21.2 percent less than the funding level for FY 1996.

To promote excellence in environmental science and engineering, EPA established a new national fellowship program and substantially increased its support for investigator-initiated research grants. The increase in funding for grants (with reliance on quality science and peer review) and for graduate fellowships (to support the education and careers of future scientists) will provide for a more balanced, long-term capital investment in improved environmental R&D.

The funding for the grants program increased from $44 million in FY 1995 to $80 million in FY 1996, and will increase again by a yet undetermined amount in FY 1997. The augmented grants program will fund research in the areas including ecological assessment, air quality, environmental fate and treatment of toxic and hazardous wastes, and exploratory research. The portion of these grants that will be awarded for meteorological research during FY 1997 cannot be foreseen, but it is certain that the grant awards will increase the base amount of $6.7 million listed above for directed meteorological research.

The EPA is continuing its development and validation of air quality dispersion models for air pollutants on all temporal and spatial scales as mandated by the Clean Air Act, as amended. Research will focus on indoor, urban, mesoscale, and regional models which will be used to develop air pollution control strategies, and human and ecosystem exposure assessments. There will be increased emphasis placed on meteorological research into regional and urban

transport of ozone and particulate pollution, while research into acid deposition model development and evaluation winds down. Increased efficiency of computation and interpretation of results are being made possible by means of high performance computing and scientific visualization techniques.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Nearly all of NASA's funding in meteorology is for supporting research. The requested funding for supporting research in FY 1997 is $164.8 million, which is 1.9 percent higher than the FY 1996 funding level. These funding levels are composed of the estimated meteorology share of the supporting research and analysis programs, to include the Earth Observing System (EOS) and Earth Probe instruments, EOS science, and the EOS Data and Information Systems (EOSDIS). The FY 1997 level reflects a near 10 percent increase in the EOS and EOSDIS funding levels, respectively, from the corresponding FY 1996 levels. The Earth Probes line for FY 1997 is nearly the same as that for FY 1996. This line reflects reductions due to recent launch of NASA Scatterometer (NSCAT) and Total Ozone Mapping Spectrometer (TOMS) and the upcoming launch of the Tropical Rainfall Measuring Mission (TRMM). This reduction is offset by the initiation of the New Millennium Program (NMP) and the Earth System Science Pathfinders (ESSP). NMP provides for the infusion of innovative new technologies in to the second and third series of EOS measurements, and will emphasize fast-track development and low cost demonstration missions. ESSP features an expedited procurement process, accelerated development schedules, low life-cycle costs, peer-reviewed science, and missions based on best science value.

NUCLEAR REGULATORY COMMISSION (NRC)

The NRC requested funding is for meteorological operations. The FY 1997 request is essentially unchanged from the FY 1996 request.

The meteorological support program in the U.S. Nuclear Regulatory Commission is focused solely on obtaining and analyzing meteorological data and information to be utilized in atmospheric transport and dispersion models used in dose projections, plume pathway characterizations, and concentration estimates related to the safe operation of nuclear facilities and the protection of public health and safety and the environment. Obtaining current, accurate, and relevant meteorological information on a real-time basis for use during emergencies is the primary consideration. The NRC budget in this area reflects this priority.

AGENCY FUNDING BY BUDGET CATEGORY

Table 3.2 depicts how the agencies plan to obligate their funds for meteorological operations broken down by "budget category." The two major categories are "Operations Support" and "Systems Acquisition." To a large degree, these categories correspond to non-hardware costs (Operations Support) and hardware costs (Systems Acquisition). For agency convenience in identifying small components that do not fit into these two major categories, a third category is added called "Special Programs." Programs that provide support to several government agencies such as the Air Force's DMSP are listed on a separate line.

Table 3.3 describes how the agencies plan to obligate their funds for meteorological supporting research according to the budget categories. The agencies' supporting research budgets are subdivided along similar lines--Research and Development (non-hardware), Systems Development (hardware), and Special Programs for those items 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 is a similar breakout for supporting research funds. Table 3.4 reveals that "basic" services require approximately 56 percent of the total operational costs while aviation services require about 37 percent. The remaining 7 percent is used to support the other specialized services. The definitions of specialized and basic services are described below.

TABLE 3.2 AGENCY OPERATIONAL COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

	Operations Support		Systems Acquisition		Special Programs		Total			% of FY96
AGENCY	FY96	FY97	FY96	FY97	FY96	FY97	FY96	FY97	%CHG	TOTAL
Agriculture	12003	12105	0	0	0	0	12003	12105	0.8	0.6
Commerce/NOAA	580203	586878	467658	630760	21899	12638	1069760	1230276	15.0	57.7
Defense(Subtot)	395534	388571	47144	36328	168	242	442846	425141	-4.0	19.9
Air Force	255147	242896	12490	16639	0	0	267637	259535	-3.0	12.2
DMSP*	23302	26682	19621	15742	0	0	42923	42424	-1.2	2.0
Navy	94681	98784	816	635	0	0	95497	99419	4.1	4.7
Army	22404	20209	14217	3312	168	242	36789	23763	-35.4	1.1
Interior/BLM	870	600	300	200	0	0	1170	800	-31.6	0.0
Transportation/CG	6774	6774	0	0	0	0	6774	6774	0.0	0.3
Transportation/FAA	276142	301399	105803	147660	2515	3944	384460	453003	17.8	21.2
EPA					------ Not Applicable ------					
NASA	3383	3403	916	50	0	0	4299	3453	-19.7	0.2
NRC	289	289	0	0	0	0	289	289	0.0	0.0
TOTAL	1275198	1300019	621821	814998	24582	16824	1921601	2131841	10.9	100.0
% of FY TOTAL	66.4%	61.0%	32.4%	38.2%	1.3%	0.8%	100.0%	100.0%		

*DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

TABLE 3.3 AGENCY SUPPORTING RESEARCH COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

AGENCY	Research & Development FY96	Research & Development FY97	Systems Development FY96	Systems Development FY97	Special Programs FY96	Special Programs FY97	Total FY96	Total FY97	Total %CHG	% of FY96 TOTAL
Agriculture	15727	15467	0	0	0	0	15727	15467	-1.7	4.2
Commerce/NOAA	55798	56278	26633	23870	4350	4350	86781	84498	-2.6	22.8
Defense(Subtot)	95631	88729	4500	5000	0	0	100131	93729	-6.4	25.3
Air Force	50374	41691	0	0	0	0	50374	41691	-17.2	11.3
DMSP*	18213	17964	0	0	0	0	18213	17964	-1.4	4.9
Navy	13946	14647	0	0	0	0	13946	14647	5.0	4.0
Army	13098	14427	4500	5000	0	0	17598	19427	10.4	5.2
Interior/BLM					------ Not Applicable ------					
Transportation/CG					------ Not Applicable ------					
Transportation/FAA	12965	5873	1285	0	0	0	14250	5873	-58.8	1.6
EPA	8500	6700	0	0	0	0	8500	6700	-21.2	1.8
NASA	118600	118000	42200	45800	0	0	160800	163800	1.9	44.3
NRC					------ Not Applicable ------					
TOTAL	307221	291047	74618	74670	4350	4350	386189	370067	-4.2	100.0
% of FY TOTAL	79.6%	78.6%	19.3%	20.2%	1.1%	1.2%	100.0%	100.0%		

*DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

TABLE 3.4 AGENCY OPERATIONAL COSTS, BY SERVICE

(Thousands of Dollars)

AGENCY	Basic Meteorology		Aviation		Marine		Agriculture & Forestry		General Military		Other		Total	
	FY96	FY97	FY96	FY97	FY96	FY97	FY96	FY97	FY96	FY97	FY96	FY97	FY96	FY97
Agriculture	0	0	0	0	0	0	12003	12105	0	0	0	0	12003	12105
Commerce/NOAA	1008280	1168796	35596	35596	24945	24945	2795	2795	0	0	2500	2500	1074116	1234632
Defense(Subtot)	17189	16901	296511	290606	28363	27837	0	0	96599	83766	4184	6031	442846	425141
Air Force	0	0	267637	259535	0	0	0	0	0	0	0	0	267637	259535
DMSP*	0	0	0	0	0	0	0	0	42923	42424	0	0	42923	42424
Navy	17189	16901	28649	30820	28363	27837	0	0	18144	18890	3152	4971	95497	99419
Army	0	0	225	251	0	0	0	0	35532	22452	1032	1060	36789	23763
Interior/BLM	0	0	0	0	0	0	1170	2000	0	0	0	0	1170	2000
Transportation/CG	5730	5730	0	0	1044	1044	0	0	0	0	0	0	6774	6774
Transportation/FAA	0	0	384460	453003	0	0	0	0	0	0	0	0	384460	453003
EPA	------ Not Applicable ------													
NASA	0	0	0	0	0	0	0	0	0	0	4299	3453	4299	3453
NRC	199	199	0	0	0	0	0	0	0	0	90	90	289	289
TOTAL	1031398	1191626	716567	779205	54352	53826	15968	16900	96599	83766	11073	12074	1925957	2137397
% of FY TOTAL	53.6%	55.8%	37.2%	36.5%	2.8%	2.5%	0.8%	0.8%	5.0%	3.9%	0.6%	0.6%	100.0%	100.0%

*DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

TABLE 3.5 AGENCY SUPPORTING RESEARCH COSTS, BY SERVICE

(Thousands of Dollars)

	Basic Meteorology		Aviation		Marine		Agriculture & Forestry		General Military		Other		Total	
AGENCY	FY96	FY97	FY96	FY97	FY96	FY97	FY96	FY97	FY96	FY97	FY96	FY97	FY96	FY97
Agriculture	0	0	0	0	0	0	15727	15467	0	0	0	0	15727	15467
Commerce/NOAA	85156	82873	1625	1625	0	0	0	0	0	0	0	0	86781	84498
Defense(Subtot)	1484	1675	50374	41691	13946	14647	0	0	34312	35901	200	0	100316	93914
Air Force	0	0	50374	41691	0	0	0	0	0	0	0	0	50374	41691
DMSP*	0	0	0	0	0	0	0	0	18213	17964	0	0	18213	17964
Navy	0	0	0	0	13946	14647	0	0	0	0	0	0	13946	14647
Army	1484	1675	0	0	0	0	0	0	16099	17937	200	0	17783	19612
Interior/BLM							------ Not Applicable ------							
Transportation/CG							------ Not Applicable ------							
Transportation/FAA	0	0	14250	5873	0	0	0	0	0	0	0	0	14250	5873
EPA	0	0	0	0	0	0	0	0	0	0	8500	6700	8500	6700
NASA	0	0	0	0	0	0	0	0	0	0	160800	163800	160800	163800
NRC							------ Not Applicable ------							
TOTAL	86640	84548	66249	49189	13946	14647	15727	15467	34312	35901	169500	170500	386374	370252
% of FY TOTAL	22.4%	22.8%	17.1%	13.3%	3.6%	4.0%	4.1%	4.2%	8.9%	9.7%	43.9%	46.0%	100.0%	100.0%

*DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

Basic Services

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

Specialized Meteorological Services

Aviation Services. Those services and facilities established to meet the requirements of general, commercial, and military aviation.

Marine Services. Those services and facilities established to meet the requirements of the DOC, DOD, and DOT on the high seas, on 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 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.

General Military 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.

Other Specialized Services. Those services and facilities established to meet meteorological requirements that cannot be classified under one of the preceding categories; such as, space operations, urban air pollution, global climate change, and water management.

PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS

Table 3.6 depicts agency staff resources in meteorological operations. The total agency staff resources requested for FY 1997 is 15,942. This total represents a decrease of 4.8 percent from FY 1996.

INTERAGENCY FUND TRANSFERS

Table 3.7 summarizes the reimbursement of funds from one agency to another during FY 1996. Agencies routinely enter into reimbursable agreements when they determine that one agency can provide the service more efficiently and effectively than the other. While specific amounts may vary from year-to-year, the pattern shown is essentially stable and reflects a significant level of interagency cooperation.

Department of Commerce. The NWS will reimburse DOT $25,000 for Alaska housing utilities and technological advances. NASA will receive $60,000 for stratospheric studies and a total of $305.2 million for satellite acquisition and launching--polar orbiting ($132.8 million) and geostationary ($172.4 million).

Department of Defense. The Air Force will reimburse DOC a total of $3.86 million for WSR-88D Operational Support Facility support ($2.1 million), COMET participation ($950,000), Shared Processing Program ($162,000), OFCM support ($140,000), and supporting research ($515,000). The Navy will reimburse DOC $532,000 for climatological analysis and forecasting. The Army reimbursements to DOC include $650,000 to maintain precipitation reporting stations. The Army will also reimburse the U.S. Geological Survey $410,000 for operations and maintenance of hydrologic and precipitation reporting stations. Additionally, the Army will reimburse NASA $185,000 for basic supporting research.

Department of Transportation. The FAA will reimburse NOAA $5.5 million in FY 1997 for procurement of WSR-88D and ASOS systems. Additionally, NOAA will receive $24.5 million for operational support--$7 million for WSR-88D and ASOS maintenance, $7.7 million for aviation weather observations, $7.6 million for the Center Weather Service Units at all Air Route Traffic Control Centers, $1.4 million to establish the World Area Forecast System, $360,000 for meteorological instructors at the FAA Academy, and $300,000 for studies and dissemination.

The FAA will reimburse the National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA) a total of $11.9 million for supporting research. The NSF will receive $10.6 million and NASA will receive $1.28 million for aeronautical hazards.

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

AGENCY	FY 1996	FY 1997	%CHG	% of FY 1997 TOTAL
Agriculture	98	98	0.0	0.6
Commerce/NOAA	6549	6297	-9.0	39.5
Reimbursed**	210	200	-4.8	1.3
Defense(Subtotal)	6344	5789	-8.7	36.3
Air Force	4179	3701	-11.4	23.2
DMSP*	283	283	0.0	1.8
Navy	1502	1476	-1.7	9.3
Army	380	329	-13.4	2.1
Interior/BLM	13	12	-7.7	0.1
Reimbursed**	8	6	-25.0	0.0
Transportation/CG	106	106	0.0	0.7
Transportation/FAA	3417	3433	0.5	21.5
EPA	0	0	0.0	0.0
NASA	0	0	0.0	0.0
NRC	1	1	0.0	0.0
TOTAL	16746	15942	-4.8	100.0

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

National Aeronautics and Space Administration (NASA). The Air Force will receive reimbursement of $1.13 million for observations and forecasts. NOAA's National Data Buoy Center will receive reimbursements of $97,000 for operations of data buoys; NWS will receive $1.16 million for spaceflight weather support and $20,000 for upper-air analyses.

Environmental Protection Agency (EPA). NOAA's Air Resources Laboratory (ARL) will be reimbursed $5.2 million for development, evaluation, and application of air quality dispersion models, and for providing meteorological expertise and guidance for EPA policy development activities.

Department of Energy (DOE). The NOAA/OAR will be reimbursed $4 million to support the Nuclear Support Office at the Nevada Nuclear Test Site.

Nuclear Regulatory Commission (NRC). The NRC will reimburse NOAA's ARL ($89,000) and DOE ($90,000) for technical assistance.

FACILITIES/LOCATIONS for TAKING METEOROLOGICAL OBSERVATIONS

Table 3.8 indicates the number of facilities or platforms at which the federal agencies carry out (or supervise) the various types of weather observations.

TABLE 3.7 INTERAGENCY FUND TRANSFERS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

Agency Funds Transferred from:	Agency Funds Transferred to:	FY 1996 Funds ($K) Estimated or Planned	
		Operations	Supporting Research
Commerce/NOAA	DOT/USCG	25	
	NASA Studies	60	
	NASA (Procurement)	305,202	
Defense/Air Force	DOC	3,345	515
Defense/Navy	DOC/NOAA/NCDC	532	
Defense/Army	DOC/NOAA/NWS	650	
	DOI/USGS	410	
	NASA/GFSC/GISS		185
Transportation/FAA	DOC/NOAA	24,571	
	DOC/NOAA (Procurement)	5,500	
	NSF		10,634
	NASA		1,281
NASA	DOD/USAF	1,131	
	DOD/NOAA/NWS	1,175	
	DOC/NOAA/NDBC	97	
EPA	DOC/NOAA/ARL		5,200
DOE	DOC/NOAA/OAR	4,000	
NRC	DOC/NOAA/ARL	89	
	DOE	90	

TABLE 3.8 FACILITIES/LOCATIONS for TAKING METEOROLOGICAL OBSERVATIONS

TYPE OF OBSERVATION/AGENCY	No. of Locations (FY 1996)
Surface, land	
Commerce (all types)	796
Air Force (U.S. & Overseas)	160
Navy (U.S. & Overseas)	50
Army	12
Marine Corps (U.S. & Overseas)	13
Transportation (Flight Service Stn)	61
Transportation (Lim Aviation Wx Rptg Stn)	114
Transportation (Contract Wx Observing Stn)	124
Transportation (Auto Wx Observing Stn)	175
Transportation (Auto Sfc Obs Sys, fielded)	318
Transportation (USCG Coastal)	124
Interior	470
Agriculture	1080
NASA	3
Surface, marine	
Commerce (SEAS-equipped ships)	140
Commerce (Coastal-Marine Autom Network)	65
Commerce (NOAA/NOS/PORTS)	4
Commerce (Buoys--moored)	69
Commerce (Buoys--drifting)	100
Commerce (Buoys--large navigation)	10
Commerce (Water-level gauges)	189
Navy (Ships with met personnel)	23
Navy (Ships without met personnel)	313
Transportation (USCG Ships)	72
NASA	2
Upper air, balloon	
Commerce (U.S.)	97
Commerce (Foreign, cooperative)	33
Air Force, Fixed (U.S. & Overseas)	9
Air Force, Mobile	11
Army, Fixed (U.S. & Overseas)	11
Army, Mobile	50
Navy, Fixed (U.S. & Overseas)	18
Navy, Mobile	39
Navy, Ships	29
Marine Corps, Fixed (U.S. & Overseas)	1
Marine Corps, Mobile	11
NASA (U.S.)	2

TYPE OF OBSERVATION/AGENCY	No. of Locations (FY 1996)
Upper air, rocket	
NASA	2
Air Force	2
Navy	1
Army	1
Doppler weather radar (WSR-88D) sites	
Commerce (NWS)	120
Air Force	28
Army	2
Transportation	12
Off-site WSR-88D Processors (PUPs)	
Commerce (NWS)	63
Air Force	102
Navy	26
Army	3
Marine Corps	8
Transportation	25
Airport terminal Doppler weather radars	
Transportation (Commissioned)	3
Conventional radar (non-Doppler) sites	
Commerce (NWS)	134
Commerce (at FAA sites)	27
Air Force, Fixed (U.S. & Overseas)	17
Air Force, Remote Displays	4
Air Force, Mobile Units	3
Navy, Fixed (U.S. & Overseas)	3
Navy, Remote displays/RADIDS	17
Marine Corps, Fixed (U.S. & Overseas)	2
Marine Corps, Mobile units	5
Weather reconnaissance (No. of aircraft)	
Commerce (NOAA)	3
Air Force Reserve (AFRES)	10
Geostationary meteorological satellites (No. operating)	
Commerce (planned config of 2; 2 additional satellites in standby status)	2
Polar meteorological satellites (No. operating)	
Commerce (planned config of 2)	2
Air Force (planned config of 2)	2

SECTION 4

SPACE WEATHER--A NEW CHALLENGE FOR METEOROLOGISTS[1]

INTRODUCTION

Information about weather has become increasingly popular in recent years. This escalation in interest is due in part to improvements in communications and packaging. The ability to pinpoint each day's most important weather events and present them as riveting news stories makes for compelling entertainment. However, perhaps the most important reason for the recent increase in weather awareness in the general population is that, despite our seemingly successful efforts to control our environment, our lives are in many ways as sensitive to weather as they have ever been. Space weather is poised to undergo a similar surge in interest. The existence of weather in space and its potential impacts have been known for some time. However, real impacts have been limited, and the general population has been largely unaware of them. That is about to change.

During the current solar minimum, the application of technologies which are vulnerable to space weather have exploded in the commercial and consumer sectors. When the sun becomes increasingly active near the turn of the century, space weather can be expected to interfere with daily activity in ways that are different from terrestrial weather, but can be equally as obnoxious and can occasionally pose threats to human health and property. It is not unreasonable to expect space weather information to become part of a routine flight weather briefing for aircraft operations so that aircrews will know when and where their communications and navigation systems may not work as expected. We may even see space weather information in television weather reports to let the populace know when they may experience difficulty getting their high-tech systems like cellular phones to work properly. Understanding space weather and its impacts, and communicating that information to potential customers poses a new challenge to meteorologists. The following will acquaint meteorologists with some important aspects of that challenge.

This section begins with an explanation of the basics of space weather and its impacts. The roles of the sun, the interplanetary medium, and the upper regions of the Earth's atmosphere (the magnetosphere and ionosphere) will be discussed, followed by examples of how space weather interferes with operations and can damage or destroy components or systems. With that background, an interdepartmental effort to improve our capability to observe and forecast the space environment, called the National Space Weather Program, will be discussed.

SPACE WEATHER AND ITS IMPACTS

Space Weather Primer

"Space weather" refers to conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health. Space weather is similar to terrestrial weather in at least one aspect--its source of energy is the sun. However, while terrestrial weather is driven by radiative energy from the sun, space weather responds to both radiative and particle energy. Variations in solar output may affect long term climatological trends but have not been shown to impact daily terrestrial weather. On the other hand, the variations in the sun's radiation and particle emissions trigger rapid and often dramatic change in the space environment. Several solar processes cause variations in the sun's emissions:

- *Solar Wind.* Continuous particle emissions form a low energy plasma, which comprises the solar wind. As the solar wind moves outward from the sun, it

[1] This section was prepared by Colonel Jud Stailey, USAF, who is assigned to the OFCM as the Assistant Federal Coordinator for the Air Force and Army affairs. In addition to serving as the Executive Secretary to the National Space Weather Program Council, Committee for Space Environment Forecasting, and the Working Group for the National Space Weather Program, Colonel Stailey serves as the Secretary for the Working Groups for Climate Services and Meteorological Information Management as well as the coordinator for the Interdepartmental Hurricane Conference. Colonel Stailey joined OFCM in 1995 after serving for three years as the Commander of the Air Force Combat Climatology Center, Scott AFB, Illinois.

interacts with the Earth's magnetic field. This process creates the magnetosphere, a tear-drop shaped region which is compressed to a distance of five to ten Earth radii on the daylight side of the Earth and stretched on the nighttime side to distances sometimes exceeding the orbit of the moon (See Figure 4.1).

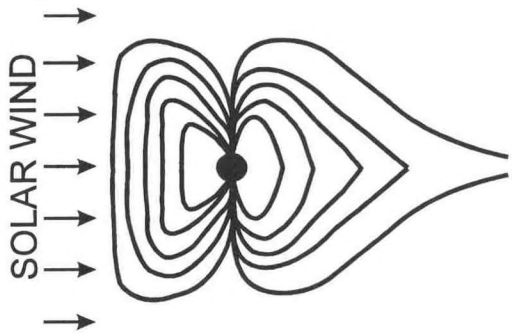


Figure 4.1 Interaction of Magnetosphere and Solar Wind

▸ *Sunspots.* Areas of strong magnetic field on the surface of the sun are cooler than the surrounding solar surface and appear darker. These visible features serve as an indicator of solar activity, and they are often the site of solar flares. The number of sunspots follow an 11-year cycle. The last solar maximum occurred in 1989, and solar minimum occurred in 1996 (See Figure 4.2).

▸ *Solar Flares.* Short-lived (minutes to hours), intense bursts of energy, solar flares radiate throughout the electromagnetic spectrum, from gamma and X rays through the visible range to radio waves. Visible as bright spots on the surface of the sun, flares can also be detected as bursts of radio noise.

▸ *Coronal Mass Ejections.* Violent releases of bubbles or tongues of gas, coronal mass ejections can suddenly accelerate up to a billion tons of matter into space at up to two million miles per hour, twice the normal speed of material released from the sun.

▸ *Prominences.* Visible as dark filaments, prominences are clouds of solar material suspended above the surface of the sun by the solar magnetic field. Prominences eventually erupt, releasing solar material into space.

▸ *Coronal Holes.* Open field lines in the sun's magnetic field, coronal holes are long-lasting (months-years) features which are visible in the X-ray region of the spectrum. They allow the outflow of high velocity solar wind.

Within 30 minutes of a major solar flare, energetic protons released during the flare can shower the Earth. Some of these particles can be captured in the magnetosphere and move downward along the field lines, triggering a proton event.

Within 1 to 4 days after a flare or eruptive prominence, a cloud of matter and magnetic field can reach the Earth, buffeting the magnetosphere and causing a geomagnetic storm. These storms, which last for several days, are characterized by a worldwide disturbance in the Earth's magnetic field, causing it to vary rapidly in direction and intensity. Through processes which are not well understood, storms disrupt the equatorial regions of the ionosphere, causing intensification of normally occurring spatial irregularities in electron density (scintillations). Geomagnetic storms and increased ultraviolet emission from flares can also heat the Earth's upper atmosphere, causing it to expand upward.

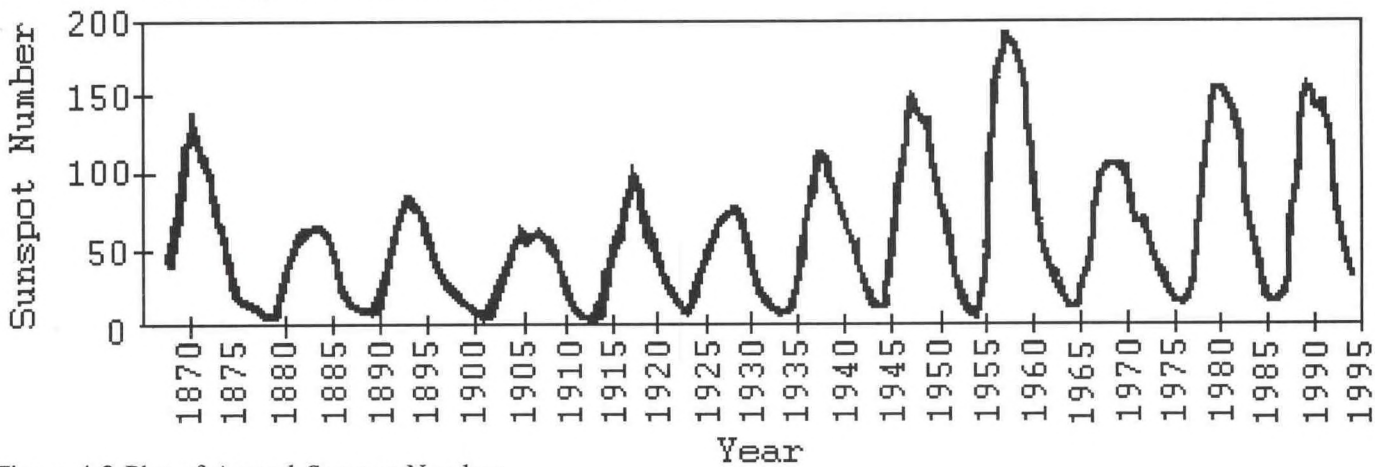


Figure 4.2 Plot of Annual Sunspot Number

Substorms occur when charged particles are captured by the magnetosphere and then release their energy, a process characterized by visible aurora and development of intense currents in the ionosphere--the atmospheric layer underlying the magnetosphere. Substorms usually last a few hours, originating near local midnight and spreading into both the evening and morning sectors.

Space Weather Impacts

In terms of impacts on people and society, space weather stands in a unique and curious juxtaposition with terrestrial weather. Terrestrial weather affects people directly and dramatically, and society has applied technology to alleviate its impacts. Space weather, on the other hand, has historically had little impact on daily human life. It was only when we began using technology on a large scale and/or in sophisticated ways that we felt the impacts of space weather. Several types of systems are affected by space weather:

▸ *Satellites.* Upward expansion of the atmosphere during geomagnetic storms or in response to enhanced ultraviolet emissions from the sun increases the density of the atmosphere at low earth orbit altitudes. This process, in turn, causes an increase in drag on satellites, affecting orbital parameters and complicating the use of data from satellites whose missions require precise knowledge of the position of the satellite. In the worse case, the increase in drag can cause premature reentry of satellites, shortening their orbital life. Satellites are also vulnerable to the effects of energetic particles. Very energetic particles penetrate electronic components causing spurious electronic signals which can result in erroneous (and often deleterious) commands or bad data from an instrument. During geomagnetic storms, satellites traveling through an environment of somewhat less energetic particles develop differential charges on different areas and materials on the spacecraft. The charge can build to a point where arcing occurs, and sensitive components can be damaged.

▸ *Power Systems.* When magnetic fields move about in the vicinity of a conductor such as a wire, an electric current is induced into the conductor. Power transmission lines are susceptible to this type of current induced by dramatic changes in ionospheric currents that occur during geomagnetic storms. Power surges produced by these induced currents can cause power network failures and damage equipment in power generation plants and transmission systems. In the past, this phenomenon has caused millions of dollars in damages and deprived millions of people of commercial electrical power for several hours. Over recent decades, power systems have become more interconnected, used more complex controls and technologies, and increased the practice of transferring power over large distances. While these changes have made power more affordable and reliable under normal circumstances, they have also increased the vulnerability of the systems to disruption and damage by space weather effects.

▸ *Navigation Systems.* The very low frequency radio signals used in systems such as LORAN and OMEGA are affected when solar activity disrupts their wavelengths. Changes in the ionosphere caused by proton events, solar flares, or geomagnetic storms can cause positional errors as large as several miles. Ionospheric conditions also affect radio waves from Global Positioning System (GPS) satellites. Normally, the signals from GPS satellites can be used to calculate very accurate positions. However, changes in the ionosphere can refract and slow GPS radio waves, introducing significant errors in position. In addition, GPS receivers can experience a loss of signal lock when the signal traverses an ionospheric disturbance (scintillation).

▸ *Communications Systems.* Radio-wave communications over a broad range of frequencies are affected by space weather. High frequency (HF) communications are more routinely affected because this frequency depends on reflection from the ionosphere to carry signals great distances. Ionospheric irregularities contribute to signal fading, and highly disturbed conditions can absorb the signal completely and make HF propagation impossible. Higher frequency radio signals, such as ultrahigh frequency, are often used for communications which pass through the ionosphere as they are relayed by satellite. Properties of these signals can be altered by ionospheric conditions to the extent that they can not be accurately received.

▸ *Manned Space Flight.* The flux of very high energy particles can increase several orders of magnitude during intense solar flares and can also increase to dangerous levels during large geomagnetic storms. The Earth's atmosphere and magnetosphere provide adequate protection at ground level from these particles, as all but the most energetic cosmic ray particles are absorbed. However, in space, the penetration of high energy particles into living cells

can lead to chromosome damage and cancer. Large doses can be fatal immediately. The greatest risk is to astronauts performing extra-vehicular activity, spacecraft in high inclination orbits, and crews and passengers on high altitude aircraft flying in the polar regions.

IMPROVING SPACE WEATHER SUPPORT

Meeting the needs for space weather support is extremely challenging. The vast volume of the environment in which space weather occurs and the lack of *in situ* observations make specifying the current state of the weather difficult and forecasting its future state out to a few days nearly impossible. Interactions between regions of the space environment complicate the problem. For example, a particular location of interest in the ionosphere changes in response to the ionospheric conditions around it, to magnetospheric conditions, and to radiation directly from the sun. But the magnetosphere, meanwhile, is responding to both the solar wind and other particle and electromagnetic solar emissions, and variations in those phenomena are caused by events on the sun.

A robust suite of observations from the ionosphere and magnetosphere would allow for timely forecasts of some important events which impact operations. The ability to carefully observe and monitor conditions on the sun and characterize in detail the nature of solar emissions would allow forecasters to broaden the range of events for which they could provide timely warnings and forecasts. However, the ability to meet all space weather requirements would necessitate timely and accurate forecasts of events on the sun.

Current Capabilities

Operational space weather support is provided to civilian customers by NOAA's Space Environment Center (SEC) in Boulder, CO. The 50th Weather Squadron (50 WS), located at Falcon Air Force Base, CO, supports military space weather requirements. Information on products and capabilities of these organizations is available in Appendix A (for SEC--under National Weather Service and the Office of Oceanic and Atmospheric Research) and Appendix B (for 50 WS--under United States Air Force, Space Environment Services). A more detailed, although somewhat dated, explanation of the entire space environment support system is given in the OFCM's *National Plan for Space Environment Services and Supporting Research, 1993-1997.*

Plans for the Future--The National Space Weather Program

A few years ago members of the space science community recognized the need for improving the nation's ability to specify and forecast space weather. They also recognized the potential for significant improvement in that ability if a concerted effort were made to capitalize on research efforts planned and underway. Because space weather operations and space science research efforts spanned several agencies of the federal government, the Office of the Federal Coordinator for Meteorology (OFCM) was asked to facilitate an effort to develop an interagency space weather program. The result was the National Space Weather Program (NSWP), which was instituted in August 1995 with the chartering of a program council to oversee the NSWP and the adoption of the National Space Weather Program Strategic Plan.

The overarching goal of the NSWP is to achieve an active, synergistic, interagency system to provide timely, accurate, and reliable space environment observations, specifications, and forecasts within the next 10 years. Participating agencies include the following:

- The Departments of Commerce and Defense, which support research and include organizations which provide operational services.

- The National Science Foundation and the National Aeronautics and Space Administration, which support and/or conduct research in the space sciences.

- The Departments of Energy and Interior, which operate sensors which collect space weather data and conduct some related research.

Providing timely, accurate, reliable space weather forecasts will require several elements of a system, including comprehensive observations, coupled with physics-based models of the various regions of the space environment, and an educated community of producers and users of space weather information. The recently published National Space Weather Program Implementation Plan addresses these elements in detail and lays out a roadmap for meeting NSWP goals. The implementation plan recognizes the importance of research early in the program and is heavily focused on that element. Other elements are addressed in somewhat less detail.

To provide some organizational structure to an extremely complex undertaking, the implementation plan divides the research element into two dimensions. First, research is conducted in three areas--physical understanding, model development, and observations.

- *Physical understanding* involves increasing our knowledge of the physical processes controlling the space environment. This area could best be thought of as basic scientific research.

- *Model development* is a common way of expressing the physical understanding derived from basic research. Models provide a "deliverable" from the research process which can be adapted to support operations.

- *Observations* encompass several thrusts--to provide data for improving physical understanding, to help determine what data will be required by operational physics-based models, and to develop and improve the technology of observing systems.

Secondly, the NSWP Implementation Plan divides the space environment into three regions.

- *Solar/Solar Wind* includes coronal mass ejections, solar activity/flares, solar and galactic energetic particles, solar UV/EUV/Soft X rays, solar radio noise, and solar wind.

- *Magnetosphere* includes magnetospheric particles and fields, geomagnetic disturbances, and radiation belts.

- *Ionosphere/Thermosphere* includes the aurora, ionospheric properties, ionospheric electric fields, ionospheric disturbances, ionospheric scintillations, and the neutral atmosphere.

For each of these areas a detailed time line was developed showing what research observations will be needed, what research-grade models will be developed to express the understanding of the physical processes at work, what operational models will be implemented based on the research-grade models, and what operational observation systems will be needed to support those models.

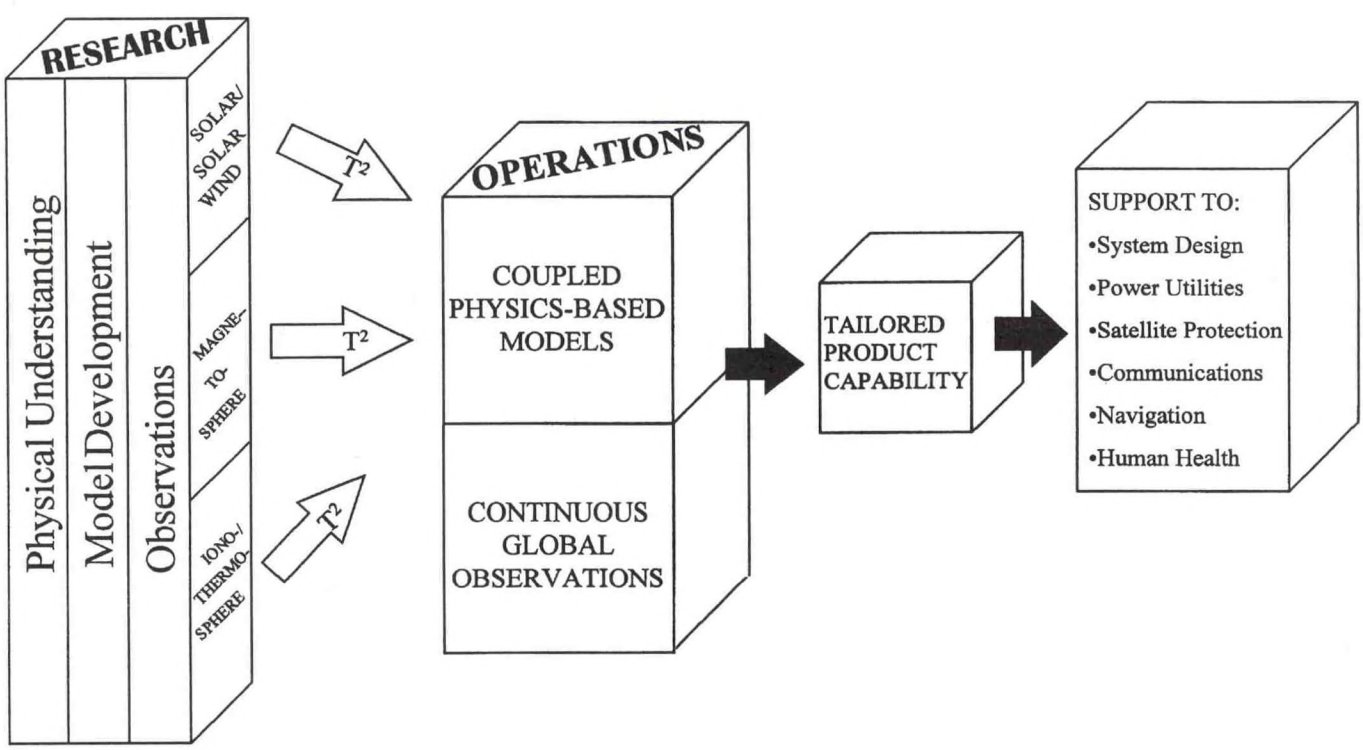


Figure 4.3 National Space Weather Program Roadmap

The implementation plan also prioritizes NSWP efforts by suggesting areas for near-term emphasis, discusses potential education efforts, and provides information on program management such as OFCM management structure, non-federal involvement, metrics, and agency roles and responsibilities.

Finally, the implementation plan addresses the difficult issue of moving technology from the laboratory or academic community into the operational environment. There are many aspects of this issue, which fall under the general heading of "technology transfer" or T^2--building and deploying long-life operational sensors, moving data where it is needed in real time, using operational databases, etc. However, the plan focuses on one of the tougher issues which will be an early and constant challenge during the program--converting research-grade models into operational models. The plan suggests employing rapid prototyping, a process which provides immediate feedback to a development team as they iteratively test implementation concepts in a quasi-operational environment.

Figure 4-3 depicts the overall scheme of the NSWP. The two dimensional nature of the research effort is shown producing new capabilities which proceed through a technology transfer (T^2) process into the operations environment where continuous observations support coupled, physics-based models. This model output is used to produce tailored products which support various missions.

In July 1996, the National Science Foundation awarded $1.3 million to support 23 research projects associated with the NSWP. With detailed research requirements well documented, the focus of the NSWP will shift, in the coming years, toward moving new technology into the operational environment.

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

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 educational 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.

The basic enabling legislation and authority for weather services are summarized as follows:

- 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

NWS 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 Centers for Environmental Prediction (NCEP). The NWS core mission also depends on the study, development, and testing of new methods for improving basic warning and forecast capabilities through research.

Weather Warnings and Forecasts. Both Weather Service Forecast Offices (WSFO) and Weather Service Offices (WSO) issue local warnings for severe weather, such as hurricanes, tornadoes, severe thunderstorms, flash floods, and extreme winter weather. WSFOs prepare forecasts for zones which are comprised of typically one or more 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 and a generalized statewide forecast twice daily, including an 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. In preparing local warnings and forecasts, WSFOs use forecast guidance prepared by NCEP, which is based on worldwide meteorological observations. Two of NCEP's science-based centers--the Storm Prediction Center and the National Hurricane Center/Tropical Prediction Center--provide specialized central support for the local warning program.

Weather Service Meteorological Observatories (WSMO) are additional sources of data for surface observations, upper air observations, and/or radar data. These observations are also used in the NCEP database for generating guidance products used by field forecasters.

Aviation Weather Services. The NWS provides a broad range of services in support of the aviation community. Fifty-two WSFOs prepare site-specific airport terminal forecasts 3 times per day with amendments as needed for over 500 public-use airports in the 50 states and in the Caribbean. These offices also produce about 300 individual route-oriented forecasts 3 times a day for the 48 contiguous states. WSOs also take observations to meet local aviation requirements.

NCEP's Aviation Weather Center prepares Area Forecasts 3 times daily describing general aviation weather conditions over the lower 48 states. This unit also issues in-flight advisories of hazardous weather conditions associated with thunderstorms, icing, turbulence, strong low-level winds, and broad areas of low clouds and/or restricted visibility. In Alaska and Hawaii, these products are issued by WSFOs.

River and Flood Warnings and Forecasts. River Forecast Centers (RFC) 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. NCEP 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 NCEP's Marine Prediction Center, marine weather forecasters at coastal and Great Lakes 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 on 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), which provides real-time operations, data acquisition and data processing, and distribution of meteorological and oceanographic data from moored and drifting buoys and automated observing stations at selected coastal locations. NDBC also provides systems integration, deployment, maintenance and repair, and redeployment of data buoys and coastal

stations. The NWS, through its Port Meteorological Officer Program, also coordinates and manages data acquisition from cooperative merchant ships under the international Voluntary Observing Ship program sponsored by the World Meteorological Organization.

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. Localized weather forecasts are issued, as required, during all wildfire. 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.

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.

Over the last several decades, NWS has made major improvements in forecasting synoptic-scale (large-scale, slowly evolving) weather. As modernization efforts continue, further improvements will be realized in the severe weather and flood warnings program with continuing improvements in larger scale, centrally prepared weather guidance products for Day II 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. Integral to the modernization effort, NWS is reorganizing its field structure to focus more on warnings and short-range forecasts, and, in FY 1995, NMC was restructured to serve a broader mission required by the NWS modernization. The modernized operations concept includes a vertically integrated forecast process in which national centers provide products based on output from numerical models, statistical adjustments to model fields, and value-added products prepared by national center forecasts. This product suite will be transmitted to the modernized Weather Forecast Offices (WFO) in digital form, where forecasters will use them to prepare local forecast products. Under the new, modernized office structure, the responsibilities of the WSFOs and the WSOs will be subsumed by the WFOs.

National Centers for Environmental Prediction (NCEP)

Improved technologies allowed NOAA to reorganize the National Meteorological Center (NMC) into NCEP with seven science-based, service-oriented centers that generate environmental prediction products and two central support centers that develop and operate numerical models on which predictions are based. The structure includes an evolutionary operational numerical model suite, from which forecast products are derived by skilled forecasters, and a supporting research and development program, which emphasizes the relationship between NCEP and the broader scientific community.

The nine national centers that comprise NCEP are:

Hydrometeorological Prediction Center (HPC). The HPC, located at NCEP headquarters in Camp Springs, Maryland, supports the hydrometeorological forecast functions of the NWS. The HPC incorporates the latest in technological support, maintaining an up-to-the-minute monitoring of all precipitation-related events, such as rain, snow, and ice, across the contiguous United States. While basic weather forecasts are prepared mainly for NWS field office guidance, they are also used by the entire meteorological community. Specifically, the National Precipitation Prediction Unit produces forecasts of rainfall and snowfall amounts out to 72 hours. The HPC also prepares analyses of weather conditions at sea level for North America every 3 hours and for the Northern Hemisphere every 6 hours. The HPC also has coastal-marine forecast guidance responsibilities originally planned for a seperate Marine Prediction Center.

Storm Prediction Center (SPC). The SPC, located in Norman, Oklahoma, is the primary NWS center of expertise for forecasting hazardous weather and econonmically disruptive weather events. It provides short-term guidance products for hazardous weather over the contiguous United States and coordinates with NWS field offices on the short-term aspects of

hazardous weather, such as flash floods, thunderstorms, tornadoes, winter storms, blizzards, and freezing precipitation. The SPC draws some of its heritage from the Severe Local Storms Unit of the former National Severe Storms Forecast Center (NSSFC) but differs in that SPC's mission is broader. The SPC also provides internal scientific support and techniques development. This support includes researching, developing, evaluating, and testing forecast methods.

Aviation Weather Center (AWC). The AWC, located in Kansas City, Missouri, enhances aviation safety by issuing warnings, forecasts, and analyses of hazardous weather for aviation interests. The AWC identifies existing or imminent weather hazards to aircraft in flight and creates warnings for transmission to the aviation community and originates operational forecasts for weather conditions that will affect domestic and international aviation interests out to 2 days. The AWC also collaborates with universities, governmental research laboratories, Federal Aviation Administration facilities, international meteorological watch offices, and other NWS components to maintain a leading edge in aviation meteorology hazards training, operations, and forecast techniques development. These functions were formerly handled by three collaborating NWS offices.

Tropical Prediction Center (TPC)/National Hurricane Center (NHC). The TPC, located at Florida International University in Miami, Florida, employs rapid advances in technology and research to issue increasingly accurate and timely watches, warnings, forecasts, and analyses for tropical weather conditions to save lives and protect property. To fulfill national and international responsibilities, the TPC prepares tropical storm and hurricane watches and warnings, tropical aviation and marine warnings and forecasts, and tropical analyses. The NHC remains an integral part of TPC and will continue its responsibility of tracking and forecasting tropical cyclones. The hurricane forecasting and warning programs remain critical for the protection of life and property along the vulnerable areas of the North Atlantic Ocean, Caribbean Sea, Gulf of Mexico, and the eastern North Pacific Ocean. The TPC also has a responsibility to conduct forecast techniques development as necessary to sustain an acceptable level of forecast accuracy and public service. This includes conducting studies and developing and evaluating forecast models.

Climate Prediction Center (CPC). The CPC, located in Camp Springs, Maryland, provides climate services to users in government, the research community, private industry, and the public both in this country and abroad. Services include operational prediction of climate variability, monitoring of the climate system and development of databases for determining current climate anomalies and trends, and analysis and assessment of their origins and linkages to the rest of the climate system. These services cover climate time scales ranging from weeks to seasons, extending into the future as far as technically feasible, and cover the domain of land, ocean, and atmosphere, extending to the stratosphere. The CPC supports and stimulates the application of climate information and services with particular attention to applications in agriculture, energy, transportation, water resources, and health. It monitors, analyzes, and, where possible, predicts large-scale climate variations, such as the El Niño and the Great Flood of 1993, as well as numerous regional climate fluctuations. To support these services, CPC engages in diagnostic research and studies of model output to improve monitoring, analysis, and predictions of the physical climate system. A major milestone occurred in January 1995, when CPC issued the first official long-lead outlooks for the United States out to a year in advance. This effort is part of a plan for delivery of U.S. national climate services for socioeconomic benefit and improved decision-making.

Space Environment Center (SEC). The SEC, located in Boulder, Colorado, provides national and international forecasts, alerts, and warnings of extraordinary conditions in the space environment, solar radio noise, solar energetic particles, solar X-ray radiation, geomagnetic activity, and conditions of stratospheric warming. The SEC observes, assesses, and predicts activity in the space environment to promote public safety and to mitigate economic loss that could result from disruption of satellite operations, communications and navigation systems, and electric power distribution grids. The SEC issues specific predictions of the activity level of space weather for the next 3 days and more general predictions up to several weeks in advance. Weekly summaries of observed solar-terrestrial conditions are also published. The SEC supports theoretical and experimental research to understand the fundamental physical processes governing the space environment and the development of operational techniques and processes. Research

activities focus on areas where advanced applications can be developed to help improve the Nation's space weather service.

Environmental Modeling Center (EMC). The EMC, located in Camp Springs, Maryland, improves NCEP's numerical weather, marine, and climatic predictions through a broad program of data assimilation and computer modeling. In support of the NCEP operational mission to provide ocean prediction, mesoscale prediction (thunderstorms, hurricanes, tornadoes, etc.), and global prediction, EMC develops, adapts, improves, and monitors data assimilation systems and models of the atmosphere, ocean, and atmosphere/ocean system using advanced modeling methods developed internally, as well as cooperatively with scientists from universities, the international scientific community, NOAA laboratories, and other government agencies. The EMC integrates research and technology through its Model Test Facility (MTF). The MTF serves as an efficient and effective interface between NCEP and the scientific community which may develop ideas, models, and techniques that will improve NCEP products. The MTF provides consultation, programming, and computer resources to outside scientists using the NCEP system and coordinates initial evaluations of their work. The EMC conducts applied research and development and publishes research results in various media for dissemination to the world meteorological and oceanographic community.

NCEP Central Operations (NCO). The NCO, located in Camp Springs, Maryland, is responsible for all aspects of NCEP operations, including access to real-time data, and its quality control and use in numerical weather prediction systems. The NCO provides management, procurement, development, installation, maintenance, and operation of all computing and communications-related services which link the individual NCEP activities together. The NCO is the focal point for the establishment and execution of policies, standards, procedures, and documentation for computing and communications within the entire NCEP organization. The NCO houses and runs the supercomputer facility and implements and monitors the management of all operational modifications to NCEP products to ensure the reliability of scheduled services. The NCO provides the technical transition between the research and development of numerical weather and climate prediction models and their operational use. The NCO also manages the NCEP databases for use by numerical weather and climate prediction systems and other operational and developmental efforts of NCEP. In addition, NCO provides 24-hour information services and operational support for NCEP computing systems, including the network which ties together internal NCEP communications, NWS mainframe and supercomputer systems, workstations, graphics plotters, and personal computers.

SUPPORTING RESEARCH

The 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. The NWS conducts 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 the Next Generation Weather Radar (NEXRAD) with Doppler capability, and geostationary satellites with higher resolution (GOES-NEXT).
- 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. The NWS develops 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 NWS River Forecast System.
- Specialized flood and flash flood forecasting procedures using linked hydrological and meteorological models.

- Algorithms to combine WSR-88D precipitation estimates with data from satellites and other ground-based observation systems.

MODERNIZATION

A Strategic Plan for the Modernization and Associated Restructuring of the NWS 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 102-567 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 II and beyond through advanced forecasting models and the requested increased computer processing capability are essential to successful implementation of mesoscale forecasting in NWS field operations, where field forecasters will concentrate on the small-scale, short-lived processes that occur in the 0 to 36-hour timescale.

The National Implementation Plan will provide a planning framework and general strategies for accomplishing the transition as well as advanced notification of when implementation activities are scheduled to occur at each site. The interrelationships of all of the activities--facilities preparation, staffing augmentation, training, commissioning of systems, and realigning operations and services--have begun so that the demonstration can begin in 1996. In addition to preparations for the demonstration, nationwide planning and implementation have begun. Facilities construction is ongoing; training for field personnel is being conducted with necessary backup personnel to cover operational shifts; software development continues; new communications are being established; and all NWS offices have developed and are updating 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 warnings, flood warnings, and forecasts through the acquisition of the following new technologically advanced systems:

- Automated Surface Observing System (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.
- Computer Facility Upgrades 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 warning.

NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE

The National Environmental Satellite, Data, and Information Service (NESDIS) manages United States civil operational environmental satellite systems, as well as global databases for meteorology, oceanography, solid-earth geophysics, and solar-terrestrial sciences. From these sources, NESDIS 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 development and management of environmental resources.

NESDIS was established as a NOAA line office on 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 in sun-synchronous orbits with equatorial crossing times in the early morning (circa 7:30 a.m. LST) and early afternoon (circa 1:40 p.m. LST). These satellites collect global data four times per day that provide atmospheric and surface measurements in support of short-term weather forecasting and longer-term global climate change research. An agreement to be finalized in 1996 with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) will give EUMETSAT responsibility for the morning segment of the polar environmental mission, with U.S.-provided payload instruments and sensors, beginning early in the next decade.

NESDIS is also responsible for operating two geostationary operational environmental satellites (GOES). One monitors the Atlantic Ocean, the U.S. East and Gulf Coasts, and the U.S. Midwest; the other monitors the Pacific Ocean and West Coast.

The first of a new series of NOAA geostationary satellites, GOES-8, was successfully launched on April 13, 1994, and subsequently moved to its new operating position of 75°W. GOES-9 was launched on May 23, 1995 and, after extensive testing was repositioned at 135°W, reaching its final position on January 11, 1996. This operational configuration of east and west satellites establishes routine geostationary satellite coverage of the entire U.S. and adjacent waters at 15-minute intervals by the new generation of GOES.

ENVIRONMENTAL SATELLITE SERVICES

The Office of Satellite Operations (OSO) 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) stations, which command and control, track, and acquire data from these environmental satellites.

The Office of Satellite Data Processing and Distribution (OSDPD) 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 (NWS) and other domestic and foreign users.

Arctic Drifting Buoy Program. The United States Interagency Arctic Buoy Program (USIABP) was established in 1992 to provide the management structure and coordination necessary to maintain a baseline network of drifting buoys. Buoys within the array provide sufficient spatial resolution to define surface synoptic scale atmospheric pressure, air temperature, and sea-ice drift fields. Data are used in real-time for operational weather and ice forecasting and for research in the Global Climate Change Program. The USIABP is a collaborative program that draws operating funds and services from the collective contributions of eight government agencies and/or programs. These organizations include: the Naval Oceanographic Office, ONR, NASA, NSF, and NOAA's NESDIS, OAR, and OGP.

The NWS Satellite Field Distribution Facilities (SFDF) distribute processed geostationary satellite products to regional NWS offices and other federal, state, and private sector agencies. The products also are made available to private groups at their expense. SFDFs are located in Washington, D.C., Miami, Florida, Kansas City, Missouri, Honolulu, Hawaii, San Francisco, California, and Anchorage, Alaska. The Anchorage, Washington, San Francisco, and Honolulu SFDFs redistribute data from both the polar-orbiting and geostationary systems. The San Francisco, Anchorage, and Honolulu SFDFs also have the capability of receiving data broadcast directly from the polar-orbiting satellites via the High Resolution Picture Transmission (HRPT) Image Processing System (see "Polar-Orbiting Systems" below.)

The Office of Research and Applications (ORA) provides guidance and direction for NESDIS research and applications activities. It coordinates the efforts of the Satellite Research Laboratory and Satellite Applications Laboratory. These laboratories conduct studies on the use of satellite data to monitor environmental characteristics and change and develop algorithms to analyze these data for applications to operational weather prediction. Further, ORA participates in the development of new spacecraft and sensors for future systems. It also carries out a vigorous program to calibrate and validate satellite data to ensure its quality for long-term studies. Staff from

these laboratories also conduct a strong technology transfer program through scientific presentations, technical reports, and training workshops at domestic and international sites.

Polar-Orbiting Systems

These satellites increase the accuracy of weather forecasting by providing quantitative data required for improved numerical weather forecast models. Currently, the primary operational spacecraft are NOAA-14 and NOAA-12. NOAA-14 was launched December 30, 1994 to replace NOAA-11 as the primary afternoon spacecraft. NOAA-9 and NOAA-11 also provide data from operational sensors. NOAA polar satellites carry instruments to provide atmospheric temperature and moisture profiles. They also provide multi-channel images and carry a data collection and platform location system, and a Search and Rescue Satellite-Aided Tracking (SARSAT) subsystem. The SARSAT subsystem is used to detect and locate distress alerts from maritime, aviation, and land-based users. They are provided through the International COSPAS-SARSAT Program. Russia, the United States, France, and Canada provide the space segment and related ground systems for COSPAS-SARSAT. Over 25 states are now formally associated with COSPAS-SARSAT as ground segment providers or user states. NOAA operates and maintains the United States SARSAT Mission Control Center and seven ground stations. The ground stations receive Doppler signals directly from the satellites and process the information to provide the location of distress transmissions.

During the lifetime of the NOAA system, new instruments may be added or substituted for others. NOAA-14 carries a sensor to measure ozone. NOAA-9 carries a sensor 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 meters long, 1.88 meters in diameter, with an orbit weight of 735 kg. NOAA-14, NOAA-12, NOAA-11, and NOAA-9 operate in near-polar, sun-synchronous orbits and provide environmental observations of the entire Earth eight times each day. As of January 1996, NOAA-12 crosses the Equator in a southward direction at 0658 local standard time; NOAA-14 crosses the Equator in a northward direction at 1350 local standard time; NOAA-11 crosses the Equator in a northward direction at 1824 local standard time; and NOAA-9 crosses the Equator in a southward direction at 0945 local standard time. The orbital period of the satellites ranges from 101.11 to 102.07 minutes which produces 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. The AVHRR instrument provides stored and direct-readout radiometer data for day and night cloud cover, sea surface temperatures, vegetation indices, and snow and ice mapping. AVHRR read-out is accomplished by the following:

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

The TIROS-N 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). HIRS/2, the primary instrument providing tropospheric data, is sensitive to energy from the visible to the carbon dioxide absorption region of the infrared (IR) 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 absorption 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 absorption region of the microwave spectrum and is used in conjunction with the two IR instruments. The microwave data permit computations to be made in the presence of clouds.

The Data Collection System (DCS) is provided by the Centre National d'Etudes Spatiales of France and is called the ARGOS DCS. The ARGOS DCS 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 especially in the polar regions, beyond transmission range of the geostationary satellites. An upgrade to allow forward message downlinking is being considered for the NOAA-N'satellite.

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 two sensors included within this instrument are the Total Energy Detector (TED) and the Medium Energy Proton and Electron Detector (MEPED), in addition to a common data processing unit. This instrument augments the measurements made by NOAA's geostationary satellites. The data from the SEM are processed at Suitland, Maryland, and transmitted over a dedicated data link to NOAA's Space Environment Center in Boulder, Colorado, within 1 hour of the spacecraft readout. Space environment data from the NOAA satellites, as well as the geostationary 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. SEM data are archived and disseminated to other government agencies, industry, and the public by the National Geophysical Data Center.

In addition to the four primary instrument systems, the "afternoon" NOAA series spacecraft carry the Solar Backscatter Ultraviolet Radiometer (SBUV/2). SBUV/2 is a non-scanning (fixed nadir viewing) spectrometer designed to measure scene radiance and solar spectral irradiance from 160 nanometers to 400 nanometers. Data obtained from the instrument are used to compute the amount and vertical distribution of ozone in the Earth's atmosphere on the sunlit side of the Earth. Ozone data obtained from the SBUV instrument on Nimbus-7 and the SBUV/2 on NOAA-11 were merged to yield a continuous data set from 1979-1983. This data set is being used to determine trends in the global ozone distribution. Subsequent incorporation of data from the SBUV/2 instruments on NOAA-9 and NOAA-14 will allow the data set to be extended to 1996.

The ground system required to receive large volumes of digital data from NOAA satellites consists of two major subsystems--the Polar Acquisition and Control Subsystem (PACS) and the Central Environmental Satellite Computer System (CEMSCS). The PACS includes the Wallops, Virginia, and Fairbanks, Alaska, CDA stations and the SOCC at Suitland, Maryland. All the CEMSCS components are in the NOAA facility at Suitland.

PACS is used to command and control the spacecraft, monitor its health via housekeeping telemetry, and retrieve and transmit the spacecraft environmental data to the CEMSCS processing and data handling facility. The delivery of NOAA system data from the CDAs to Suitland is accomplished by using the General Electric 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 CEMSCS for processing. The CEMSCS ingests the raw satellite data and pre-processes and stores them along with appended auxiliary information, such as Earth location and quality control parameters. The data processed by the CEMSCS are used for environmental products and operational weather predictions which are disseminated to users throughout the world.

Geostationary Satellite Program

GOES-9, launched May 23, 1995, completed its check-out phase in October 1995 from 90° West. During the month of November, NOAA then conducted an Extended Research Checkout (ERC) using the new satellite to scan the contiguous United States every three minutes to build data sets for future

meteorological research. Following ERC, GOES-9 was maneuvered to drift to its operating position of 135° West. GOES-9 replaced the 9 year old GOES-7 for all western operations, including WEFAX, DCS, and SARSAT, on January 11, 1996. The spacecraft was stopped at 135° West on January 23. NOAA will follow GOES-9 with the launch of GOES-K, possibly as early as April 1997.

GOES-8 and GOES-9 now cover virtually the entire western hemisphere for operational meteorological services. New operating schedules allow acquisition and distribution of imagery from the satellites four times per hour over the much of North America in Routine mode, and eight times per hour over the continuous U.S. during severe weather situations.

GOES-7, the last in NOAA's series of spin-stabilized geostationary spacecraft, has been placed in a standby mode over a central longitude. Following some cross-satellite calibration tests, no further imaging will be scheduled from this spacecraft.

The projected launch schedule and associated instruments for geostationary satellites are shown in Table A.1.

The GOES-Next satellites host an imager capable of detecting atmospheric, sea surface, and land properties in five spectral bands including the new 3.9 micron (μ) and 12.0μ wavelengths. Unlike GOES-7, the new GOES satellites transmit all five spectral bands simultaneously affording the user community continuous views of atmospheric measurements in various wavelengths, each with its own meteorological and hydrological application. GOES-Next spacecraft were also designed for flexible scanning of the Earth; a variety of scans or sector coverage can be scheduled within a 30-minute time frame. For example, the full earth disk is scanned once every three hours and requires the entire 30 minute time period. Depending on weather, 30 minute periods during the 2½ hours

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TABLE A.1 PROJECTED SATELLITE LAUNCH SCHEDULE

POLAR-ORBITING SYSTEM

Satellite Designator	Planned Launch Date*
NOAA K	CY 1997
NOAA L	CY 2000
NOAA M	CY 2001
NOAA N	CY 2004
NOAA N'	CY 2007

GEOSTATIONARY SYSTEM

Satellite Designator	Planned Launch Date*
GOES K	CY 1997
GOES L	CY 2000
GOES M	CY 2004

Instruments for Advanced TIROS N Series

AVHRR	Advanced Very High Resolution Radiometer
SEM	Space Environment Monitor
SBUV	Solar Backscatter Ultraviolet Radiometer
HIRS	High Resolution Infrared Sounder
SAR	Search and Rescue System (Antenna)
DCS	ARGOS Data Collection System
AMSU-A	Advanced Microwave Sounding Unit-A
AMSU-B	Advanced Microwave Sounding Unit-B

Instruments for GOES-Next Series

Imager	
Sounder	
SEM	Space Environment Monitor
SXI	Solar X-Ray Imager (GOES L or M)
SAR	Search and Rescue
DCS	Data Collection System

*Launch date depends on performance of prior spacecraft.

after the full disk scan may be a mixture of 15 minute interval (routine weather) or 7½ minute interval (severe weather) scans over the United States, with other time spent imaging selected regions of the Atlantic and Pacific Oceans as well as South America (GOES-East) and New Zealand (GOES-West). The five channels and respective resolutions are as follows:

- Channel 1 (Visible, .55μ to .75μ)--1 km.
- Channel 2 (Infrared, 3.8μ to 4.0μ)--4 km.
- Channel 3 (Water Vapor, 6.5μ to 7.0μ)--8 km.
- Channel 4 (Infrared, 10.2μ to 11.2μ)--4 km.
- Channel 5 (Infrared, 11.5μ to 12.5μ)--4 km.

GOES-Next satellites are capable of providing hourly atmospheric sounder coverage over the continental United States for input to weather forecast models and other near-real-time analyses.

The GOES-8 and GOES-9 sounder, consisting of 19 spectral channels (GOES-7 has 12 spectral channels), is used for measurements of atmospheric temperature and moisture profiles, surface and cloud top temperatures, and ozone distribution. Products derived from the sounder include precipitable water and lifted index--a measurement of atmospheric stability. Comparable to the imager, the sounder is capable of providing various scan coverages, such as full Earth imagery, sectorized imagery, and local imagery. An independent sounder platform, governed under its own schedule, leads to an expansion of sounder-data coverage and an increase in the frequency of transmissions.

The GOES also carries a DCS 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. GOES satellites rebroadcast imagery, meteorological analyses, and other environmental data to remote locations using the WEFAX system. Data are collected for warnings of solar activity using SEM. This block of instruments is more extensive than on the polar spacecraft. The GOES SEM instruments include X-ray monitors that detect solar flares, energetic particle sensors, and three-component vector magnetometers to measure changes in the ambient magnetic field. Real-time SEM data are used to support operational NOAA and DOD space environment forecasts and alerts. Data from GOES SEM sensors are archived by the National Geophysical Data Center and provided to retrospective users on-line via Internet and on a variety of computer media.

A system similar technically to the DCS, but used for a different purpose, is the SARSAT transponder. The operational SARSAT transponders on GOES-8 and GOES-9 are capable of providing an immediate distress alert. While the present GOES system is incapable of providing location of the distress signal, it provides advance warning to the SARSAT Mission Control Center which then begins to verify the location of the alert through other means. Future COSPAS-SARSAT distress beacons, utilizing Global Positioning System (GPS), will have the capability to provide location information in the distress message. Remapped GOES-8 and GOES-9 images for the NWS AWIPS began flowing to "Pathfinder" sites at Boston and Pittsburgh via the point-to-multipoint data feed known as NOAAPORT in 1995. NWS will deploy another 14 AWIPS sites in 1996, and the remaining 100 or so in the following two years. NOAAPORT delivers GOES imagery available to forecasters within seconds of satellite scanning and makes it a valuable new real-time capability.

As AWIPS development and deployment proceed, NESDIS will continue to supply digital GOES images to a group of NWS sites equipped with the RAMM Branch Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS)--a PC-based image display and analysis system. These sites acquire the images via the Internet for demonstration, evaluation, and familiarization purposes. RAMSDIS enables forecasters to perform operations such as looping, enhancement curve changes, and local image recombination.

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 (OSO) which consists of the SOCC and two CDA stations at Wallops, Virginia, and Fairbanks, Alaska. The OSO

is responsible for the operation and safety of NOAA polar and geostationary satellites and for providing satellite data to the OSDPD Suitland, Maryland.

Another major component is the Environmental Satellite Distribution/Interactive Processing Center (ESD/IPC) in Camp Springs, Maryland. The ESD/IPC is connected in turn with the Fairbanks and Wallops CDA stations and the six SFDFs.

A third major component, managed and operated by OSDPD, is the NOAA Operational Satellite Active Archive (SAA) for satellite data and metadata access, display, and electronic transfer. Developed as a collaborative effort between OSDPD and NOAA's National Climatic Data Center, the SAA offers the user a wide range of capabilities, including data catalog and inventory search, AVHRR image browse, on-line data selection and file transfer protocol (FTP), and off-line data selection and delivery. On-line system documentation, data guides, and help files will assist the novice user and provide valuable time-saving tips to all users. While developed as an independent system, the SAA serves as NOAA's initial interoperable interface to the National Aeronautics and Space Administration's (NASA) Earth Observing System Data and Information System (EOSDIS). In 1994, AVHRR Level 1B data sets became the first SAA satellite data available for browse and delivery on the Internet. In September 1995, TOVS (HIRS, MSU, and SSU) Level 1B data sets were added and a system established, though not yet operational due to lack of resources, for providing retrospective (pre-1994) AVHRR data and browse products. Development efforts are underway to add NOAA-K, RADARSAT, and DMSP special sensor data by the end of FY 1997.

SUPPORTING RESEARCH PROGRAM

The requirements and goals addressed by NESDIS supporting research in FY 1997 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 Space Sciences).
- The NWS modernization effort (including strengthening the environmental observing and prediction systems and improving the application and dissemination of products and services) (per P.L. 100-685).
- Improvement in monitoring of the global ocean and in managing coastal zone resources.
- The management of data that will be needed to support the above.
- The development, evaluation, validation, and implementation of new products and services from GOES-8 and GOES-9: this activity also supports NWS modernization.
- The continuation and improvement of products and services from the polar-orbiting satellite system. The GOES-Next satellites provide higher resolution, enhanced multispectral imaging and separate sounding systems. Ongoing research will focus on new applications and products from this new sensor suite. Hourly soundings are being produced for the continental United States and adjacent waters. These have been tested in current and developmental numerical models to support NWS modernization initiatives. Special products, such as precipitable water and atmospheric stability, are being evaluated. These products, together with wind, temperature, and moisture profiles and ASOS, will improve temporal and spatial observations, particularly in coastal and mountainous sounding areas, complementing the improvements expected in the global polar soundings after the launch of NOAA-K.

The new capabilities of GOES-8 and GOES-9, along with improved data collection and archival resources, have already provided unprecedented opportunities in 1995 for assessing rapid interval imagery over a wide variety of weather systems. Special 1-minute and 3-minute interval data sets were collected for a large number of case studies, which included severe thunderstorms, land falling hurricanes, and lake effect snow events. During the entire month of November, 1995, GOES-9 provided nearly continuous 3-minute imagery over the continental United States. Those data were collected and archived for analysis by NOAA/NESDIS at the Cooperative Institute for Research in the Atmosphere (CIRA) in Colorado. A number of significant Great Lakes snow events occurred during the November test, as well as significant cyclones with a blend of snow, freezing rain, and heavy rainfall. The cases are currently under investigation by NESDIS scientists at CIRA in conjunction with NWS Science and

Operations Officers. The data are being studied to identify features which appear in rapid interval imagery but are either not observed or not depicted well in 15- and 30-minute interval imagery. Test results suggest that highly accurate cloud motions at both cumulus and cirrus levels can be derived from both the 1-minute and 3-minute interval imagery. The measurements clearly depict the extent of cyclonic flow at the top of hurricanes, and in some cases cloud drift winds have been derived in and near the hurricane eye wall.

Early results from research on tornadic storms with the new data show the importance of 1-minute interval imagery in the detection of very-small-scale interactions between two thunderstorms just prior to one or both of the storms becoming tornadic. 1-minute imagery also shows differences in the development of the anvils of the tornadic storms, as they build upshear against the prevailing flow, blocking the upper level jet. Other cases are being investigated with special data sets collected during the Verification of the Origins of Rotation Experiment (VORTEX) that took place in Oklahoma, Kansas, and Texas during the spring of 1995. Those cases involve both research and operational Doppler radar data, aircraft, and special chase teams.

The RAMSDIS has been providing digital satellite data to select NWS Forecast Offices across the U.S. for over 2 years. The RAMSDIS project was developed to make high quality digital satellite imagery available to NWS Forecast Offices as a means of familiarizing forecasters with use of GOES-8 and GOES-9 digital imagery and in preparation for AWIPS implementation. There are currently over 50 RAMSDIS sites across the country. RAMSDIS also includes several satellite data analysis applications developed by the CIRA/RAMM team. The response from the forecasters indicates that RAMSDIS: (1) is easy to learn and is quickly accepted by staff, (2) significantly improves utility of satellite imagery and improves the quality of NWS forecast/nowcast products, and (3) provides early exposure to high quality imagery, better preparing staff for the integration of digital satellite data into a full AWIPS workstation capability. Forecasters recommended that RAMSDIS be implemented at all NWS Forecast Offices with Internet capability.

Research focusing on the new IR channels is exceptionally encouraging. The GOES 3.9μ channel is already providing a variety of new and exciting applications of digital satellite imagery. During daytime, 3.9μ imagery is composed of both emitted terrestrial radiation and reflected solar energy. At night, only the emitted component is present.

At night, the 3.9μ and 10.7μ channels may be used in combination to develop an image product which can be used to distinguish between ice clouds and lower water clouds. This nighttime product is referred to as the "fog product" and has been found to be very useful in depicting fog and stratus at night when visible images are unavailable and when the 11μ IR images show very little temperature difference between the top of the fog or stratus and the adjacent clear areas. Image products and interpretation techniques using the GOES 3.9μ channel have been introduced for real-time evaluation on RAMSDIS and have received enthusiastic response from the user community. The "fog product" has proven to be a very useful product at the NWS Aviation Forecast Center in Kansas City where digital imagery analysis capability has existed for over a decade.

Research and development of applications of environmental satellite data are devoted to the improvement 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, volcanic aerosol detection, programs for agriculture, fisheries, coastal zone management, and 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 (winds, temperature, and moisture structure) that is essential for numerical weather analysis and forecasting.

NESDIS is developing products and procedures to assist forecasters in computing Quantitative Precipitation Forecasts for heavy precipitation events. High values of precipitable water (PW) often become antecedent conditions prior to the development of heavy precipitation and flash floods. High values of PW frequently appear as plumes, areas or surges of moisture in the 6.7μm data. Experimental blended PW products have been developed for detecting these all important surges or areas of high concentrations of moisture. One of the blended PW products uses

Special Sensor Microwave Imager (SSM/I) from the DMSP and GOES-9 with Aviation Model derived PWs filling the data voids. This product is designed for medium range forecasting and covers the western hemisphere between 70°W and 170°W. The second, designed for 0 to 24 hour forecasting of heavy precipitation, includes a region slightly larger than the Continental United States and extends south to 20°N. This product is a blend of both SSM/I and GOES-8 and GOES-9 data with the ETA model filling data voids.

An experimental Automatic Flash Flood Precipitation Estimator has been developed for the analysis of heavy precipitation over the United States and surrounding areas. This algorithm produces instantaneous and accumulative amounts at any time interval. This algorithm was developed by calibrating the GOES-8, 10.7μm cloud top temperatures with Doppler rainfall rates. This algorithm is further modified by a Moisture Correction Factor (based on PW and Relative Humidity) and a simple IR gradient detector to screen out cirrus. In the near future, cloud growth will be included to help detect active/heavy rain areas of convective systems. In addition, a validation methodology is being established that will compare estimates from the automatic technique with rain gages. Validation of the operational Interactive Flash Flood Analyzer algorithm for diagnosing flash floods continues and will be used as a benchmark for the Automatic Flash Flood Precipitation Estimator.

Extremely heavy rainfall amounts falling over already saturated soils can accentuate the adverse impact of flash floods. A knowledge of antecedent soil conditions can assist forecasters and, thereby improve timely and reliable information to users regarding the potential for flash floods. An experimental Soil Wetness Index has been designed to identify soil surfaces that are either extremely saturated or flooded. Such a product can be used to assist forecasters in their preparation of flash flood watches and warnings.

Climate analysis, diagnosis, and monitoring performed by NCEP's Climate Prediction Center depend upon global satellite observations of the incoming and outgoing radiation fluxes, clouds, and aerosols. Improvements in the estimation of the Earth's radiation fluxes at the top of the atmosphere are planned. A scene-dependent model will replace the global model that computes the planetary albedo from the visible and near infrared channels on the AVHRR. Also, a two-dimensional histogram of shortwave vs. longwave fluxes will be produced, replacing the two one-dimensional histograms of the fluxes. This will provide additional information on the fluxes not available heretofore. Experimental products of longwave fluxes (at the top, bottom, and within the atmosphere) derived from the HIRS have been developed and will be undergoing improvements and testing. The means for globally detecting cloud and cloud-free pixel arrays and for specifying total cloud amount from the AVHRR has been developed over the last several years. This information has been enhanced by the development and testing of the global pixel-scale analysis system for multiple-layered cloud types; validation and improvements of the resulting products will continue. Cloud optical and microphysical properties are to be derived from these products. The NCEP models could be greatly enhanced with information on the layering of the clouds. The aerosol optical thickness is currently available from the AVHRR. The current single-channel algorithm requires some estimate of the size distribution. A two-channel algorithm is being investigated for the next generation of polar satellites (beginning with NOAA K), where potentially both a size distribution parameter and the aerosol optical thickness will be available. This effort should yield a more accurate estimate of the aerosol optical thickness.

NESDIS scientists at the CIRA and the Cooperative Institute for Meteorological Satellite Studies played a key role in the development of the first Satellite Data interpretation module produced by the Cooperative Program for Operational Meteorology, Education and Training (COMET). The module, "Satellite Meteorology Remote Sensing Using the New GOES Imager" is the first such module to be on CD-ROM. The module will be used extensively throughout the NWS and DOD communities for training of forecasters in the use of digital GOES imagery. The module is also available for use in universities and is an excellent teaching tool for students. Although the title of the module refers to GOES, which is the main satellite whose data are addressed, it has great utility across the board for those interested in interpretation of satellite imagery from any meteorological satellite. The various sections address science-related issues that include

radiative transfer, the sun-earth-atmosphere energy system, selective absorption by atmospheric gases, and channel selection for various meteorological applications. The module includes case studies that address phenomena, such as severe weather, tropical storms, and the identification of fog and stratus at night. Various sections have short subjects tests to allow users to track their progress.

ENVIRONMENTAL DATA CENTERS

National Climatic Data Center (NCDC)

NCDC has the principal responsibility to manage the national climatological data program, including data and information services. To meet this responsibility, NCDC:

- Performs all data management functions regarding retrospective meteorological data, including data from in-situ and remote sensing sources (satellites, radars, etc.). Such functions include acquisition, archiving, retrieval, indexing, quality assessments, evaluation, synthesis, dissemination, and publication of data collected by global and national observation networks or systems. Meteorological data that have enduring value to the Nation and are sufficient to describe the climate are included.
- Designs and implements new systems as necessary for ingesting, processing, quality control and archiving of new data streams from the NWS modernization program.
- Operates as a designated Agency Records Center for processing, storage, and servicing of retrospective meteorological data 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 databases 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 (WMO) programs.
- Operates the World Data Center-A (WDC-A) for Meteorology under the auspices of the International Council of Scientific Unions. In this capacity, NCDC archives the data collected by internationally sponsored research programs and actively exchanges climate data with foreign countries.

NCDC is the archive for meteorological data sets from World Climate Research Program and WMO World Climate Data and Monitoring Program projects, such as the Tropical Ocean-Global Atmosphere (TOGA) Program, the Global Precipitation Climatology Program (GPCP), the International Satellite Cloud Climatology Program (ISCCP), etc.

Climate Data Management. Along with the modernization of weather services, the use of new technologies and the expansion in use of modern communication services will bring data into the archives much quicker. Therefore, more timely access by users to climate data and products will be achieved. Activities and plans for FY 1997 include:

- NOAA holds extensive collections of foreign meteorological and climate data in the NOAA Central Library and at NCDC's foreign data library. Heretofore, the data held in publications, microform and magnetic media had not been cataloged in an automated catalog system that could be accessed outside of the two libraries. The data holdings were cataloged and entered into the NOAA's Master Directory and are available for searching in NOAA's automated catalog system called NOAALINC. Both systems can be accessed by telephone dial-in and contents can be searched using keywords including country and climate parameters.

- NCDC has continued technology and systems upgrades (i.e., computers, workstations, on-line storage and access, communication, etc.) to meet data management and services requirements into the next decade. The Hierarchical Data Storage System (HDSS) providing on-line access to digital data will be expanded in FY 1997 to hold 50 terabytes of data to meet the increasing demand. The acquisition of data and products from NCEP will be migrated from mail services and to telecommunications and directly ingested into HDSS. This will include data and products such as surface synoptic and upper air data collected from Global Telecommunications System, model output (global analyses), aircraft reports from Aircraft Reports Management System, etc.

▸ Data (Level III products and Level II data) from about 100 WSR-88D systems are currently received for archiving. During FY 1997, data from all 160 WSR-88D sites will be available for archiving and servicing. To aid users in accessing these data and products, interactive browsing and data ordering systems will be placed on the World Wide Web.

▸ As part of a continuing program to update and modernize processing systems, NCDC completed the development and implementation of the hourly precipitation data processing system. Smarter quality control coupled with interactive graphics has brought higher quality data with less manual effort. The Hourly Precipitation Data publication was modified so that data quality flags are presented along with precipitation values. During 1997, an new processing system for Monthly Climate Data for the World (MCDW) will be implemented with improved quality control resulting in an increase of global data.

▸ NCDC currently ingests via telecommunications five data sets (1-minute data, 5-minute observations, hourly observations, daily summary data, and systems log information) from over 200 commissioned ASOS sites producing Local Climatological Data (LCD) publications and providing digital data to a variety of users. Continued commissioning of ASOS sites will increase the data volumes substantially and will make these data more readily available to users. During 1997, sophisticated monitoring capabilities will be added to the ingest system to insure a more complete receipt of the data.

▸ NCDC continues to place high priority environmental databases on-line for easy access by researchers and others. Metadata are provided to adequately describe the data and their availability. NCDC continues to develop tools to assist the users in obtaining the data they need to browse and to visualize the data. CLIMVIS, an interactive WWW graphics system using NOAA's Environmental Data archived at NCDC has been implemented. CLIMVIS dynamically generates time series, contour and vector plots in real time. Another program, CLISERV provides capability to integrate various types of data for a particular location or time. CLISERV also provides the capability for viewing on-line inventories (WSR-88D, ASOS, etc.) and to order data on-line. This system maximizes the use of Internet GUIs and WWW navigation tools in making data and metadata accessible to researchers. Additional capabilities, expanded user tools, and more data sets will be will be available in 1997. CLISERV and CLIMVIS can be accessed on NCDC WWW homepage.

▸ Working with the WMO, NCDC continues to collect climate data and metadata from foreign countries for the preparation of a high priority global data set to monitor climate change. The Global Climate Perspectives System (GCPS) is a joint scientific venture between NOAA's Environmental Research Laboratory (ERL) Climate Diagnostics Center Laboratory (CDCL) and NESDIS/NCDC, sponsored by NOAA's Office of Global Programs. The GCPS is available for comparing current climate observations with long-term trends to put current observations into perspective. Using this system, researchers are be able to access data, perform analyses and inter-compare parameters. In FY 1996, a mapping and gridding routine was assembled for station and gridded data. Complex quality control procedures have been put into place, gridded global products have been produced, and numerous scientific papers have been published. In FY 1997, a client-server version of GCPS will be completed, additional data sets will be added, and additional tools for analyzing data will be made available, including some consolidation of homepage analysis systems.

▸ The Comprehensive Ocean-Atmosphere Data Set (COADS) project is a multi-year/multi-agency program funded by Office of Global Programs (OGP) and ESDIM to provide an updated reference data set covering the world's ocean environment. In FY 1996 via a cooperative effort among NESDIS/NCDC, ERL and NCAR, the data period of record will be updated through the mid 1990s, additional data will be added to data-sparse periods, and some known problems corrected. FY 1996 accomplishments include the completion of the keying of 2 million Maury Obs (ship observations for the period 1820-1860) in the Peoples Republic of China, and Quality Control of 1 million U.S. Merchant Marine observations for the 1912-1946 period. Conversion software was developed for converting 24 of the Merchant Marine keying formats to a common format compatible to COADS.

In FY 1997, COADS Release 1b will be completed, the Film Optical Sensing Device for Input to Computer (FOSDIC) film recovery of additional information will be performed, the conversion software for converting the Maury Collection to the common COADS format will be completed, and the

60 percent of the U.S. Merchant Marine collection that has been quality controlled will be converted to the COADS common format for merging into COADS Release 2.

▸ The Comprehensive Aerological Reference Data Set (CARDS) project completed the building of a database containing daily global upper air observations for the period 1948-93. It is composed of 23 GB of data for a total of 2500 stations. Data from some 20 different sources were combined to form this Complex Quality Controlled on-line database. A baseline set of core stations will be identified. In FY 1997, the CARDS project will complete the building of the global upper air database through 1996. The database will be made available both in time sort (synoptic) and station sort. Inhomogeneities (biases) will be identified and adjusted for a core set of stations. A comprehensive station history will also be made available.

▸ NOAA ERL's Climate Monitoring and Diagnostics Laboratory (ERL/CMDL) and NESDIS/NCDC have been working for the past four years on a NOAA Office of Global Programs-sponsored Trace Gas Project. Global baseline trace gas data sets, such as CO_2, CH_4, O_3, and CFC's have been collected by CMDL and with the help of NCDC, the data sets have been quality controlled, documented, placed on line, and secured in the NCDC archive. Others have been put on the Internet/WWW for user access. Work has been competed during FY 1996 to update all data sets, prepare documentation and establish procedures for performing the work on an operational basis.

▸ The 19th Century FORTS/Signal Corps project, a project to digitize the meteorological observations taken at U.S. military forts and by the Signal Corps during the 19th century, has concentrated on establishing a preliminary data set, identifying stations, digitizing the manuscript records, and quality controlling the data. During FY 1996, the efforts will concentrate on the 1822-1860 period to complete the processing and archiving of these data and associated metadata. These will be available to research in FY 1997.

▸ The United States Historical Climatology Network (USHCN) is a joint project between the DOE/CDIAC and NESDIS/NCDC. Data sets of numerous climatological variables have been prepared and quality controlled with many inherent biases removed. During FY 1996, data set updating was initiated and will continue on a workstation-based system for much improved efficiency and data handling capability. Data can now be analyzed shortly after month's end.

▸ The United States Precipitation Metadata project has been supported by the NOAA OGP for the past 4 years and is producing unbiased data sets of monthly rainfall and snowfall for GCIP. Wind-induced turbulence biases have been removed by applying algorithms based on a combination of information and data, such as observing gage sitings, gage shields, and average monthly wind speeds. In FY 1997, these corrections will be applied to the USHCN data set.

▸ The NCDC functions as the Surface Reference Data Center (SRDC) for the World Climate Research Program Global Precipitation Climatology Project (GPCP). The SRDC is supported by NOAA OGP which is supporting precipitation validation within the GPCP. The SRDC has provided support to GPCP by collecting and validating surface-based precipitation station data from a number of globally distributed test-site areas. Work during FY 1996 concentrated on the production of area-averaged validation data for all test sites, with the application of precipitation/elevation adjustment algorithms. In FY 1997, a paper containing the results on the comparison of precipitation calculated from remotely sensed data from satellites with in-situ precipitation measurements will be completed and available to research.

▸ The Global Historical Climatology Network (GHCN) is a cooperative data collection and quality assurance project between the DOE/CDIAC and NESDIS/NCDC of global monthly temperature, pressure, and precipitation data. The GHCN version 1, consisting of monthly temperature, precipitation, and pressure data was released three years ago and work has since progressed on version 2. This version will include many more global stations extending back to the 19th century. The data for Version 2 will be quality controlled using sophisticated algorithms and will also be homogeneity-adjusted. In FY 1996, version 2 release includes a maximum/minimum temperature data set in addition to monthly mean temperature. Population metadata will be available in order to more accurately determine global temperature trends that are free of

urban heat island biases. In FY 1997, a complete version 2 will be released with the addition of precipitation and pressure data. A near-real-time update and analysis system will be implemented to keep the data set current as new data are received.

- NCDC is collaborating with NESDIS' ORA in a study of the effects of changes in land use/land cover on monthly and seasonal averages of diurnal temperature range (DTR). The study is combining AVHRR data with monthly temperatures and associated metadata from the USHCN for the period 1981-90. Preliminary results show that significant differences in DTR could be associated with certain predominant land use/land cover types. This work will be completed for the current series of satellites and will be available in FY 1997.
- NCDC is continuing work in collaboration with the WMO on the collection, compilation, and quality assurance of climate normals for the globe for the period 1961-90. More than 100 countries have sent in normals data for a wide-range of climatological parameters. The data will be sent in publication-ready format to the WMO Secretariat during FY 1996.

- For FY 1997, NCDC will complete the production of the publication *Climatology #20 of the United States*. This publication is based on normals data collected for 1961-90 for selected U.S. sites and includes such parameters as degree days, precipitation probability, freeze data, growing degree units, daily maximum and minimum temperature, monthly temperature means, extremes, days with selected meteorological elements, and precipitation totals.

Climate Data Services. The demand for basic climatic data and information services has continued to increase. NCDC expects to service over 157,000 request for data and information during FY 1997. In addition, over 2 million accesses to on-line data and information services are expected to be handled by the Center's automated systems. To meet the demand for data and information, on-line services are being expanded utilizing dial-in services and the Internet (WWW and mosaic/homepage). Currently, 20 data sets are accessible on-line. The number of data sets available on-line will be expanded to 30 in FY 1997 and the volume of data available increased. NCDC's home page will be frequently updated with added data and access capabilities. Researchers can access the homepage and view the availability of data and information by accessing the following URL address: *http://www.ncdc.noaa.gov*.

NCDC and NESDIS/OSDPD implemented the operational SAA making near real-time satellite data available on-line for browsing images and/or accessing and ordering data. Data can be transferred computer-to-computer or ordered for off-line delivery.

There is also a demand for climate data and information products on CD-ROM media. NCDC has previously released 19 CD-ROM volumes. An additional 9 volumes are pending release in 1996 and another five are planned in FY 1997. Available volumes and planned releases can be viewed on NCDC Homepage.

National Oceanographic Data Center (NODC)

The 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 TOGA program, the World Ocean Circulation Experiment (WOCE), and the Joint Global Ocean Flux Study (JGOFS). 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, and shipping industry.

Data Management. 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 manages subsurface thermal data in support of TOGA. This activity is now part of a larger, global effort called the Global Temperature-Salinity Pilot Project (GTSPP). A

cooperative international project, GTSPP was initiated to improve the quality, volume, and accessibility of global ocean temperature and salinity data.

NODC is participating in the JSAL by 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 137 stations in the Pacific Ocean Sea Level Network originally established as part of the North Pacific Experiment.

An initial project of JCRMOD was the establishment and operation of a data information unit in support of WOCE. An on-line information system called Oceanic provides WOCE and TOGA program information to principal investigators and other researchers. In addition to an oceanographic component, TOGA Coupled Ocean-Atmosphere Response Experiment (COARE) also includes ocean-atmosphere and atmospheric interface components, thus extending the types of data to be tracked beyond those for WOCE. An information system for TOGA/COARE analogous to Oceanic is also operational.

To promote efforts to locate and preserve older, historical ocean data, the NODC/WDC-A, Oceanography, is the project lead for the WMO-approved Global Oceanographic Data Archaeology and Rescue (GODAR) Project. The success of initial GODAR activities has already resulted in the submission to NODC of an additional 960,000 temperature-salinity profiles from 9 countries, and nearly 300,000 station profiles from 4 countries.

NODC's research group has published a series of scientific papers described by decadal-scale variability of the North Atlantic Ocean as determined from the analysis of historical data. In particular, time-series data from Ocean Weather Stations "C" and "5," and a seven-volume ocean atlas providing objective analyses of major ocean parameters has been published. Also, a nine-CD-ROM series of the 1994 World Ocean Atlas has been published.

Data Services. During FY 1994, NODC filled 10,712 user requests and disseminated over 750 gigabytes of digital data to customers. CD-ROM continues to be an increasingly important medium on which to disseminate large ocean data sets. At the end of FY 1994, NODC had released about 60 individual disks holding several major ocean data sets and other ocean data products. In early FY 1994, NODC established Gopher and Mosaic servers on the Internet. These servers contain information about NODC, and its products and services. These servers enable basic data browse and electronic data ordering services to be conducted interactively. Internet accesses average about 5,000 sessions each month and have resulted in reducing client servicing times from an average of 4 days to 2 days per client request.

NODC has management responsibility for the NOAA Library and Information Network which includes:

- The NOAA Central Library in Silver Spring, Maryland, where usage has increased threefold in 1 year.
- Regional libraries at major NOAA facilities in Miami, Florida, and Seattle, Washington.
- More than 30 field libraries and information centers at other NOAA locations throughout the United States.

Technology Enhancements. An upgraded Ethernet local area network (LAN) links the distributed computing resources at NODC's headquarters offices. Silicon Graphics workstations function as distributed servers to support NODC database operations, user services, and data communications. Peripheral devices include magnetic tape drives (9-track, 8 mm, IBM 3480 cartridge), an optical disk drive, and an optical "Jukebox" that provides over 300 gigabytes of mass storage. The Ethernet LAN operates with TCP/IP protocol and supports about 90 nodes, including both high speed workstations and PC-class computers. Internet processing of oceanographic data is now done using in-house resources in an interactive mode.

National Geophysical Data Center (NGDC)

NGDC participates in a number of national and international programs that provide data for research in meteorology and climatology. NGDC provides data processing and archival programs concerned with atmospheric emissions recorded by satellite instruments, as well as indirect or proxy measures of past climates. NGDC also provides services for supporting data sets including global environmental in-situ measurements and data describing the cryosphere.

At NGDC, NOAA established a program to assemble global information on paleoclimate and to

cooperate in research projects to employ the combined global paleoclimate database for climate model verification and climate change studies. Support for this program from the NOAA Climate and Global Change Program (CGCP) is continuing.

NGDC has actively sought and acquired many paleoclimate databases derived from tree-rings, pollen and macrofossils, lake and bog sediments, marine sediments, ice cores, and other geological and biological sources. Digital data sets have been enhanced with custom display and search capabilities. These research tools are currently being distributed to the paleoclimate community. Objectives of the program are to cooperate with researchers from NOAA, other agencies, and academia to describe the global patterns of decade-to-millennial scale climate change, to identify and understand the causes of this climate change, to improve the ability of separating man-induced climate change from the natural variability, and to validate the models that are being used to predict global climate change the next several centuries.

NGDC uses in-house data archives to conduct research in past, present, and future climates. NGDC is computing the amount of carbon released into the atmosphere by fires on a global scale. The computation combines our Global Inventory of Biomass Burning from satellite imagery with statistical and laboratory models of vegetation type and combustion efficiencies.

NGDC prepares research-quality archival data sets from the complete complement of operational DMSP satellites. Instruments on DMSP satellites use remote-sensing techniques to monitor the horizontal and vertical structure of the atmosphere. NGDC's processing system is very extensive covering data rescue, calibration, navigation, and quality control. The archival data sets include visible, near infrared, thermal infrared, and microwave imagery of clouds, cloud types, snow, ice, fires, lightning, oil flares, etc., microwave sounding of atmospheric temperature and water vapor profiles, ionospheric plasma parameters, and the Earth's magnetic field. Data services include tape copies, on-line search and browse, and image display and analysis software.

Long-term, global records of solar electro-magnetic variability archived at NGDC are the principle data bases available to support research into the impact of changing solar energy output affecting Earth and climate change. Older ways of observing solar activity continue to provide continuity between the past and modern observations using new technology deployed on the Earth and in space. Satellite instruments now monitor total solar irradiance and spectral irradiance at a few selected wavelengths before modification by the Earth's atmosphere. However, proxy data sets from the long-term archives are required to provide longer term records that describe the past output of solar energy. Both the long term archives and the total solar irradiance and some of the spectral irradiance data are available from NGDC. Data services include tape copies and on-line access.

Another source of energy input into the Earth's upper atmosphere is particles of external origin which are monitored by instruments on NOAA satellites. Because these particles are electrically charged, they provide both direct and indirect means to transfer energy to the atmosphere. NGDC archives the Space Environment Monitor data sets from DMSP and the NOAA polar-orbiting and GOES satellites. Data services include tape copies, on-line search and browse, and display software. Reduced volume data sets are also available on CD-ROM.

The National Snow and Ice Data Center (NSIDC) at the University of Colorado, and associated with NGDC, maintains several cryosphere-related data sets 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 NOAA snow cover and DOD-NOAA sea ice chart digitizing programs. NSIDC provides data management services for the Second Greenland Ice Sheet Program and the National Science Foundation (NSF) funded Arctic System Science Ocean-Atmosphere-Ice Interaction research programs. In addition, NSIDC has developed gridded sea ice products (sea ice concentration and multiyear ice fraction) based upon passive microwave data collected by the Scanning Multi-channel Microwave Radiometer on Nimbus 7 and the DMSP Special Sensor Microwave Imager. The passive microwave data sets are being distributed on CD-ROM. In addition, NSIDC serves cryospheric and polar users of DMSP data from the NGDC digital archive. Under NOAA funding, NSIDC is acquiring snow cover, glacier, and sea ice records from former Soviet Union scientists and institutes.

NGDC is integrating multithematic global and continental data for intercomparison and analysis related to studies of global change. Various elements of this program include:

- Global Ecosystems Database, an integrated multidisciplinary environmental CD-ROM database structured for Geographic Information Systems and designed to support global characterization and modeling research.
- Africa Global Change Database, initially constructed as a pilot database for the pedecessor to the Global Ecosystems Database, is now an educational product being made available to the teaching and research communities.
- Regional integrated databases for China, North America and South America. Additions to the Ecosystems database are released annually. The past releases included global data sets of topography, AVHRR-derived monthly vegetation indices, vegetation, ecosystems, and land-cover classifications, methane emissions, soil classes and properties, long term average monthly temperature, precipitation, cloudiness, geographic boundaries, and model-derived outputs. Global View, a four CD-ROM set was released in 1995. These data, circulated to the global change research community, included the Global Ecosystem, Global Vegetation Indices, Digital elevation Models and Coastal Change Analysis databases.

In addition to integrated database products distributed on CD-ROM, NGDC also maintains and improves individual disciplinary data sets related to its mission, to include the Generalized Monthly Global Vegetation Index, Experimental Calibrated Biweekly Global Vegetation Index, Tateishi Monthly Global Vegetation Index and derived land-cover class, Olson World Ecosystems, Varlyguln/Basllevitch above-ground phytomass, CZCS marine phytoplankton pigment concentrations, global and continental topography, global geographic boundaries, numerous geophysical data sets, and an operational archive of DMSP satellite meteorological data. In support of these databases, graphic browse and visualization software is being developed. These databases and the associated supportive access software will play an important role in the NOAA CGCP.

OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH

ENVIRONMENTAL RESEARCH LABORATORIES

The R&D programs of the Environmental Research Laboratories (ERL) support NOAA meteorological, oceanographic, and space 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 warnings and forecasts and improved utilization of data and numerical products. Severe weather includes any major natural hazard, such as flash floods, strong winds, thunderstorms (including tornadoes, lightning and hail), heavy snowstorms, extreme cold or drought, and geomagnetic storms. ERL laboratories will continue to conduct both in-house and cooperative research with other NOAA components, joint institutes, and universities.

Observing Technology. The Environmental Technology Laboratory (ETL), formerly the Wave Propagation Laboratory, develops and experimentally evaluates new environmental remote-sensing concepts and systems. ETL also improves the Nation's atmospheric research and warning and forecasting services through the transfer of remote-sensing technology.

As an outcome of ETL research, ERL's Forecast Systems Laboratory (FSL) is operating the wind profiling Doppler radars that make up the Wind Profiler Demonstration Network (WPDN). This network, located mainly in the central United States, is providing hourly winds aloft data to weather forecasters and is helping improve weather warnings and forecasts.

During FY 1996, ETL will continue development of new sensors and techniques for combining observing systems synergistically and economically. Specific efforts include the development and integration of the radio-acoustic sounding system (RASS) into wind profilers to augment their capability with temperature profiles and continuing development of techniques that can integrate the data from

ground-based and satellite-borne profiling systems for more effective use of this data in forecasts. ETL and FSL will continue investigating the use of inexpensive GPS receivers to achieve real-time, continuous observations of total atmospheric water vapor.

ETL will also continue development of Lidars and infrared Doppler multifrequency radars as research tools to improve our knowledge of atmospheric winds, turbulence, and moisture processes. Development of dual-polarization Doppler and multifrequency radars and passive radiometers will also be undertaken to study convective storms and their precursors, including in-cloud and entrainment processes. ETL will also continue research in the area of ocean remote sensing, including theoretical and experimental studies of rough surface scattering processes.

Tropical Atmospheric Research. The Tropical Dynamics and Climate Program of the Aeronomy Laboratory (AL) is using a network of remote-sensing wind profilers in a long term study of tropical circulation and its impact on global climate. The Trans-Pacific Profiler Network consists of an array of wind profilers and Integrated Sounding Systems that make continuous measurements of atmospheric winds and other parameters in the tropical Pacific. In addition to 50 MHz wind profilers, the network is incorporating 915 MHz lower tropospheric wind profilers recently developed at AL. The observations, which extend from the boundary layer to the lower stratosphere, reveal the relationship between atmospheric vertical motions and convective systems in the tropics. Precipitation measurements can be made with sufficient vertical resolution to categorize precipitation in deep and shallow convective systems and in stratiform conditions. The network will (1) provide valuable improvements to the boundary layer and convective parameterization schemes used in general circulation models and (2) contribute to climate forecasting by furthering the understanding of the coupled ocean-atmosphere dynamics that governs the El Niño-Southern Oscillation (ENSO) phenomenon, the dominant component of interannual climate change.

Routine wind observations are made at Christmas Island using a 50 MHz and 915 MHz profiler. Lower tropospheric wind measurements using 915 MHZ profilers are made at San Cristobal, Ecuador, and Tarawa, Kiribati. In addition, surface and upper air measurements are being made at Nauru and Manus Island, Papua New Guinea, using Integrated Sounding Systems installed by AL. Data from these systems are used by NCEP and the European Center for Medium Range Weather Forecasting in their operational analysis and forecast products. The data are also used by climate researchers to support investigations of the variability of tropical atmospheric circulation systems.

Severe Weather Analysis and Forecasting Research. The National Severe Storms Laboratory (NSSL) in Norman, Oklahoma, and the Forecast Systems Laboratory in Boulder, Colorado, focus on research to understand and forecast severe weather systems and their associated hazards, such as tornadoes, hail, high winds, heavy rain and snow, lightning, and ice storms. The parameters of storm development and intensification are identified and studied by incorporating observations from Doppler weather radar, satellites, remote-sensing wind profilers, instrumented aircraft, and lightning-location networks. Work is being expanded to include assessment and improvement of numerical models to forecast severe weather systems.

NSSL provides significant technical and scientific support, including research and development, for the WSR-88D program. In FY 1996, NSSL will continue to develop techniques in cooperation with the NWS to forecast and warn of weather hazards to aviation and the general public. Work with the resultant data from the 1994-1995 VORTEX experiment will lead to new understanding of severe thunderstorms, improved ways to model and predict these storms, and new generation algorithms for severe storm detection. Immediate technology transfer will be effected by close association with the WSFOs, particularly those in Norman, Oklahoma, and Phoenix, Arizona.

Also, ERL will continue to transfer knowledge of Doppler radar applications, severe weather systems, and heavy rainfall events; much of the transfer is through courses at the NWS training center. Visits and interactions with NWS centers, regional headquarters, and forecast offices continue and FSL and NSSL are participating directly in training programs such as the COMET in Boulder and the WSR-88D Operational Support Facility in Norman.

Improvement of short-range (1-12 hour) forecasting will be accomplished by the development

and evaluation of new local data system technologies and techniques, many of which can be incorporated into operational weather forecasting in the near term. FSL develops and evaluates prototype workstations for forecast office environments. Specifically, FSL has and will continue to develop capabilities to allow the forecaster to integrate, view, and manipulate observations from current and planned meteorological sensing systems using computer-assisted data display and synthesis techniques. By maintaining state-of-the-art capability for use in research and development of operational techniques, it continues to provide a mechanism to evaluate weather service requirements for AWIPS.

FSL will continue its emphasis on data application from GOES, Doppler radar, Aeronautical Radio Incorporated (ARINC) Communications Addressing and Reporting System (ACARS), and the WPDN as inputs to quantitative analysis and prediction models, such as the Mesoscale Analysis and Prediction System and the Local Analysis and Prediction Systems. FSL is expanding service improvement efforts to include non-severe as well as severe weather to assist NWS modernization and restructuring and to help upgrade NCEP operations.

A multiyear program of coastal meteorology research continues at the Pacific Marine Environmental Laboratory (PMEL). This program also involves ETL and NSSL, the NWS Forecast Office in Seattle, NCAR, and the University of Washington. Support for the program is also being provided by the Office of Naval Research (ONR) and NSF. This research is intended to improve the understanding of the effects of prominent terrain on U.S. West Coast weather, with the ultimate goal of providing improved forecasts of coastal winds, sea state, and storm surges. The early emphasis has been on the upstream effects of the coastal terrain in the storm environment when the background forcing is strong and the coastal forecasts are most critical. The approach being taken involves a combination of special field observations and diagnostic studies using experimental numerical simulations. Field work featuring a NOAA WP-3 research aircraft, for example, has yielded meteorological data for the Pacific Northwest coast with low-level winds of up to 85 knots, in the vicinity of two of the strongest cold fronts ever observed in detail over the ocean. The case studies from this work will provide immediate insights on the influences of the coastal terrain on landfalling storms, and high quality data sets for numerical model initialization and validation.

Mesometeorology and Precipitation Forecasting and Warning Research. NSSL and FSL develop techniques to improve short-term forecasts of significant weather events. Through detailed case studies and regional climatologies, scientists from these two laboratories have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storms complexes. Studies underway include the precipitation structure of mesoscale convective systems, interactions between mesoconvective systems and the larger environment, using satellites to infer storm development and rainfall, and winter storm forecasting procedures. In FY 1996, NSSL will continue to use polarization information to improve radar procedures for rainfall estimation.

Midlatitude Mesoscale Meteorology Research. At the Aeronomy Laboratory, the Atmospheric Dynamics Program combines observational and theoretical studies of mesoscale, high frequency atmospheric processes, focusing on internal gravity waves and vertical air motion. By improving the understanding of these dynamical processes, the research contributes to improvements in weather forecasting and the transfer of advanced meteorological measurement technology to operational use. Data for the studies is obtained from the 50 and 915 MHz wind-profiler radars at the Flatland Meteorological Observatory, which make continuous horizontal and vertical wind measurements in the very flat terrain near Champaign-Urbana, Illinois. The observatory also includes a 915 MHz RASS to measure temperature, an array of 24 digital barometers spread over Illinois, and standard surface and balloon-borne instruments. The research has shown that all enhancements of gravity-wave energy are associated with meteorological events, such as fronts, convection, or jet streams, and that such events always cause enhancements. In 1995, a multi-year program was initiated to study the dynamics of the atmospheric boundary layer, including measurements of the vertical entrainment velocity, which is of great importance to the vertical transport of trace species into the free atmosphere.

Hurricane Analysis and Prediction Research. The Hurricane Research Division (HRD) of the

Atlantic Oceanographic and Meteorological Laboratory (AOML) explores hurricanes in dedicated research flights aboard the WP-3D aircraft operated by NOAA's Aircraft Operations Center (AOC). The P-3s carry a suite of instruments to measure a wide range of meteorological quantities, including standard flight-level data, remotely sensed surface winds, vertical soundings, radar reflectivity, and Doppler radar winds. In addition to the airborne observations, HRD develops techniques for real-time analysis and display of hurricane data, especailly of surface winds. It also carries out modeling and theoretical studies closely tied to the observational program and studies interannual and interdecadal changes in hurricane activity.

During the 1996 hurricane season, AOC will commission a new Gulfstream IV (G-IV) jet that will extend the envelope of observations throughout the depth of the troposphere. These three airplanes present an unprecedented opportunity for better understanding and forecasting of hurricanes through detailed observations. Of special interest are the hurricanes' inner core and the oceanographic and upper tropospheric synoptic-scale forcings that control intensity and motion.

The motivation for acquisition of the G-IV was a statistically rigorous demostration, based upon more than a decade of experiements with the P-3s, that intensive observations of the flows surrounding hurricanes can produce dramatic (16-30 percent) reductions in track forecast errors. The forecast system currently has limited skill in prediction of intensity. Though continuing research with the expanded aircraft fleet, the Nation can realize the experimentally demonstrated potential for improvement as much more accurate routine operational track forecasts. A second, equally significant, outcome is the promise of dynamically based, skillful intensity forecasts. Because hurricanes inflict costs on the U.S. economy of billions of dollars per year, even incremental improvements in forecasts have large benefit to expenditure ratios.

In addition to HRD research activities, the ERL scientists carry out hurricane research at the Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey. GFDL's Hurricane Dynamics group performs hurricane modeling research to study the genesis, development, and decay of tropical storms using multi-nested three-dimensional computer models of the hurricane system and its surrounding environment.

Because of the success of the group's research model in predicting the behavior of observed storms, GFDL scientists have worked with scientists at NOAA's NWS to develop a version of their research model for use in operational hurricane forecasting. The subsequent success of this model during the 1993 and 1994 hurricane seasons caused NWS in June 1995 to the name GFDL model as its official hurricane forecast model for the 1995 hurricane season.

Numerical Analysis and Prediction Modeling. As part of its weather research activities, GFDL conducts long lead-time research to understand the predictability of weather on both large and small scales and to translate this understanding into improved numerical weather prediction models. Three groups at GFDL are engaged in weather research activities: Experimental Prediction, Mesoscale Dynamics, and Hurricane Dynamics (described above).

Experimental Prediction at GFDL develops and improves numerical models of the atmosphere-ocean-land system in order to produce useful weather forecasts with lead times ranging from weeks to seasons and beyond. The group is pursuing several avenues of research to achieve such improvements. First, GFDL scientists are investigating methods of stochastic dynamic prediction in order to extract as much forecast information as possible from numerical prediction models, given imperfectly observed initial conditions. In addition, laboratory scientists are developing methods for the assimilation of ocean observations into prediction models in order to improve the forecast of the atmosphere and the ocean.

Mesoscale Dynamics at GFDL develops and utilizes atmospheric models with limited spatial domains to understand mesoscale phenomena and the interaction of these regional scale features with the atmosphere's larger-scale synoptic processes. As part of these research activities, GFDL scientists investigate the practical limits of forecast models to predict the behavior of these mesoscale features through model sensitivity studies.

Air Quality Research. The Air Resources Laboratory (ARL) carries out research on processes that affect the quality of the atmosphere, primarily in the context of air pollution, deposition, and

emergency preparedness; much of this work is in support of other agencies such as DOE, Environmental Protection Agency (EPA), and DOD.

The ARL Headquarters Division in Silver Spring, Maryland, develops models for air quality prediction, for use in special forecasting (both weather and air quality) programs and in emergency response. The Atmospheric Sciences Modeling Division, in Research Triangle Park, North Carolina, develops predictive models on local, regional, and global scales, for assessing changes in air quality and air pollution exposure, as affected by ecosystem management and regulations. This work is primarily to provide technical guidance to the EPA on air pollution control strategies for attainment and maintenance of ambient air quality standards. The Atmospheric Turbulence and Diffusion Division, in Oak Ridge, Tennessee, conducts studies to improve understanding of atmospheric transport, diffusion, and air-surface exchange processes, and to develop new predictive models. The Field Research Division, in Idaho Falls, Idaho, designs and conducts field studies to evaluate the performance of transport and dispersion models, over local, regional, and continental scales. The Special Operations and Research Division, in Las Vegas, Nevada, conducts research on problems of mutual interest to NOAA and DOE, that relate to the Nevada Test Site, its atmospheric environment, and its emergency preparedness and emergency response activities. (Note: See the DOE discussion in Appendix D for more details).

The Aeronomy Laboratory (AL) conducts research on air quality as part of its tropospheric chemistry program. A primary focus is on understanding the processes of near-surface ozone formation in rural regions. Field experiments, laboratory work, and numerical modeling studies assess the relative roles of natural hydrocarbons emitted from vegetation, anthropogenic hydrocarbons, and nitrogen oxides in controlling ozone production. A series of field experiments have been conducted in recent years in the southeastern United States, a heavily vegetated region which frequently experiences elevated levels of ozone. Since 1994, these field studies have expanded to include measurements from an aircraft platform, the NOAA WP-3D, in addition to ground-based observations. In certain areas, analysis of the data has linked ozone production most strongly to anthropogenic nitrogen oxides and natural, but not manmade, hydrocarbons. It has also underscored the regional nature of the ozone formation process and suggested that some municipalities are affected by events beyond their control. These results have implications for regulatory approaches to controlling air quality in the region.

Ozone production on the global scale is being studied by AL in the North Atlantic Regional Experiment. The study has been undertaken in response to the growing concern that long range ozone transport may influence air quality on an interhemispheric scale. Comprehensive chemical and dynamical measurements, made from both ground-based and from airborne platforms during several field missions of this experiement, track the changing composition of air masses containing pollutants from eastern North America as these air masses were carried into the North Atlantic. Results indicate that the quantity of ozone generated photochemically from anthropogenic emissions on the North American continent exceeds that injected from the stratosphere. This conclusion supports the contention that ozone derived from anthropogenic pollution has a hemisphere-wide effect at northern temperate latitudes.

ETL uses its suite of remote sensors, including a mobile profiler network, airborne and ground-based ozone lidars, Doppler lidar, and supporting turbulence instrumentation, to understand and better model the transport, transformation, and fate of primary and secondary pollutants in both rural and urban environments, as well as in complex orography.

Space Environment Services. NOAA and the Air Force jointly operate the National Space Weather Operations group in NOAA's Space Environment Center (SEC) in Boulder, Colorado. The SEC, working closely with the Air Force's 50th Weather Squadron (50WS), 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 DOD, DOT, DOC, DOI, DOE, NASA, NSF, commercial users, and the research community:

- To optimize the operation of technical systems that are adversely affected by disturbances in the space environment.

- 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 high altitude aircraft and in space, degradation of surveillance and monitoring systems for defense, errors in navigation systems, perturbations of satellite orbits, and disruptions in power distribution networks.

SEC serves as the international World Warning Agency for the solar-terrestrial environment. It collects international data--X ray, sunspot, corona, magnetic, etc.--in real time and from these data provides International URSIgram and World Days Service and meets additional specific needs of other government agencies. SEC distributes (receives) data to (from) other countries and issues a consensus set of daily forecasts for international use.

SEC operates with observations received from agencies that contribute their data and, in return, receive the synthesized and integrated services to meet their needs. Agencies making major contributions of data include: DOD, NASA, DOC, NSF, DOE, and DOI. SEC cooperates directly with NESDIS to receive solar X-ray, particle, in-situ magnetic field, and plasma data from the Space Environment Monitors on GOES and the polar-orbiting NOAA satellites.

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

Voluntary Observing Ship (VOS) Program. OAR operates a global VOS Program that provides real-time meteorological and oceanographic data from selected vessels. Data are collected with the Shipboard Environmental Data Acquisition System, which transmits the information to NOAA via the GOES system. The information is then disseminated nationally and internationally using existing data networks. Presently, there are over 120 vessels in the program which record and transmit surface meteorological information four times per day at synoptic hours. Of these vessels, about 60 also are equipped to collect expendable bathythermograph data.

Southern Hemisphere Drifting Buoy Program. In support of Global Climate Observing System (GCOS) requirements, OAR, in cooperation with NWS, OGP, AOML, and the Scripps Institution of Oceanography, maintains a network of approximately 100 meteorological drifting buoys in the Southern Hemisphere. The buoys measure sea level atmospheric pressure, air temperature, and sea water temperature. Observations are obtained through the ARGOS data collection and platform location system on-board the NOAA polar-orbiting satellites.

Tropical Atmosphere Ocean (TAO) Moored Array. OAR is a partner with OGP in the implementation of the TAO moored-buoy array. TAO is a basin-wide array of moored ATLAS buoys deployed in the tropical Pacific that report surface wind, air temperature, sea surface temperature, 10 subsurface temperatures to a maximum depth of 500 meters, and 2 subsurface pressures in real-time via the ARGOS system. There are 70 buoys deployed. The array is operated by the TAO Project Office located at PMEL in Seattle, Washington, where NOS has responsibility for management of project operations and logistics. While the principal objective is to support research objectives, the real-time availability of data makes it extremely valuable to operational meteorological centers.

Military. The U.S. Air Force operates the 50th Weather Squadron (50WS) in Colorado Springs, Colorado, to provide space weather support to DOD assets. The 50WS operates and maintains the solar observing network with sites at Palehua, Hawaii; Learmouth, Australia; San Vito, Italy; Ramey, Puerto Rico; Sagamore Hill, Massachusetts; and Holloman AFB, New Mexico. The 50WS shares space weather support responsibilities with its civilian counterpart the SEC.

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 the development of national policy for the oceans and their users. NOS efforts are coordinated with marine programs administered by the other components of NOAA. Operational ocean observing activities administered by NOS include water-level programs and real-time currents/current prediction programs.

National Water-Level Observation Network (NWLON). NOS operates and maintains the NWLON for the collection of water-level data, as well as other oceanographic and meteorological data. The NWLON consists of 189 stations located in U.S. coastal areas and the Great Lakes. Through its strategic locations and data dissemination capabilities, NWLON supports a number of NOAA and other federal programs, such as the NOS Tide Prediction Program, NWS Tsunami Warning System and storm surge warning/forecast activities, Climate and Global Change Program, and the U.S. Army Corps of Engineers lake-level regulation, dredging operations, and coastal construction efforts.

Physical Oceanographic Real-Time System (PORTS). PORTS is a data acquisition and dissemination system which integrates a number of important meteorological and oceanographic parameters, including currents, water levels, and marine winds. Traditional NOAA tide and current prediction tables provide only the astronomical tides and currents and do not always meet the needs of users who must also consider the non-tidal effects of river flow, winds, and other meteorological forces. PORTS measures and integrates these important data and provides a data dissemination system that includes telephone voice response, as well as modem access.

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 MacDill AFB in Tampa, 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 instruments, integrates user-supplied instruments into the automated systems, and processes and analyzes data sets 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 update hurricane track/intensity analyses and forecasts. The AOC aircraft have primary responsibility for reconnaissance of tropical storms and hurricanes over foreign airspace that may be restricted for military operations. AOC also augments Air Force Reserve operational aircraft reconnaissance when storms are within 24 hours of landfall of the continental United States and whenever DOC needs exceed DOD resources. In addition, AOC provides a quick response capability for investigation of storm activity east of 80° longitude from August 1 through September 30 each year.

The AOC is scheduled to begin the operation of the new high altitude jet for hurricane surveillance, which is expected to improve hurricane track predictions by 20 percent or more, saving about $10 million per hurricane in warning and preparedness costs. With some additional instrumentation, the jet

will become a prototype for the next generation hurricane reconnaissance aircraft, as well as serving as a platform for air chemistry and other research in the upper troposphere, from 25,000 to 45,000 feet, which is above the WP-3D's altitude limit.

APPENDIX B

DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates a military environmental service system to provide specialized worldwide meteorological, space environmental and oceanographic analysis and prediction services in support of military forces. This system directly supports all phases of military operations, from strategic planning to tactical operations. While the Army and Marine Corps each have a small specialized weather support capability, the Naval Meteorology and Oceanography Command and Air Force Weather are the primary sources of military weather products. The military weather services contribute to the national and international weather observing capability by taking conventional observations on land and at sea where there are no other conventional weather observing capabilities and where the observations are most needed to meet military requirements. In addition, DOD maintains specialized observing capabilities, such as the Defense Meteorological Satellite and Global Weather Intercept Programs, 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 AIR FORCE

METEOROLOGICAL SERVICES

The Air Force functional manager for meteorological and space environmental services is the Director of Weather (HQ USAF/XOW), within the HQ USAF, Deputy Chief of Staff for Plans and Operations. HQ USAF/XOW oversees the development and implementation of weather support concepts, doctrine, policies, plans, and programs to ensure effective weather support for the Air Force, Army, and other agencies as directed by the Chief of Staff, USAF. The Air Force also provides support to DOD Joint operations as directed by the Joint Chiefs of Staff under the Unified Action Armed Forces (JCS Publication 0-2) document. HQ USAF/XOW also interfaces with other military departments, federal agencies, and international organizations concerning coordination, cooperation, standardization, and interoperability of weather services.

Air Weather Service (AWS), a field operating agency (FOA) reporting to HQ USAF/XOW, provides centralized weather support to designated users through two centralized support organizations: Air Force Global Weather Center (AFGWC) and the Air Force Combat Climatology Center (AFCCC). Air Force Space Command provides space environmental support through the 50th Weather Squadron (50 WS), formerly the Air Force Space Forecast Center.

Observations. Meteorological observations are classified as surface, upper air, radar, or satellite observations. Observation and sensing of the space environment are discussed in the Space Environmental Services section.

Surface observations are taken by Air Force personnel to support military operations and for weather analysis and forecasting. Observations from both Air Force and Army locations (fixed and tactical) are made available to local users and are transmitted to AFGWC and to other military and civil locations throughout the world. There are 160 Air Force-operated 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 comes from U.S. and foreign rawinsonde sources and military and civilian satellite-derived data. Additional upper air information is obtained from military and civilian pilot reports.

Weather radar is a principal source of information for providing warnings of severe weather. By 1997, the Air Force will be operating 29 WSR-88Ds (Weather Surveillance Radar-1988 Doppler) and 148 off-site WSR-88D remote processors. The Air Force also operates approximately 7 conventional weather radars and 3 tactical weather radars. Many of the radars are part of the U.S. basic weather radar network or are used to support the National Hurricane Operations Plan. The tactical weather radars are used to support contingency operations. The Air Force is evaluating

concepts for a tactical doppler weather radar which could operate in both mobile and fixed locations.

The Air Force manages the Defense Meteorological Satellite Program (DMSP), which provides a large volume of cloud, upper air, and space environmental data, and is the most important single source of global weather data used for combat support. On-board sensors provide AFGWC and the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) with visible, infrared, and microwave imagery of the entire globe, temperature and moisture sounding data, auroral electron counts, and other specialized space environment data. DMSP also supplies direct, real-time readout of regional image and mission-sensor data to selected land-based and shipborne terminals located worldwide.

The present DMSP satellite series (Block 5D-2) uses an operational linescan system (OLS). The visible detectors were selected to optimize distinction among clouds, ground, snow, 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 and humidity sounder (SSM/T) which provides vertical temperature moisture and height profiles of the atmosphere. The microwave imager (SSM/I) observes rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data.

Communications. The utility of meteorological information depends on an effective communications network. The USAF global weather communications system provides for the collection of meteorological data from multiple, worldwide sources, delivers these data to weather centrals and forecast facilities, and distributes products to the field. The Air Force communications system consists of conventional alphanumeric networks, high-speed automated digital facilities, long-haul, point-to-point data circuits, facsimile networks, and high-frequency intercept facilities.

The Air Force-operated Automated Weather Network (AWN) is the backbone of military weather communications. Computers inter-connected with 2400 baud to 56 kilobaud circuitry deliver foreign and domestic weather data to designated users. Weather intercept sites in key overseas areas obtain World Meteorological Organization (WMO) weather broadcasts, as well as non-WMO broadcasts, for AWN delivery to AFGWC. The AWN also delivers these data to the Navy and to NOAA's National Centers for Environmental Prediction.

Overseas collection and dissemination networks deliver data to, and exchange data with, the AWN Automatic Digital Weather Switch (ADWS) at Hickam AFB, Hawaii, and RAF Croughton, UK. In the CONUS, the ADWS at Tinker AFB, Oklahoma, provides alpha numeric products to the Automated Weather Distribution System (AWDS), the CONUS Meteorological Data System (COMEDS), and other special teletype systems, and provides direct support to AWDS in the collection and dissemination of weather information. These circuits also collect and disseminate military Notice to Airman (NOTAM) message traffic to all DOD CONUS users.

The Communications Front-End Processor (CFEP) at Offutt AFB, Nebraska, is the hub of all communications at AFGWC. It drives dedicated circuits, the Interdepartmental Meteorological Data Exchange System (IMDES), and the weather chart facsimile system, which provides graphic data to worldwide military users. CFEP also interfaces with the AWN and drives separate graphics networks serving the CONUS, Alaska, Europe, Central America, and the Pacific.

Preparation of Analyses and Forecasts. The primary center for providing weather analyses and forecasts for Air Force and Army operations is AFGWC at Offutt AFB, Nebraska. AFGWC uses a networked computer system and an interactive graphics and imagery system to implement a "build-and-apply" concept. Worldwide weather data are relayed to AFGWC and blended with civil and military meteorological satellite data to construct a real-time, integrated environmental database. Computer programs further digest the data to construct models of the atmosphere and to forecast its future behavior. Manual tailoring of the data is critical for application to the specific needs of the warfighters. The interaction between forecaster and machine is accomplished with the Satellite Data Handling System (SDHS). SDHS consists of approximately 38 interactive workstations capable of high-speed interaction with satellite and conventional meteorological data to prepare forecasts and other environmental products. AFGWC also provides backup for the National Weather Service (NWS) facsimile network, the NWS Automation of Field Operations and Services (AFOS) products, and the National Severe Storms Forecast Center.

In support of DOD combat operations, Air Force Weather operates centralized units consisting of AFGWC, AFCCC, 50 WS, fixed theater Forecast Units (FU), fixed Weather Support Units (WSU), and provides personnel to deployed Joint Meteorological/Oceanographic (METOC) Operations Center (JMOC). Normally weather support is a mix of centrally and locally produced meteorological products. AFGWC is shifting to a regional emphasis with special cells designed for major world regions. These regional cells provide large scale analyses, forecasts and guidance for local meteorologists who apply the information to specific 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 JMOC provides the same services as a theater forecast unit; however, it is deployed to support a specific combat operation or exercise which is not or cannot be supported by theater forecast unit. AFGWC directly supports Air Force, Army, and Joint forces when the theater forecast unit lacks support capabilities and when a JMOC is not established.

Dissemination of Forecasts and Warnings. The Air Force and Army require worldwide meteorological services for 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, testing, training and deployment of military forces, and contingency operations.

Air Force Weather enhances the unique global capability of military aviation while indirectly assisting civil aviation. Air Force personnel provide flight weather briefings, air/ground radio services, and tailored observations, forecasts, watches, and warnings for military operations.

A special aspect of the military weather mission is the need to provide decision assistance to commanders and resource managers. To fulfill this requirement, designated Air Force weather personnel serve as part of the working staff of operational Air Force, Army, and Joint force units. In this capacity, Air Force weather personnel identify all weather-sensitive areas of the operation, monitor the weather service provided in these areas, and provide expert advice to mitigate weather impacts on training or combat operations. This effort helps ensure that Air Force, Army, and Joint force units fulfill their missions regardless of the weather and results in efficient use of weather resources by gearing them to mission needs.

Deployed weather teams are the basic units providing weather support in a combat theater. These teams provide surface and upper air observations, staff weather officer services, and forecasts. The tactical forecast 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 (HFRB) system is used to augment AFC4's transmission of alphanumeric and facsimile products to the theater weather force. The HFRB system consists of regional broadcast stations at Andersen AFB, Guam, Elmendorf AFB, Alaska, Elkhorn, Nebraska, and Croughton, England.

Specialized Support. AFCCC, Scott AFB, Illinois, provides environmental data and specialized studies to support the Air Force, Army, and other government agencies. Typical support satisfies requirements for assessments of natural environmental effects on military plans, weapon systems, facilities, and intelligence activities. AFCCC collects environmental data from AFGWC and then sorts, checks, stores, and employs these data to produce tailored products. AFCCC also operates a facility, collocated with the National Climatic Data Center in Asheville, North Carolina, to facilitate cooperation and data exchange. AFCCC typically collects, quality assures, and applies worldwide surface and upper air observations, a three-dimensional (3-D) cloud analysis extracted from meteorological satellite imagery (Real-time Neph-analysis), a global analysis of snow cover, solar, geomagnetic, and space observations and indices, and many other specialized environmental data sets.

The Air Force also supports an array of Air Force and Army specialized requirements. Some of these are described below.

The Army weather support mission is completely integrated into the Air Force's overall mission concept. The Army trains and educates Air Force personnel about Army organizations, concepts of operations, and the weather sensitivities of Army operations and equipment. Air Force weather units are aligned and integrated with the Army intelligence organization. Weather products are tailored to be directly usable and

understandable by Army personnel and are integrated into Army communications systems. Mobile and fixed meteorological equipment is programmed by the Air Force. In a tactical environment, weather personnel serve with echelon-above-corps, corps, divisions, separate brigades, regiments, aviation brigades, armored cavalry regiments, ranger regiments, and special forces groups (as well as subordinate battalions deployed at forward operating bases). The Air Force provides observer support to all command levels identified above. The Army Forward Area Limited Observing Program (FALOP) and the Army artillery meteorology (ARMYMET) program augment the Air Force observations in the tactical environment.

The Air Force provides meteorological products to the Nation's space and missile programs. This includes a wide range of weather observing services at the Air Force Eastern Range and the Kennedy Space Center. The Air Force also provides launch forecasting service for NASA's manned and unmanned launches and for commercial launches from the Kennedy Space Center. The Air Force also provides specialized meteorological services for the Air Force Western Range at Vandenberg AFB, California, and the Pacific Missile Range which includes Point Mugu and San Nicholas Island, California, and Barking Sands, Hawaii. In addition, the Air Force supports the White Sands Missile Range, New Mexico, the Kwajalein Missile Range, and other DOD research and test facilities.

The Air Force and Navy operate the Joint Typhoon Warning Center (JTWC) on Guam under the Naval Pacific Meteorology and Oceanography Center West, Guam. JTWC provides tropical cyclone warning services to DOD units and other U.S. subscribers in the area west of 180 degrees to the east coast of Africa in both hemispheres.

The Air Force 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.

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

The Air Force also provides Agrometeorological output to the USDA's Foreign Agricultural Service and other national customers. The output provided includes diagnostic soil hydrology and other meteorological output pertinent to crop growth and yield estimation.

DOD Modeling and Simulation Executive Agent for the Air and Space Natural Environment. The Air Force was confirmed in 1995 by the Executive Council for Modeling and Simulation (EXCIMS), representing the Office of the Under Secretary of Defense for Acquisition and Technology as the Executive Agent. The Executive Agent is responsible for ensuring authoritative air and space environment models, algorithms, and data intended for cross-agency/cross-Service laboratories in air and space natural environmental boundaries. As of 1996, the Executive Agent will reside at AFCCC. It will be structured as a multi-service Modeling and Simulation division.

Air National Guard (ANG). There are two distinct functions within the ANG weather program. The traditional program consists of 33 weather flights, ranging in size from 13 to 25 personnel. The flights meet monthly to train for their wartime missions and support both Army National Guard (ARNG) and U.S. Army Reserve (USAR) units as well as ANG flying units. A Weather Readiness Center operates at Camp Blanding, Starke, Florida, to provide Army tactical skills training that is not available elsewhere in the Air Force. The ANG is also responsible for peacetime weather operations at locations where the ANG is responsible for airfield operations. Service employees of the ANG provide weather support at six locations, while contracted services are provided at six others.

Planned Enhancements. Air Force, Army, and joint force operational requirements for environmental support are the basis for all Air Force actions to improve existing or acquire new capabilities. The Air Force assesses these requirements and attempts to satisfy them through either hardware acquisitions or technique development. AWS and the Naval Meteorology and Oceanography Command are working on initiatives to improve environmental support to joint, interservice, and service operations. They focus on the strengths of each of the services and build on existing cooperative efforts.

The Air Force is modernizing and improving its base-level weather systems. This includes the Automated Weather Distribution System (AWDS)

Pre-Planned Product Improvements (P3I) and Next Generation Weather Radar (NEXRAD--WSR-88D) programs. WSR-88D installations are in progress. AWDS installations were completed in Spring 1994.

To enhance AWDS in base weather stations and to expand forecasting capabilities, the AWDS P3I program consists of the following phases:

- Phase I. Interoperability with other command, control, communications, computer, and information (C4I) systems.
- Phase II. Improvement of processor speed of all workstations.
- Phase III. A remote briefing capability, an intra-AWDS product preparation capability, and improved meteorological satellite ingest capability.

The WSR-88D is being procured under the auspices of the NEXRAD Joint System Program Office. It is an automated, digitized, S-band Doppler system that was jointly developed and procured. It is operated and maintained by DOD, NOAA, and FAA within the CONUS and by the Air Force and Navy overseas. The system incorporates the latest technological advances in Doppler radar, data processing, communications, and display. The CONUS WSR-88D network will satisfy weather radar requirements in support of the general public, the military, and the aviation community. Installations of the WSR-88D are in progress and are expected to be completed by 1996.

The Centralized Data Management System (CDMS) transition is a related series of distinct acquisition, development, and integration efforts to transition AFGWC from a database-dependent applications environment to a centralized database management system. Under the CDMS transition, AFGWC centralized the management of a number of key databases on one computer for both unclassified and classified production. This acquisition will be integrated with improved AFGWC hardware/software systems and will transition to the centralized database management environment under planned programmed steps. CDMS transition reached initial operational capability in 1992 with operational support to the Global Applications Database. Full operational capability is currently scheduled for FY 2002 in conjunction with the AFGWC SDHS replacement.

The Cloud Depiction and Forecasting System (CDFS) II will make major software and hardware modifications at AFGWC to upgrade the weather satellite data processing, cloud depiction and forecasting, and classified weather support functions to meet customer-stated support requirements. CDFS II will also incorporate weather satellite data, cloud depiction and forecast data, and supporting databases into the AFGWC CDMS.

The MARK IVB Direct Readout program has procured new satellite receiver terminals to replace the aging MARK IIIs and some of the MARK IV terminals. In addition to providing high resolution satellite imagery from polar and geosynchronous weather satellites, the MARK IVB terminals accepts and uses data from the DMSP microwave imager and sounders and the TIROS microwave sounding units A and B. The MARK IVB produces both uniform gridded data fields and traditional meteorological products.

The Small Tactical Terminal (STT) program will procure small, lightweight, ruggedized, modularized, interoperable, first-in satellite receive terminals that will receive data transmitted by geostationary and polar orbiting (Automatic Picture Transmission) meteorological satellites. Full-scale production began in FY 1996.

SPACE ENVIRONMENTAL SERVICES

50th Weather Squadron (50 WS) is the Air Force focal point for operational space environmental support. 50 WS also participates with NOAA in the joint operation of the Space Environment Center (SEC) in Boulder, Colorado. Under existing agreements, SEC and 50 WS provide limited backup for each other during contingencies. Many DOD systems operate in, or are affected by, conditions above 50 kilometers. The space environment includes the thermosphere, ionosphere, and magnetosphere, as well as the regions that influence them, such as the sun and interplanetary space. 50 WS provides basic and specialized space environmental support to military electromagnetic communications, surveillance, and warning systems which operate in this environment. Space environment forecast products and/or specialized services are provided for the following:

- Ionospheric conditions.
- Energetic particle fluxes at satellite orbits.
- Solar flare, solar particle, and geomagnetic storm events.

- Upper-atmospheric density variations by providing geomagnetic and solar indices.
- High frequency (HF) radio wave propagation.
- Detailed post-analysis studies of operational system problems to determine if the space environment was a contributing factor.

The effects of the space environment on DOD systems are many and varied. The magnetosphere affects satellite operations through such phenomena as single event upsets (SEU) and spacecraft charging. Manned spaceflights are vulnerable to intense radiation from large solar flares and geomagnetic storms, particularly for high inclination orbits. Ionospheric conditions have a profound effect on the propagation of radio waves and radar signals, leading to communications blackouts and erroneous radar returns. Variations in the neutral atmosphere affect satellites orbiting at relatively low altitudes.

Sources of Space Environmental Data. To obtain solar data, the 50 WS operates a network of solar optical and radio telescopes. Solar Electro-Optical Network (SEON) observatories are located at Sagamore Hill, Massachusetts, Ramey, Puerto Rico, Holloman AFB, New Mexico, Palehua, Hawaii, San Vito, Italy, and Learmonth, Australia. The 50 WS also receives real-time solar X-ray and energetic particle data from the Geostationary Operational Environmental Satellites (GOES); DMSP, NOAA, and other DOD geostationary satellites provide additional energetic particle data in low-Earth and geosynchronous orbits.

A world-wide (primarily northern hemisphere) network of ionosondes and polarimeters provides ionospheric data. AWS is currently deploying the automated Digital Ionospheric Sounding System (DISS) to replace older instruments and provide improved ionospheric coverage. Of the 19 DISS sites programmed, 14 sites are operational, and the remaining 5 will be installed in the next few years.

The 50 WS monitors variations of the geomagnetic field using ground-based magnetometers through a cooperative agreement with the USGS, computes a real-time geomagnetic index, and transmits the derived index to users.

Warning and Forecast Services. In near-real-time, 50 WS provides operators advance warning of conditions that could degrade performance of their systems. Notifications include:

- Solar X-ray events which can disrupt HF communications on sunlit paths.
- Solar radio bursts which can disrupt communications systems and interfere with radar systems.
- Solar proton events which can produce radiation hazards to spacecraft and absorption of transpolar HF radio waves.
- Ionospheric disturbances which can degrade HF and satellite communications systems.
- Geomagnetic disturbances which can affect the orbital parameters of low altitude satellites, cause spacecraft charging and/or physical damage, disrupt HF radio wave propagation, or interfere with radar systems.

Future Improvements in 50 WS Support. 50 WS is enhancing its ability to observe the space environment, analyze data, and model the near-Earth environment.

The Ionospheric Measuring System (IMS) is a planned replacement for the current polarimeter network. IMS, using signals from Global Positioning System (GPS) satellites, will measure total electron content. The initial purchase and deployment of five IMS units is in progress.

The SEON Upgrade will improve the capabilities of the SEON observatories. Efforts to upgrade obsolete and non-supportable equipment to maintain current capability continue.

A Solar X-Ray Imager (SXI) will be flown on the GOES-NEXT series of satellites. 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 SEC and transmitted to 50 WS in real-time.

The Solar Wind Interplanetary Measurements (SWIM) is an Air Force Phillips Laboratory investigation using data from NASA's WIND research satellite launched on 1 November 1994. SWIM provides two hours of real-time interplanetary solar wind data to 50 WS each day. Additionally, there will be two campaigns a year during which real-time data will be provided 8 hours a day. The expected life of SWIM/WIND is 5 to 7 years.

Solar Radio Burst Locator (SRBL). This new ground-based system is projected to be operational in 1999. SRBL radio mappings of active regions on the solar disk will augment the present optical observations of these phenomena which are limited by clouds and other atmospheric obscurants. Precise location of active regions on the solar disk is crucial to accurate forecasting of solar flare impacts on the near-earth environment.

The Space Environmental Technology Transition (SETT) program transitions state-of-the-art space environmental models to operational use at 50 WS. These models will specify and forecast the space environment from the Sun to the Earth's upper atmosphere. The output of these models will drive specific application programs tailored to customer needs. The transition of the SETT models to the 50 WS will be complete by 1999. Follow-on model development will focus on improving model accuracies and will replace surrogate parameters (as model inputs) with direct measurements wherever possible.

- Magnetospheric Models. The Magnetospheric Specification Model (MSM) provides specification of magnetospheric particle fluxes at geostationary altitudes and precipitating particle fluxes in the auroral zone. An upgrade to this model, the Magnetospheric Specification and Forecast Model, will provide forecast capability and increase the MSM coverage area. One application of MSM output will be as input for satellite anomaly programs. The MSM became operational at the 50 WS in FY 1995.

- Ionospheric Models. The Parameterized Real-Time Ionospheric Specification Model specifies global electron density using near-real-time satellite and ground-based data. It becomes operational in late FY 1996. A second ionospheric model, the Ionospheric Forecast Model (IFM) will be based on a model developed by Utah State University. When completed, IFM will provide an ionospheric forecasting capability; it is currently undergoing validation. Ionospheric model output will be used as input for space track radar correction and HF radio wave propagation programs. Another variant of ionospheric models, the Wide-Band Model, will provide estimates of ionospheric scintillation severity between two endpoints. The specification accuracy of this model has recently been improved by the inclusion of equatorial and high latitude climatological data.

- The Interplanetary Shock Propagation Model is designed to predict the time of arrival and the dynamic pressure pulse associated with solar flares. This will provide a 1-3 day warning of geomagnetic storms resulting from solar activity.

- The Integrated Space Environmental Model is a coupling model and executive system being developed to integrate the SETT models into a single system sharing input and output data. It will provide a single framework to coordinate and facilitate the execution of all SETT models using scientific expertise and decision-making ability within the program, which will increase consistency of the outputs, optimize run times, and decrease forecaster workload.

SUPPORTING RESEARCH

The objective of the Air Force meteorological research program is to provide comprehensive knowledge of the atmosphere, how it works, how it limits system performance, and how it can be exploited to the advantage of the Air Force as a force multiplier. Improved measurement and prediction techniques, together with an early evaluation of weather effects on new systems, can make a significant difference and bring the Air Force, Army, and joint forces closer to their goal of conducting operations in all kinds of weather. Requirements for research and technology in meteorology are expressed in Mission Area Assessments and Mission Need Analyses. In addition, the AWS provides guidance in the form of documented Technology Needs.

Within the Air Force, the Phillips Laboratory, Geophysics Directorate (PL/GP) at Hanscom AFB, Massachusetts, is responsible for conducting both in-house and contractual basic research, exploratory development, and advanced technology development in the environmental sciences, including meteorology and space weather. Its exploratory development program in meteorology emphasizes moisture and cloud numerical weather prediction, satellite remote sensing, climatological studies, weather simulation, atmospheric density measurement and prediction, battlefield weather observing and forecasting, and tactical weather decision aids. Research and development (R&D) for DMSP, the Strategic Environmental Research and Development

Program (SERDP), and the Defense Modeling and Simulation Office (DMSO) are also conducted. The entire Air Force atmospheric sciences R & D program is being carefully coordinated with similar efforts in the Army and Navy.

Weather Prediction. Research in weather prediction techniques and models is focused on mesoscale or battlefield domains. Particular emphasis is placed on cloud processes in the atmospheric boundary layer and studies of their formation, evolution, and dissipation. Procedures to better account in numerical models for surface exchange processes and for representing surface characteristics in model data bases will be stressed. These include: soil type, vegetation type and growth stage, soil moisture and temperature, and snow cover and depth. On-going studies of the sensitivity of boundary layer processes to the representation of surface characteristics will be translated into model algorithms for test and evaluation. Mesoscale model data impact studies will focus on both ground-based (profiler and surface sensors) and satellite (imagery and sounding) sources. Tactical wartime data denial experiments will also be conducted as part of these studies. Theater-scale analysis and forecasting models will be developed for use in a workstation environment.

Research to support the increasing needs for a global cloud prediction capability at AFGWC will take two approaches. Multivariate diagnostic algorithms from global and regional-scale numerical models will be evaluated to infer cloud characteristics (total cloud and layered amounts, bases, tops) for prediction intervals beyond 12 hours. Short-range cloud prediction (0-12 hr) techniques will seek to exploit new global cloud analysis capabilities to be available at AFGWC through the CDFS II hardware/software upgrade. Here imagery extrapolation methods will be augmented by simple physical models to account for short-term cloud growth and decay and by highly resolved (in space and time) cloud climatology statistics. In addition, diagnostic algorithms to provide surface and hazard predictions for Theater Battle Management are being sought.

Research to improve hazardous weather warning capabilities at air bases from WSR-88D Doppler weather radars will be focusing on better tornado, hail, and severe storm structure algorithms due to the use of a new mesocyclone detection model which was developed in FY 1994. The development of algorithms to define fine line features (such as gust fronts and synoptic-scale frontal boundaries) will be completed by FY 1996. Studies to identify lightning precursors in WSR-88D data for air mass thunderstorms will be initiated. Studies of the atmospheric electric field distribution aloft and its relationship to aerospace vehicle-triggered lightning will continue. These studies will focus on measurements taken with electric field sounding rockets in field programs to be conducted in FY 1996.

Satellite Remote Sensing. To enhance Air Force, Army, and joint force operations, a major effort is directed toward using satellites to determine temperature and water vapor vertical profiles and horizontal fields. Research efforts also include effectiveness studies for active satellite sensors, such as satellite-borne lidars and radars, for determining the profiles of wind and other weather variables with very high vertical resolution for initialization and assimilation into weather prediction models.

Techniques will be developed to incorporate microwave imagery and geosynchronous satellite 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 specify cloud characteristics; e.g., cloud height, cloud physical thickness, optical depth, particle size, cloud phase, and rain areas. The design of satellite sensors in terms of wavelength, resolution, and bandwidth and the calibration of deployed satellite measurement systems, such as the DMSP SSM/T-2 water vapor sounder, will continue primarily in support of DMSP. Research on integration of the environmental information from a number of satellite measurement platforms and sensors is underway.

Characterization of cloudiness on the operational theater scale, based on direct readout of satellite weather data, is being implemented in support of tactical operations. A package of satellite cloud analysis algorithms, called TACNEPH, has been developed and will be implemented in the DMSP Small Tactical Terminal.

Climatology Studies. Support of Environmental Requirements Cloud Analysis and Archive (SERCAA) is the new global cloud analysis program for use in determining the radiative and hydrological effects of clouds on climate and global change. SERCAA is the prototype of the next-generation, real-time automated cloud analysis model. The first phase of SERCAA

directly supports the CDFS II. An archive of these quality cloud products, which will be useful in environmental monitoring and climate change research, is planned.

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. Simulation of time evolution of 3-D scenes of weather elements will initially concentrate on cloud scenes. Whole-sky imagery data and concomitant satellite imagery will provide the basis for developing algorithms for ground-based and satellite (or aircraft)-based viewing scenarios. Weather simulation computer models for conceptual design and studies and analysis applications will continue.

The first of two DMSO projects focuses on developing techniques for simulating Environmental Effects for Distributed Interactive Simulation (E2DIS) and to conduct related requirements and capabilities surveys. The second is to implement into E2DIS format the 3-D cloud scene model developed in the first project.

Two programs are in progress to develop a more complete understanding of atmospheric effects on laser propagation. The first of these programs supports the Airborne Laser Program and is evaluating the effects of atmospheric phenomena near the tropopause on laser propagation. Modeling and measurements in support of a more complete understanding of turbulence, aerosols, and cirrus clouds on such propagation are the focus. In the second of these programs, investigations are underway to evaluate the ability to measure winds with a Doppler Lidar in support of weapons targeting (the so-called ballistic wind problem). Actual measurements are being conducted together with supporting meteorological observations and analyses.

The Climatological and Historical Analysis of Clouds for Environmental Simulations (CHANCES) program was initiated in 1994 and will continue into 1996 to expand the climatological analysis to include the tops and bottoms of layered clouds. The program is developing a very high resolution, global cloud climatology from conventional and meteorological satellite observations for planners of satellite and high-altitude aircraft surveillance operations.

Atmospheric Density. The objective of the atmospheric density work is to develop very accurate methods to measure and predict the 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 the current physical understanding of the processes that drive the upper atmosphere. Models will be used to calculate accurate trajectories of satellites, reentry vehicles, and space debris.

Battlefield Weather Observing and Forecasting. The battlefield weather program completed development of the electro-optical tactical decision aid (EOTDA) in FY 1994. This software is used on microcomputers in base weather stations and host command and control computer systems using an AFGWC-provided data base. This automated forecasting aid is used to predict acquisition and lock-on ranges for precision-guided weapons and target acquisition systems used by the Air Force, Navy, and Army.

The Air Combat Targeting/Electro-Optical Simulation effort in the Weather Impact Decision Aids (WIDA) program has developed a prototype scene simulation capability for mission planning systems used by tactical aircraft pilots. This prototype combines global terrain and features, target structure, meteorological and operational planning data, target infrared contrast and EO sensor performance models to provide commanders and aircrews complete in-theater environmental situational awareness. Another WIDA program is developing Night Vision Goggle (NVG) Operations Weather Software (NOWS) for predicting the impact of weather on operations which depend on NVGs for their success. The primary NOWS user is the Air Force Special Operations Command. Coordination to incorporate Navy requirements into NOWS is underway.

UNITED STATES NAVY

METEOROLOGICAL SERVICES

The U.S. Navy, operating in the atmosphere, oceans, and the interface between the two, has the unique requirement to integrate meteorological and oceanographic support globally. Sponsored by the Chief of Naval Operations, Office of the Oceanographer of the Navy, the Navy provides meteorological support for Navy and joint forces, meteorological products to the USMC, and oceanographic support to all elements of DOD. R&D is conducted under the sponsorship of the Chief of Naval Research and the Oceanographer of the Navy by warfare centers, laboratories, and systems commands, primarily the Naval Research Laboratory (NRL) and the Space and Naval Warfare Systems Command (SPAWARS), as well as various universities and organizations under Navy contract. Operational support to ships, units, and shore stations is provided by elements of the Naval Meteorology and Oceanography Command (NMOC). Direct support to staffs, ships, and units afloat and ashore is provided by officer and enlisted meteorology and oceanography (METOC) personnel assigned to these activities. Shore activities within the NMOC include the Fleet Numerical Meteorology and Oceanography Center, the U.S. Naval Oceanographic Office, the Naval Ice Center, four theater NMOC centers (Atlantic, European, Pacific, and Western Pacific), four NMOC Facilities, and 40 NMOC Detachments.

Fleet Numerical Meteorology and Oceanography Center (FNMOC) in Monterey, California is NMOC's processing center dedicated to running automated, state-of-the-art, operational global and high resolution regional/theater-scale atmospheric and oceanographic analysis and forecast models. The center acquires environmental data globally through links with DOD and NOAA satellite and data distribution systems. Numerically-generated products are distributed on Navy and Joint command and control, communications, computers, and intelligence (C4I) systems either directly or via the Navy theater METOC centers. These centers then develop value-added products and services tailored to specific operational requirements. In addition to its standard product suite, FNMOC is uniquely capable of providing high resolution meteorological and oceanographic products on short notice for any location in support of global contingency military and humanitarian operations. Other FNMOC products include atmospheric and oceanographic observations, data extracts, and input data for tactical decision aids. In addition to being the primary DOD global numerical weather prediction center, FNMOC is the designated national Center for Expertise for remotely-sensed microwave products by the Air Force/Navy/NOAA shared satellite processing agreement.

The Navy's program in meteorology is closely linked with oceanography, the focus of two other major Navy METOC centers. The Naval Oceanographic Office (NAVOCEANO), at Stennis Space Center, Mississippi, is responsible for collecting, processing, and distributing oceanographic, hydrographic, and other geophysical data and products. It is the Navy's primary processing facility for NOAA TIROS data and has been designated the national Center of Expertise for satellite-derived sea surface temperature measurements. NAVOCEANO's Warfighting Support Center (WSC) provides near real-time, tailored oceanographic products to support operational Navy and joint commands. Such products include global ocean front and eddy analyses, preprocessed multichannel sea-surface temperature (MCSST) analyses from polar-orbiting satellites, satellite altimetry and scatterometry data from ERS and TOPEX satellites, high-resolution ocean model output, and Special Operation Forces support. Furthermore, as NAVOCEANO is both an operational processing center and a DOD Major Shared Resource Center, R&D programs using NAVOCEANO's C-90 supercomputer can be easily transitioned to operational use in Navy METOC models.

Tailored ice forecasts and analyses are provided to DOD by the Naval Ice Center (NAVICECEN), located in Suitland, Maryland. The Navy, through NAVICECEN, NOAA and the U.S. Coast Guard, jointly operate the National Ice Center (NIC). The NIC provides sea and lake ice analyses and forecasts for the Arctic and Antarctic regions, coastal U.S. waters, and the Great Lakes to civil as well as military activities.

Four theater NMOC centers provide broad geographical METOC services within their areas of

responsibility. Aligned with specific Naval Component Commanders of the Unified Commanders-in-Chiefs (CINCs) and focused on operations within theater, these METOC centers manage and prioritize the dissemination of basic numerical METOC products from FNMOC and NAVOCEANO and add tailored services specifically to support theater requirements. They are hubs for data and product dissemination, providing full spectrum meteorological and oceanographic services to forces operating within their respective area of responsibility and a variety of special METOC products as needed to meet situational requirements of the Joint Force Commander. The Naval Pacific Meteorology and Oceanography Center (NPMOC), Pearl Harbor, Hawaii, assisted by NPMOC West, Guam, is responsible for the Pacific and Indian Oceans, Red Sea, and Arabian Gulf areas. Additionally, NPMOC West operates the Joint Typhoon Warning Center with the U.S. Air Force to provide tropical cyclone advisories to DOD and U.S. interests in the Western Pacific and Indian Oceans. NPMOC also issues tropical cyclone advisories, for the eastern and central South Pacific. The Naval Atlantic Meteorology and Oceanography Center (NLMOC), Norfolk, Virginia, is responsible for providing METOC services in the Atlantic Ocean and the Greenland, Norwegian, and Barents Seas. The Naval European Meteorology and Oceanography Center (NEMOC), Rota, Spain, provides METOC support to Joint and Naval forces operating in the Mediterranean, Black, and Baltic Seas. The Atlantic and Pacific NMOC centers share non-ice related METOC product and service support for the Arctic and Antarctic regions. Because of their in-theater presence and focus, NMOC centers are ideally suited to serve as Joint METOC Forecast Units (JMFU) or Coordinating METOC Forecast Centers (CMFC) in support of theater joint operations.

The four NMOC facilities at Jacksonville, Florida; San Diego, California; Pensacola, Florida; and Yokosuka, Japan; provide operations area, local and aviation forecast services, as well as services to aircraft, ship, and submarine staffs. Meteorological and oceanographic forecast guidance from the theater NMOC centers and FNMOC is used by all facilities.

There are 40 NMOC detachments worldwide. Primarily situated at Naval Air Stations, several are located at Naval Stations in support of sea-going units. They provide METOC forecasting and warning services to DOD and allied units within their local and functional areas of responsibility. Detachments within the continental U.S. use numerical products from both FNMOC and NOAA's National Centers for Environmental Prediction (NCEP). Overseas detachments use available USAF and foreign products in addition to core FNMOC numerical products. Two detachments provide specific technical services: one, at the National Climatic Data Center, Asheville, North Carolina, coordinates the Navy's climatological program as its part of the Federal Climate Complex; another, at Tinker AFB, Oklahoma, manages Naval data requirements for the USAF AWN.

On-Scene Support

The primary sources of on-scene Navy METOC support for forces afloat and those in-theater ashore are provided by permanently embarked Navy METOC personnel and deployable assets (Mobile Environmental Teams). METOC products and services provided to the operating forces are tailored to requirements of the Fleet and/or Joint Force Commanders and Fleet units. This support consists primarily of tactical METOC information and forecasts for operations, weapon and sensor system employment and tactical decision making, and climatological information for long-range planning. Products are made available to the operating forces via joint and Navy C4I systems, AUTODIN, the High Speed Fleet Broadcast, high frequency facsimile broadcasts, military networks, and center-maintained Bulletin Board Systems (BBSs).

The Navy's permanent afloat METOC organic assets are their OA Divisions, embarked aboard major aviation-capable combatants and command ships. Their primary objectives are safety, optimum tactical support to warfare commanders, and tailored on-scene products and services to the assigned task force/group and allied units in joint, combined, or coalition military and humanitarian operations. The centerpiece of the OA Division's suite of METOC equipment is the Tactical Environmental Support System (TESS(3)), an interactive METOC data fusion system which receives, stores, processes, displays, and disseminates meteorological and oceanographic data. TESS(3) receives data from four major sources: global and theater METOC data fields from FNMOC and NAVOCEANO via the Navy's theater centers; remotely sensed satellite data and imagery from the

onboard AN/SMQ-11 satellite data receiver/recorder; alphanumeric data via the High Speed Fleet Broadcast; and local observational data from the Shipboard Meteorological and Oceanographic Observing System (SMOOS). The TESS(3) data base and applications software is provided from the Oceanographic and Atmospheric Master Library (OAML) and the Geophysical Fleet Mission Program Library (GFMPL). The AN/SMQ-11 acquires geostationary satellite weather facsimile (WEFAX) broadcasts and DMSP and NOAA/TIROS satellite imagery. Local upper air sounding information is made available from the permanently installed AN/UMQ-12 Miniature Rawinsonde System (MRS). The division is also equipped with a PC-based high-frequency facsimile system (PCGRAFAX). Standard CD-ROM based climatology products, the Naval Oceanographic Data Distribution System (NODDS), and the PC Imaging Communications Systems (PICS) software programs are also part of the OA Division inventory.

The Mobile Environmental Teams (MET), based at the theater NMOC centers in Norfolk, Hawaii, and Rota, and at their facilities in Jacksonville, San Diego, and Yokosuka, are the Navy's deployable METOC assets. These teams provide short-term, on-scene services to units and activities without organic METOC personnel within the DOD, other government agencies, and elements of the armed forces of allied nations during combined exercises or operations. The MET have their own portable sensing and display equipment, the heart of which is the Mobile Oceanography Support System (MOSS). MOSS contains modules for tactical meteorological and oceanographic forecasting, polar-orbiting satellite ingest and processing, alphanumeric and facsimile data receipt and display, and *in situ* data collection via the MRS and expendable bathythermograph probes. METs may also deploy with a portable MRS and Alden Marine Facsimile Recorder. If required, they have the capability to install remote Navy Automated Meteorological Observing Systems (AMOS), to sense temperature, humidity, pressure, and winds and provide direct readout and/or telemetry of data via satellite.

U.S. Marine Corps (USMC)

Marine environmental forecasts are vital to the operation of the USMC. The Deputy Chief of Staff for Aviation, Headquarters, U.S. Marine Corps (Code ASL-44) is the cognizant office for Marine Corps Meteorological and Oceanographic Support and Requirements. The Marine Corps weather organization consists of two operational chains of command, one for garrison aviation weather units and the other for the Fleet Marine Force (FMF).

Garrison aviation weather units at Marine Corps Air Stations and facilities are manned by USMC METOC personnel and provide direct aviation weather support to host and tenant units. Integral to Marine Corps aviation activities, these weather units provide services to assigned activities and organizations, which include nine major air stations in the continental United States, one in Hawaii, and two in Japan.

Marine Corps METOC support activities are assigned to the FMF in the Aviation Combat Element (ACE) of the Marine Air Ground Task Force (MAGTF). ACE METOC support is derived from the Marine Wing Support Squadron (MWSS) within the parent Marine Aircraft Wing. The existing 10 MWSS METOC activities are equipped to provide support at a bare-based or expeditionary airfield by deploying the METMF. Additionally, Meteorological Support Teams from the ACE MWSSs can be assigned in direct support of the Command Element, Ground Combat Element, and Combat Service Support Element of the MAGTF.

Battlespace Management Systems

The Navy's METOC program remains focused on improving data collection, processing, and dissemination capabilities to support operations in the littoral and to ensure interoperability among the services. A key aspect of this design is a unifying fully-integrated C4I architecture allowing METOC activities to operate in unison with other service elements. Efforts in FY 1997 include:

Tactical Environmental Support System (TESS(3)). TESS(3) is a modular support system designed to provide Navy decision-makers on major combatant ships with METOC assessments and forecasts and to integrate this data with sensor and weapon platform parameters for system performance assessments. Data sources include *in situ* sensors, geostationary and polar-orbiting satellites, U.S. and foreign radio weather broadcasts, and data fields prepared ashore. The primary suppliers of these data are the theater METOC centers, which provide value-added products to fleet units in addition to the numerical prediction guidance generated by FNMOC,

using a variant of TESS, the Naval Oceanographic Data Distribution and Expansion System (NODDES). NODDES expands previous METOC data distribution capabilities by increasing automation of routine operations and enhancing on-site interactive capabilities for finished product preparation and distribution. The planned TESS(3) and NODDES evolution includes expanded options for theater center modeling; complete integration with Navy and joint C4I systems; the development of small basin, mesoscale, coupled air/sea models; and the transition to Navy standard tactical computer (TAC-X) hardware.

Navy Integrated Tactical Environmental Subsystem (NITES). Through NITES, METOC data and products are made available to Navy and Marine Corps activities afloat and ashore via the Joint Maritime Command Information System (JMCIS) network. A modular data management and distribution subset of TESS(3) and a segment on the Navy C4I network, NITES uses TESS(3) data and products to feed real-time tactical decision aids resident with JMCIS. The open system design of NITES can provide interoperability with other DOD, Federal, and Allied command and control systems.

Mobile Oceanography Support System (MOSS) Upgrade. MOSS is presently undergoing a migration towards a modular, interoperable system -- a NITES variant. It has been upgraded to include a lightweight and portable IBM Thinkpad 755CD notebook computer with an IBM Dock II docking station. This migratory version, known as MOSS-2, operates at 100 MHz and has the additional capability to ingest real-time observational data collected by AMOS. The follow-on system, MOSS-3, will be a modular data management and distribution system operating in a portable UNIX environment and incorporating much of the NITES functionality.

Primary Oceanographic Prediction System (POPS). The POPS program was initiated to provide the computational capability necessary to run massive oceanographic and atmospheric models at both global and regional scales. New Cray C-90s at NAVOCEANO (POPS-I) and FNMOC (POPS-II) were installed as part of the Navy's and Federal Government's emphasis on high performance computing. POPS-I has been designated a DOD Major Shared Resource Center, with as much as 85 percent of the computer time on the C-90 devoted to supporting DOD R&D efforts which can then be transitioned to operational use. POPS-II is the numerical engine used by FNMOC in its role as the primary DOD Numerical Weather Prediction Center. Two subsidiary information systems support POPS at FNMOC -- the Oceanographic and Atmospheric Support and Information System (OASIS) and the Distributed Processing System (DPS). DPS receives incoming data and distributes final products to external users, while OASIS processes incoming data for POPS and packages POPS output for specific customers. Output from Navy's numerical models is made available to NOAA through a memoranda of agreement.

Operational Products and Services

The Optimum Track Ship Routing (OTSR) is a ship advisory service designed to minimize the risk of damage from extra-tropical and tropical storms, high seas, and sea ice. OTSR also assists port authorities and ships in port in the path of tropical cyclones by issuing recommendations for departure time and a sortie location to the Senior Officer Present Afloat. To maximize fuel economy, OTSR provides recommendations for ocean current assistance and avoidance routes in the vicinity of strong ocean currents. OTSR advise considers individual ship characteristics, cargo limitations, and planned operations.

Optimum Path Aircraft Routing System (OPARS) at FNMOC is a flight planning system to provide tailored routing information to meet individual mission requirements. Among its many options, OPARS can calculate the fuel load needed to arrive with a specific reserve, maximum cargo for a particular flight, in-flight refueling requirements, maximum time on-station, mandatory over water reporting positions, and fuel usage for specific routes and/or altitudes. In preparation for a flight brief, electronic route requests are sent to FNMOC by the servicing NMOC detachment. To determine optimal aircraft routing, four data bases are integrated in OPARS: environmental, air route structure, aircraft performance characteristics, and prohibited air space. A tailored flight plan is returned to the originator within minutes for briefing to the pilot.

Navy Oceanographic Data Distribution System (NODDS) is a PC-based software package originally developed in 1982 to make FNMOC numerical

products available to front line DOD users. Products from FNMOC's global data bases can be selected for user-defined regions and, using an off-the-shelf licensed communications software package, are transmitted as a series of compacted ASCII files. All standard meteorological fields and synoptic observations available from FNMOC can be displayed along with a wide number of oceanographic and satellite products. NODDS can overlay up to three different fields, display individual sequence loops, zoom for more detail, display satellite imagery, and produce hard-copy output. NODDS is available to non-DOD Federal agencies and others in the civilian community through an agreement between Navy and NOAA. This version, referred to as NOAA-NODDS to distinguish it from the Navy version, makes available to NOAA unclassified real-time weather and ocean data and products from FNMOC for access by civilian users.

SUPPORTING RESEARCH

The Navy administers a diverse R&D program, ranging from software development to the engineering of sensors, interfaces, processing, display, and distribution devices. Application of R&D activities of the other services and Federal agencies is always considered, and use of existing government and commercial off-the-shelf items is made.

The Navy is a world leader in the field of numerical weather prediction for marine environmental services. Transitioning fundamental scientific research, through additional development, into the operational meteorological and oceanographic models is key to a successful numerical prediction program. This is an ongoing process at the Naval Research Laboratory's (NRL) Marine Meteorological Division, collocated with FNMOC, to keep the Navy Operational Global Atmospheric Prediction System (NOGAPS) and its companion Regional Atmospheric Prediction System (NORAPS) at the leading edge of technology. Continued upgrades to NOGAPS and NORAPS models are planned, incorporating asynoptic and remotely-sensed data in the model initialization process. The relocatable, high-resolution (15-45 km) nested NORAPS model is now used routinely for operational contingency support.

In the future NORAPS will be replaced with the Coupled Oceanographic and Atmospheric Mesoscale Prediction System (COAMPS) model. The atmospheric component of COAMPS will feature triple-nested grids to resolutions of a few kilometers, non-hydrostatic physics, explicit moisture physics and aerosols, and improved data assimilation. The underlying and fully coupled oceanographic component of COAMPS will combine the capabilities of the Optimum Thermal Interpolation System (OTIS), the Wave Model (WAM), and the Princeton Ocean Model (POM) to provide for fully interactive two-way coupling between ocean and atmosphere. With lateral boundary conditions provided by FNMOC global models, COAMPS will provide the high-resolution, relocatable, and fully-integrated meteorological and oceanographic prediction capability required to support joint littoral operations.

The principal focus of the Navy R&D program in remote sensing is the development of techniques to extract tactically significant information in the littoral regions of the world. Sensors aboard existing satellites are being exploited to the greatest extent possible, and plans are in place to incorporate new capabilities as they are introduced. Because many satellite processing algorithms are designed for use with tactical systems such as TESS(3), expert or rule-based scheme representations are employed wherever possible to reduce manpower-intensive interpretation procedures.

Development of upgraded data assimilation, quality control, and data management techniques in support of these models is also underway. A major thrust has been initiated in the area of numerical weather prediction to develop a shipboard tactical atmospheric forecast capability. This model, intended for use in TESS(3), will deliver high resolution (5 km), limited area (100's of km), short range (12-24 hour) atmospheric predictions and will assimilate locally acquired data in real-time.

ONR is exploring techniques to exploit the assimilation of environmental data through non-traditional sensors. One such effort in FY 1997 is to investigate the content and utility of a weather signal tap from the AEGIS AN/SPY-1 air search radar system, a potential candidate for a small-scale shipboard tactical weather radar.

SENSOR DEVELOPMENT

The Shipboard Meteorological and Oceanographic Observing System (SMOOS), currently being fielded, was developed as part of the

Navy R&D program in sensor development. As a follow-on to SMOOS, advanced engineering and development of new sensors and related technologies is underway. Some of these include:

- Autonomous drifting buoys for surface and subsurface data.
- Autonomous sensor suites for all Navy ships.
- Aerosol measurement sensors.
- METOC data compression techniques to facilitate communications.

The AN/WSQ-6 series expendable drifting buoys will measure and report air and sea surface temperatures, barometric pressure, subsurface ocean temperature versus depth to 300 meters, omni-directional ambient noise, wind direction and speed, directional wave spectra, optical parameters, and other properties of the near-surface air/sea environment. The buoys sample and report hourly observations via Service ARGOS; as other communications networks such as Low-Earth Orbiting satellites become available, they will be utilized. Near-real-time data reception is available via Local User Terminals and TESS(3). As funding and testing permit new sensors will be added to the buoy platform. Multi-parameter, long-life, expendable instruments, such as the AN/WSQ-6 buoys, are vital to the success of the U.S. Navy's contribution to a global ocean observing capability.

The AN/UMQ-12 Mini-Rawinsonde (MRS) consists of a surface receiver, processor, and lightweight balloon-borne expendable sensor package to measure pressure, temperature, humidity, and wind direction and speed. The Navy will be transitioning to a GPS-based mini-rawinsonde system.

Development efforts undertaken by NOAA/NWS have been leveraged in Navy's selection of the NWS Automated Surface Observing System (ASOS) for Navy and Marine Corps use ashore. Acquisition and installation of ASOS systems continue at Navy and Marine Corps stations worldwide in support of aviation and local area forecasting requirements to replace equipment that has been operated beyond its maintenance life cycles. ASOS will assist aerographers in assimilating field meteorological parameters and improving efficient entry of surface aviation observations and synoptic weather reports into the AWN.

Principal User Processor Stations (PUPS) associated with WSR-88D are providing significant improvements in radar analysis of meteorological features and severe weather over the United States. The Navy and Marine Corps are participating in the WSR-88D program and will utilize these radars to satisfy their requirements for radar coverage, where possible. On-site WSR-88D PUPS will display imagery from NEXRAD systems covering areas of routine military operations and training.

The Navy is developing an Operational Requirements Document (ORD) for procurement of a Supplemental Weather Radar that will provide radar coverage at selected Navy and USMC sites, mostly overseas, not scheduled to receive a WSR-88D PUP. This system will replace the obsolete AN/FPS-106 weather radars now in use.

The Marine Corps Meteorological Mobile Facility Replacement (METMF(R)) is a transportable system for providing meteorological support to the Marine Air Ground Task Force (MAGTF). A cost and operational effectiveness analysis of a replacement METMF has been completed, and the system is nearing the demonstration and validation phases of the acquisition process. Housed in a 20 x 20 foot standard Marine Corps van and transportable by a C-130 aircraft, this system will provide a fully functioning weather office for Marine Corps expeditionary airfields for 30 days without resupply. It will include sub-systems for data collection (MRS for upper air and a variety of local and remote sensors), data processing (modified TESS(3)), satellite image ingest and display (via the USAF Small Tactical Terminal contract), Doppler radar display, communications, briefing support, and support for remote forces. The METMF(R) will be interoperable with the Marine Corps C4I systems and METOC systems of the other services via the Global Command and Control System (GCCS).

INTERAGENCY COOPERATION

To ensure maximum efficiency and benefit for Navy and NOAA cooperative activities, an Umbrella Memorandum of Agreement (MOA) was signed in 1993. Both agencies continue to review present agreements for conversion into annexes to this MOA and identifying new areas of cooperation. Specific areas include:

- Cooperative endeavors in operational numerical modeling between FNMOC and NCEP.
- Navy/NOAA/Coast Guard operation of the National Ice Center.
- AWS/Navy/NOAA agreement on shared processing of satellite data.
- Navy/NOAA agreement on ASOS procurement, installation, maintenance, and operation.
- Distribution of unclassified Navy METOC products to the civil sector via NOAA.
- Provision of meteorological services to Guam, the Commonwealth of the Northern Marianas Islands, and Micronesia.
- Satellite altimetry data processing.

MOAs also exist between the DOC, DOT, and DOD concerning the production and operation of the WSR-88D system. Additionally, Navy is a DOD participant in the development of the DOC/DOD/NASA converged National Polar-orbiting Operational Environmental Satellite System (NPOESS).

UNITED STATES ARMY

ARMY OPERATIONAL SUPPORT

Overview of Operational Equipment and Support Missions. U.S. Army weather support is a mix of Army and USAF personnel and equipment under law and according to Army-Air Force agreement. The U.S. Army provides direct weather support to two Army missions: upper air observations for artillery fire support, and limited surface weather observations to support Army weapon systems forward of Division tactical operations centers. The Air Force Major Commands (MAJCOMs) provide operational weather services to Major Army Commands (MACOMs) in combat, contingencies, and peacetime training. U.S. Army Forces Command (FORSCOM), U.S. Army Europe (USAREUR), U.S. Army Pacific (USARPAC), U.S. Army, South (USARSO), U.S. Army Special Operations Command (USASOC), Eighth U.S. Army (EUSA), and U.S. Army Training and Doctrine Command (TRADOC) have Air Force Weather personnel providing daily installation and tactical weather support. Army Artillery Meteorological (ARTYMET) crews provide direct support to artillery units in the same MACOMs. During peacetime training and activation, the Air National Guard (ANG) provides operational weather support to the Army Reserve and Army National Guard (ARNG), collectively designated the Reserve Component (RC). In addition, during exercises the ANG augments the active forces. The ANG acts like an Air Force MAJCOM in providing support to the Army RC.

Air Force-Provided Support. Under a joint service agreement, the Air Force is responsible for providing the Army with the necessary manpower and unique tactical and fixed weather equipment to meet tactical garrison active component (AC) and RC support requirements. Army support manpower requirements are provided from active, reserve, and guard weather units. While direct support of the artillery remains an Army responsibility and is supported by Army ARTYMET teams, Air Force weather teams provide supplemental information to artillery crews for areas beyond direct observation weather support to Combat, Combat Support, and Combat Service Support units throughout the peacetime/war continuum. Peacetime garrison activities include supporting flying operations at Army Airfields and severe weather watch, warning, and advisory services for post resource protection. With regards to equipment, the Air Force is responsible for installation, operation, and maintenance of standard Air Force meteorological and observing equipment at Army Air Field Weather Stations. Tactically, the Integrated Meteorological System (IMETS) is Army fielded and maintained, but uses Air Force meteorological software, Army vehicles, communications, and weather effects software. The Army provides all other tactical equipment to Air Force Teams through an Army Table of Organizations and Equipment.

The Army also provides the operational weather support to Army Research Development, Test and Evaluation (RDTE) ranges, centers, and other research facilities using the Test and Evaluation Command (TECOM) Meteorological Teams (Met Teams) and U.S. Army Space and Strategic Defense Command (SSDC) contractors. TECOM operational support is described as part of the Army Materiel Command in the RDTE section. SSDC provides weather support to

Kwajalein Missile Range (KMR) through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field equipment and communications equipment to USAF weather teams (WETMs) for tactical operations. MACOMs have purchased off-the-shelf non-developmental items (NDI) to provide interim Army tactical equipment until the IMETS is fully fielded. IMETS is an automated mobile weather support and communications system. The Project Director (PD) for IMETS is under the direction of Program Manager, Intelligence Fusion. The Communications and Electronics Command (CECOM) and Army Research Laboratory (ARL) provide fielding and technical support to the PD, IMETS, and to artillery meteorological programs. IMETS will continue to be fielded in FY 1997.

The FORSCOM GOLDWING System is an NDI system, providing operational support until IMETS is fielded and other modern tactical communications systems become available in the MACOMs. GOLDWING will be used in conjunction with IMETS for AC or RC forces, which are not scheduled to get IMETS because of funding constraints. IMETS communicates with GOLDWING over HF radio.

Artillery meteorological crews are assigned to artillery units at division level, to Field Artillery Brigades, and to Separate Brigades with a direct support Artillery Battalion. Army soldiers regularly take tactical upper air observations to support artillery units during tactical training exercises, at permanent Army Artillery Ranges, or during the full range of combat missions. Artillery meteorological crews also take limited surface observations at tactical locations on an "as needed" basis to support artillery operational requirements.

Artillery meteorological crews currently use the Meteorological Data System (MDS), AN/TMQ-31, to take upper air observations during tactical operations. It is a mobile upper air sounding system on a 5-ton truck and trailer. The MDS provides upper air data to the Field Artillery Tactical Data System for use in adjusting artillery fire, to USAF WETMs, and to the Chemical Officer for use in smoke, and in Nuclear, Biological, and Chemical (NBC) defense operations. The MDS will continue in the active forces until replaced by the Meteorological Measuring System (MMS), AN/TMQ-41, and will be the main system in the RC for the next several years. The MMS is scheduled for fielding in FY 1996 and 1997. The MMS will be deployable on a small vehicle and reduce the size of the Artillery Meteorological Crews. MDS will be refurbished and issued to the RC as it is replaced by the MMS. The U.S. Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, develops the requirements documents and is the combat developer for artillery meteorological equipment.

The Army provides supplemental, limited surface observations when required in tactical situations to support Army operations. These observations are taken by Intelligence personnel in the forward combat areas when directed by the Intelligence Officer (S2).

Headquarters, Department of the Army, Office of the Deputy Chief of Staff for Intelligence (ODCSINT) is responsible for Army weather support policy. Office of the Deputy Chief of Staff for Operations (ODCSOPS) is responsible for validating and prioritizing weather support requirements and programs to meet Army requirements. The Army Staff also has a full-time active duty User Liaison assigned to the NPOESS Integrated Program Office.

U.S. Army Space and Strategic Defense Command (USASSDC). Army Space Command (ARSPACE), a subcommand of USASSDC, assumed a new role in FY 1995, and is expected to continue in FY 1997, to provide Army Space Support Teams to deploying Army units. One element of this support is a high resolution weather satellite receiver, which can be readily transported, and which directly acquires and processes the full telemetry stream of civilian and military weather satellites. Imagery and data are used by the staff weather officer in preparation of tailored products and forecasts for use on the battlefield. This equipment is used in contingencies and training exercises, and provides an interim capability pending delivery of IMETS, Block II and III in the FY 1997-99 time frame. Beginning in FY 1996 and continuing in FY 1997, ARSPACE is participating in Task Force XXI through its submission of the Tactical Weather (TacWx) initiative. TacWx represents a teaming with the Army Research Laboratory's Battlefield Environment Directorate to provide the Task Force XXI commander with near-real-time state-of-the-art weather information and products. The system consists of ARSPACE Deployable Weather Satellite Workstation, ARL Battlescale Forecast Model, and the AF Tactical Forecast System. Lessons learned will be forwarded to the IMETS program as IMETS moves into similar capabilities for its Block II system development.

U.S. Army Kwajalein Atoll (USAKA) is a subcommand of USASSDC, which provides operational support to the test facilities KMR. KMR meteorological services support contractor performs meteorological functions in support of missile operations and for synoptic purposes, including surface, upper air, and meteorological satellite observations, and the preparation of daily aviation, marine, and special weather forecasts for the range.

Army Corps of Engineers Civil Operational Activities. The Corps of Engineers (COE) operates a network of about 8,000 gauges of which 2,200 are land-based limited meteorological observing sites. The remainder are hydrologic in-nature. The meteorological portion measures precipitation and other data in the United States to provide information for regulating COE dams and other water projects used for flood control, navigation, hydroelectric power, irrigation, water supply, water quality, and recreation. The COE transfers funds to NOAA/NWS to collect and maintain precipitation information from 423 of these sites.

The remainder are maintained by the COE. Data from many of these sites are automatically telemetered using satellite, microwave, landlines, radio, etc. to provide for real-time use of the data. Although the COE finances the network, data are made available to all other federal agencies.

Training and Doctrine Command Programs. TRADOC manages and develops training programs, writes Army and Joint weather support doctrine (concepts and field manuals), and establishes the weather requirements documents for Army tactical weather support equipment. The U.S. Army Intelligence Center and Fort Huachuca (USAIC&FH), Fort Huachuca, Arizona, is the proponent and user representative for the tactical support in wartime, contingencies, and peacetime tactical training. The USAFAS, Fort Sill, Oklahoma, is the proponent for upper air meteorological support. The Engineer School, Fort Leonard Wood, Missouri, coordinates weather support requirements in Terrain Analysis and Topographic Engineering. TRADOC schools submit requirements for weather support to HQ TRADOC for approval. HQ TRADOC normally submits requirements filled by USAF support to Air Combat Command for implementation. Requirements for Army provided communications or tactical equipment is submitted to ODCSOPS to prioritize and program resources.

USAIC&FH is the functional proponent for tactical Army weather support. The Center's Weather Support Team writes tactical weather support concepts and doctrine; identifies deficiencies and baseline requirements; provides weather support training to Intelligence and USAF personnel supporting the Army; and establishes requirements documents for weather support equipment, except in the artillery support area. USAIC&FH sponsors the Joint Army/Air Force tactical weather concept, which embraces the "Owning the Weather" initiatives of the Army Research Laboratory's Battlefield Environment Directorate. These TRADOC concepts describe how weather support to the future Army will be provided. They also describe the employment of IMETS with its capability to integrate information from national and indigenous sources to provide a 3-D of weather and environmental effects on and above the battlefield.

IMETS is a mobile, automated system that receives, integrates, models, and processes weather data from multiple sources. It provides near-real-time weather observations and tailored forecasts using digital displays to other Army tactical users. It provides tactical decision aids and weather effects information to help Army warfighters become more effective. IMETS integrates Air Force weather processing capabilities with Army Battle Command System hardware and software in a vehicle-mounted standard shelter able to move with the supported ground force. IMETS will provide tailored weather data fields to the All Source Analysis System, Digital Topographic Support System, and other Army Battlefield Operating Systems to support Army operations.

Automated Meteorological Sensor System (AMSS), a future battlefield weather data collection system, was originally planned for procurement in FY 1996 but is currently unfunded because of budget constraints. It is planned to be a source of tactical surface observations in forward areas and to send data to IMETS to support forecasting processes. Alternate sources of funding will be sought for future years.

USAFAS trains all field artillery meteorological crew members with a staff of 30 military and civilian instructors. USAFAS also has the role of developing requirements documents for new upper air observing systems and writing operational support concepts, doctrine, and procedures to be taught in the classroom and executed in the field.

The Aviation Center, Chemical School, and Engineer School incorporate weather instruction and procedures into training programs in their mission areas. The Engineer School develops methods of measuring and forecasting state of the ground parameters for terrain analysis and trafficability assessments. This includes identifying, justifying, and documenting requirements to interface meteorological and engineer battlefield systems. It also monitors R&D advances to incorporate these in combat development initiatives. Weather is taught in the Engineer Officer Advance Course. The Aviation Center has unique operational requirements for weather observations and USAF forecast support at remote training locations. Fort Rucker operates additional observing and communications equipment to relay all types of USAF-provided weather information to these Army sites.

Headquarters, TRADOC is the TRADOC approval authority for joint weather doctrine, weather hardware requirements, and weather support policy for TRADOC.

WEATHER SUPPORT RESEARCH, DEVELOPMENT, TEST, AND EVALUATION

Army Meteorological Research, Development, Test and Evaluation. Under Army-Air Force agreement, the Army has responsibility for weather support for RDTE to support Army ground combat missions. The Corps of Engineers and the Army Materiel Command (AMC) are the major contributors to weather research. The Medical Research and Development Command does research related to soldiers performance in the range of weather conditions expected to be encountered in all theaters of operations.

Corps of Engineers (COE). The COE is responsible for reviewing all emerging Army systems for environmental effects, as stated in Army Regulation 70-1. The COE also manages the Technology Demonstration (DT-08) program. Tactical Decision Aids (TDAs) are developed for this program by three COE laboratories: Topographic Engineering Center (TEC), Cold Regions Research and Engineering Laboratory (CRREL), and the Waterways Experiment Station (WES). WES develops TDAs supporting terrain analysis. TDAs interpret the impact of weather and terrain conditions on Army systems and operations. They are based on weather and terrain limitations, known as critical values. Critical threshold values are determined from design criteria, operational testing, or other evaluations of Army capabilities in adverse weather. Critical values define system limitations and are used by decision makers to take advantage over opposing forces. Technology demonstrations are currently being transitioned to terrain and weather systems such as IMETS, the Digital Topographic Support System (DTSS), the Army Tactical Command and Control System (ATCCS), and Battle Command Decision Support System.

- Topographic Engineering Center (TEC). The TEC, Fort Belvoir, Virginia, provides basic and applied environmental support to Army R&D programs and coordinates the development of TDAs relating to environmental effects on combat systems, operations, and personnel. This includes the development and integration of environmental effects data bases and models that are relevant to military plans, operations, and the acquisition communities. TEC also develops models and techniques to assist in the generation of proxy environmental information (climate and terrain) for data sparse areas and the integration of models to enable the spreading of this information spatially over map backgrounds. TEC is also responsible for developing integrated software modules that are designed to be exploited in the synthetic environment areas and for developing techniques to portray natural and induced battlefield environments, thus enhancing computerized battle simulations. TEC also contributes to the development of policies and procedures for the consideration of realistic natural environmental conditions for application in the materiel acquisition process. As preparer and custodian of AR 70-38, TEC provides special climatological studies and guidance to materiel acquisition activities. TEC also reviews all emerging materiel systems for environmental effects.
- Cold Regions Research and Engineering Laboratory (CRREL). Under the military portion of its civil and military support mission, CRREL in Hanover, New Hampshire, provides weather support to Army weapons systems RDTE, combat, and combat support mission areas, and develops climatological studies on the effects of winter environment on Army operations. CRREL is responsible for modeling in the areas of Cold Regions Surface-Air Boundary Process, Winter

Scene Dynamics, and Spatially Distributed Prediction Over Winter Terrain. CRREL develops data bases and models predicting Infrared and millimeter wave (MMW) weapon system performance, and the capability of technology to enhance military operations in cold environments. Under a Memorandum of Understanding (MOU), the U.S. Army Test and Evaluation Command (TECOM) provides operational observing, weather instrumentation, and forecasting services for CRREL's RDTE efforts through a Met Team located at CRREL.

Army Materiel Command (AMC). The Army Materiel Command (AMC) is responsible for the design, development, test, and evaluation of equipment to satisfy requirements for meteorological support equipment. AMC provides climatological and meteorological support to RDTE projects involving electro-optics and obscurants. It is also responsible for determining weather effects critical threshold values and environmental sensitivities of battlefield systems. AMC has several subcommands and elements carrying out weather R&D responsibilities.

Test and Evaluation Command (TECOM). TECOM is a subcommand of AMC providing operational support to 11 ranges and test sites with collocated Meteorological (MET) Teams. Under responsibilities established in Army Regulation 115-10 /Air Force Joint Instruction 15-157, the TECOM MET Teams provide weather support and atmospheric characterization to Army RDTE. MET Teams provide atmospheric data collection, analysis, consultation, warning, and forecast services for Army and other DOD RDTE.

MET Team FY 1997 funding has leveled off in FY 1997 following several years of decline, using a combination of both programmed funds and users funding. This will enable TECOM to continue basic meteorological support at Army RDTE ranges and sites, but meteorological instrumentation will be acquired through Army technical development resources or through direct funding from RDTE projects for test specific or unique requirements. Personnel and funding reductions in this program have limited the development of new technology, limited the development of new technology, limited training, and limited the capability of the MET teams. Program Element 06650601 funding of $0.342M represents a 5 percent reduction in funding, but will still enable full support to the modeling and simulation, test support, and chemical/biological requirements of Dugway Proving Grounds.

Army Research Laboratory (ARL). The ARL Battlefield Environment Directorate (BE) is the lead DOD agency for R&D in the portion of the atmosphere unique to the Army warfighter's battlespace--the planetary boundary layer. BE's mission is to "Own the Weather" by providing atmospheric effects information to decision makers on the battlefield in planning and executing operations. The joint Army/Air Force OTW initiative will provide knowledge of current and forecast battlefield environment conditions, along with their effects on systems, soldiers, operations, and tactics, to provide a decisive advantage over opponents.

Under the DOD Project Reliance taxonomy, BE is the lead agency for multi-service programs in transport and diffusion modeling and mobile atmospheric profiling, with the latter technology transferring out of BE to engineering development in FY 1997. In addition, BE contributes to tri-service goals in the areas of theater data fusion and predictions, boundary layer processes, and atmospheric effects.

The BE program is driven by the Army's need for meteorological information at smaller scales than used by either the Air Force, Navy, or civilian community, and over data sparse geographic regions. The Atmospheric Modeling & Simulation Division will have been moved to Adelphi, Maryland, along with the BE management during 4th quarter-FY 1996. The Battle Weather Division is scheduled to remain at White Sands Missile Range, New Mexico, until FY 1999, when it is also planned to be moved to Adelphi, Maryland.

The Atmospheric Modeling & Simulation efforts address: (1) models and simulations of environmental effects on electro-optical systems under realistic battlefield conditions; (2) acoustic propagation and background models for predicting environmental effects on acoustic signatures and sources; (3) micrometeorology, optics and beam propagation in the boundary layer; (4) transport and diffusion of chemical/biological agents and other aerosols released into the atmosphere; and (5) in-situ and remote detection of chemical/biological agents and pollution aerosols.

As a result of the transition to Maryland, the Atmospheric Profiling Research Facility will be split, with TECOM assuming the 50 MHz profiler, which will remain at White Sands Missile Range, along with

the NOAA 404 MHz radar. ARL BE will continue to perform boundary layer profiling research with the FM-CW radar and Sodars at an eastern location. BE's acoustic field work will also be moved east, including the 56 foot long Mobile Acoustic Source.

The Battle Weather efforts include: (1) methods to provide accurate and timely artillery meteorology information for precision strike applications; (2) tactical weather data assimilation and distribution in conjunction with battlescale forecast modeling and tactical decision aids; and (3) transitioning advanced weather technology to Battlefield Automated Systems and Battle Laboratories, to allow the warfighter to exploit weather as a combat multiplier and gain tactical advantage over the enemy.

BE is working closely with Army users and other DOD organizations to ensure the highest possible payoff for its R&D dollars.

Army Research Office (ARO). The Army Research Office (ARO), Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with atmospheric dynamics at small scales, propagation of electromagnetic radiation through natural and induced obscurants, and the physics of the atmospheric boundary layers.

The basic research program is conducted through the individual investigator program and several special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer where the Army operates. Objectives of the research are to develop, from first principles, the physical basis for understanding the boundary layer processes, thereby, leading to a better understanding of atmospheric effects on soldiers, materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heterogeneous terrain features on air flow, and the development of natural obscurations. An essential element of the research is the development of instrumentation to measure the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales.

Two areas of special funding are also managed. The Augmentation Awards for Science and Engineering Research and Training program provides funding for additional graduate and undergraduate students working under existing sponsored research programs. The other area is in Congressionally mandated funding to academic institutions. This office manages one such program.

Communications and Electronics Command (CECOM). The CECOM Intelligence and Electronic Warfare (IEW) Directorate, Fort Monmouth, New Jersey, assists CECOM Systems Management Directorate and other internal organizations in developing and fielding weather support systems; and helps the Program Executive Officer for Command and Control Systems with technical management of weather programs. Current programs supported are the MMS, IMETS, and the Meteorological Profiler System (MPS).

The MMS is a light version of the Meteorological Data System (MDS). MMS is now being fielded to the active Army. MMS is an upper air meteorological data collection, processing, and dissemination system that provides data to field artillery and target acquisition users. The system meets Army requirements of "roll-on, roll-off" capability during assault. The system is NDI and the contractor, ETG, is building 40 systems for the Army.

The MPS will provide the current meteorological system with new and enhanced capabilities. It will provide a suite of sensors which will reduce the time staleness of atmospheric data. These sensors are capable of sensing the atmosphere on an almost continual basis. It also provides a four dimensional (time and space) model of local terrain to further improve the accuracy of data.

The IMETS is a tactical meteorological collection, analysis, forecasting, display, and dissemination system, operated by USAF weather teams in support of Army tactical operations. Data is collected from sources, such as military and civilian forecast agencies, satellite imagery, upper air Army artillery teams, USAF weather teams, etc. The IMETS is capable of merging two or more tactical data displays to form composite displays over various map and digital terrain backgrounds; combining satellite imagery with surface observations; and displaying forecast rain and cloud imagery movement. Data and tactical decision aids are disseminated to tactical users over landlines, area communications, and HF radio.

Medical Research and Development Command. The U.S. Army Research Institute of Environmental Medicine, Natick, Massachusetts, conducts research on the effects of temperature, altitude, work, and nutrition on the health and performance of individual soldiers or combat crews operating Army systems.

Applied research efforts in thermal physiology and biophysical modeling are directed toward improving soldier performance and minimizing health risks in climatic extremes. The sensitivity of the soldier to weather parameters (primarily ambient air temperature, dew point temperature, wind speed, and solar radiation) defines an operational envelope for unimpaired human performance. The goals of applied research efforts are to develop methods to assess and extend the boundaries of the envelope in both training and operational settings.

In support of the Army Ranger training facility at Eglin AFB, Florida, Medical Research and Materiel Command and USARIEM are participating in the development of an automated thermal injury risk assessment system. The MERCURY-Ranger test bed system is being developed in partnership with the Army Research Laboratory's Battlefield Environment Directorate (ARL/BED), the Canadian Defence and Civil Institute of Environmental Medicine, and the USAF's 46th Weather Flight at Eglin AFB. Contractor technical support for MERCURY is provided by Science Applications International Corporation and, through the Advnaced Research Project Agency, Bolt Beranack and Newman Corporation. The MERCURY program ingests data from several local surface weather stations and automatically spreads the data across a region of interest using objective and heuristic interpolation methods. The resulting high resolution (1 km) gridded weather data fields are then used as inputs to the thermal strain prediction models for heat stress, cold air exposure, or cold water immersion. Results are displayed as color coded map overlays of thermal injury risk categories or tolerance times. This highly automated test bed system is intended to provide a platform for evaluating methods needed to translate real-time weather information into robust assessments of soldier system health risks and performance limitations.

APPENDIX C

DEPARTMENT OF TRANSPORTATION WEATHER PROGRAMS

FEDERAL AVIATION ADMINISTRATION

The FAA has the responsibility to provide national and international leadership in the optimization of aviation weather systems and services. This leadership is manifested through the management of a safe and efficient National Airspace System (NAS) and the encouragement of consensus and cooperation between government agencies, private weather services, research organizations, and user groups involved in aviation weather.

AVIATION WEATHER MANAGEMENT

NAS Management. For the last few years, the Federal Aviation Administration (FAA) has been focusing on initiatives to prevent accidents and delays attributable to weather. The focus on these initiatives underscored the need for centralized aviation weather program management. Feedback from users and other weather service providers only reinforced the FAA commitment to meet that need.

By necessity, operational aviation weather activities needed to be dispersed among FAA organizations responsible for the day-to-day operational responsibilities. The research and acquisition activities associated with the aviation weather program have already been centralized into the Office of Research and Acquisition. However, the policy and requirements functions for aviation weather were dispersed throughout the offices of Flight Standards Services, Airway Facilities Requirements and Life-Cycle Management, Air Traffic Plans and Requirements, and System Capacity and Requirements. The dispersal of these activities over four different organizations was an obstacle to the development and management of an aviation weather program that would meet the needs of the NAS envisioned for the 21st Century.

In 1995, the Associate Administrators for Air Traffic Services, Regulation and Certification, and Research and Acquisition agreed to centralize FAA aviation weather policy and requirements functions into one multidiscipline organization. The Associate Administrator for Air Traffic Services supported the location of the new organization within the office of Air Traffic Requirements Service. On October 1, 1995, the Aviation Weather Division was established and staffed with personnel from diverse backgrounds, such as flight standards, meteorology, airway facilities, and air traffic.

Most of the ongoing activities within FAA aviation weather program are well known. First, FAA works in partnership with many other government agencies to integrate aviation weather issues and activities into the overall national weather program. The partnership with the National Weather Service (NWS), that has been in existence for decades, is enjoying a revitalization with the establishment of the new weather division. The new division is working diligently to reaffirm FAA's leadership role in aviation weather and the important role of NWS in meeting aviation weather requirements.

During the next 5 years, FAA will focus on four major areas for aviation weather services:

- Roles/responsibilities.
- Training.
- Technology.
- Investment strategies.

This focus will provide some immediate benefits and, more importantly, will strengthen the foundation for future NAS services.

Roles and Responsibilities. The successful execution of a national aviation weather program is first dependent upon an explicit and mutually understood definition and acceptance of roles and responsibilities both within and outside of the FAA. The execution of these roles and responsibilities will be enhanced by the chartering and complete staffing of the Aviation Weather Division, clarifying FAA lines of business, and completing intra-agency and interagency plans.

Training. Aviation weather information, which is complex and highly perishable, is most useful when customers can successfully plan, act, and respond in ways that avoid accidents and delays. FAA will improve the ability of the aviation community to use weather information through a review and upgrade of airmen training and certification programs. FAA will also develop multimedia training tools to support aviation safety and training initiatives.

STRATIGIC VIEW FOR AVIATION WEATHER MODERNIZATION

Although many of the weather activities described in this Appendix were initiated before the creation of the Aviation Weather Division, the new division will lead the development of a strategic view for a national aviation weather program and further develop the plan for implementing that program. There are four major drivers of this strategic view.

First, there is operational urgency. The FAA is committed to the prevention of accidents and delays attributable to weather. From 1989 through 1993, 23 percent of all aviation accidents were attributable to weather. In 1992, 65 percent of all delays were attributable to weather at an estimated cost of over $4 billion. The projected growth of domestic traffic over the next 10 years demands the implementation of programs that increase capacity while continually maintaining mandated safety standards. A "weather-wise" program for the 21st century will anticipate and meet user requirements for both safety and capacity.

The next driver is the large and diverse group of stakeholders in the national aviation weather program. The large number of stakeholders increases the competition for limited resources; the diversity of stakeholders frequently results in conflicting objectives and priorities. The ability to integrate the needs and requirements of these stakeholders into the policies, investment strategies, and performance metrics of the national program will be key to its success.

The rapid advancement of aviation technologies is the third driver of this strategic view. The plan will redefine and clarify basic assumptions about the nature and delivery of aviation weather services. There will be a renewed emphasis on weather information as opposed to weather data. Aeronautical Data Link will enable simultaneous real-time dissemination of weather information to both the pilot and the air traffic controller. FAA will develop display and decision-making tools that enhance rather than burden decision making. FAA will develop procedures to support the users of this new technology as well as those users who will continue to rely on ground-based information systems. Human factors studies demonstrate the need to find the optimum balance point between technology and human performance. This need will be a key consideration in the design and placement of new equipment; in the training of pilots, dispatchers, and controllers; and in the regulations and procedures applicable in the NAS.

The final driver is consideration of the changing role of government and the diminishing funding of government services. Clearly the federal government is obligated to lead the development of a national aviation weather program, and this program should, by definition, consist of standards for and definitions of program requirements and services. However, to what extent should and can the federal government accept the responsibility for funding aviation weather services? Unfortunately, a world of unlimited resources does not exist. The more fundamental question, regardless of resources, is the appropriate role of the federal government. At this point, these questions cannot be answered; but, with a "weather-wise" strategic view, the FAA, along with other stakeholders, may be able to influence the answer.

Technology. Aviation weather technology includes the ways in which aviation weather information is gathered, disseminated, and displayed. The development of this technology also demands that consideration be given to human factors and the application of decision-making tools. FAA will support the use of technology by improving aviation weather information through integration of federal and non-federal resources; applying human factor considerations to the content, format, and dissemination of weather information; and establishing configuration management criteria for the software and hardware elements of aviation weather systems.

Investment Strategies. Sound investment strategies are characterized by the integration of many activities, primarily those of identifying, planning, and evaluating. Over the next 5 years, FAA will develop a sound investment strategy for a national aviation weather program that:

- Communicates the aviation weather objectives.
- Describes where the FAA wants to be.
- Considers all FAA and non-FAA funding for aviation weather that contributes to NAS performance.
- Develops and uses metrics that provide information on the performance of the national aviation weather program.

AVIATION WEATHER ACQUISITION AND SERVICES

One of the primary functions of the new organization is the development and management of requirements for the FAA Capital Investment Plan. Recent projects have focused on weather detection and display systems for pilots and air traffic controllers to ensure that aircraft avoid hazardous weather. The following paragraphs describe those projects.

Terminal Aviation Weather Programs

The Integrated Terminal Weather System (ITWS) will integrate weather data from sensors in the terminal area to provide and display compatible, consistent, real-time products that require no additional interpretation by controllers or pilots--the primary users. ITWS will use data from automated surface observing systems, Doppler weather radars, and low-level windshear alert systems, together with NWS data and products, to forecast aviation impact parameters, such as convection, visibility, icing, and windshear, including downbursts. Initial capabilities will include sensors available now through the late 1990's. The development is now in the demonstration phase at several airports in various climatic regimes. ITWS will operate at about 45 high activity airports that are supported by terminal Doppler weather radars. Full implementation is expected after the turn of the century.

The Terminal Doppler Weather Radar (TDWR) 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 windshear at selected high activity airports. In addition, it will have the capability to identify areas of precipitation and the locations of thunderstorms.

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. TDWR scanning strategy will be optimized for microburst/windshear detection. The radar will be located near the airport operating areas in a way to best scan the runways, and the approach and departure corridors. The displays will be located in the tower cab and Terminal Radar Approach Control (TRACON).

FAA has ordered 45 TDWR systems and 2 support units for training and testing. Deliveries will be completed by the end of calendar year (CY) 1996. A software upgrade has been initiated to integrate TDWR and low level windshear alert system data.

The Low Level Windshear Alert System (LLWAS) provides pilots with information on hazardous windshear conditions that create unsafe conditions for aircraft landings and departures. A total of 110 airports have LLWAS. The basic system 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 windshear conditions to air traffic controllers for relay to pilots.

The LLWAS-Network Expansion (LLWAS-NE) is the first step in the FAA's efforts to upgrade the NAS capability to detect windshear. The earlier, six-sensor systems provided adequate protection against microbursts; however, testing at Denver Stapleton Airport and Orlando International Airport have resulted in the development of two more sophisticated windshear detection systems--LLWAS-NE and LLWAS-3. LLWAS-NE will include expanding the network of sensors, improving sensor siting and providing runway-oriented alerts.

The improvement phase, referred to as LLWAS-3, will include expanding the network of sensors, developing improved algorithms for the expanded network, and installing new information/alert displays. The new information/alert displays will enable controllers to provide pilots with head wind gain or loss estimates for specific runways. These improvements will increase the system's windshear detection capability and reduce false alarms. Improvements are also expected to reduce maintenance costs. Initially, 83 airports have been identified to receive LLWAS-3; LLWAS-3 is scheduled to be fully deployed by CY 2001.

In the future, LLWAS-3 and TDWR will work in conjunction with one another and provide a synchronous alarm of windshear to the air traffic controller; in fact, development of a system is underway that will integrate the information from these two systems into a single windshear display. Investigation is also underway on how integrated windshear information can best be communicated or displayed to the pilot. Also, studies will be conducted to evaluate other sensors for the airport approach and departure corridors. These sensors are intended to provide windshear detection out to three miles from the touchdown zone.

The Surface Weather Observing Program. The FAA has taken responsibility for observations at many airports all across the country. To provide the appropriate observational service, FAA will use automated systems, human observers, or a mix of the two. It has been necessary to place airports into four categories according to the number of operations per year, any special designation for the airport, and the frequency at which the airport is impacted by weather.

- Level D service is provided by a stand-alone Automated Weather Observing System (AWOS) or an Automated Surface Observing System (ASOS). In the future, Level D service may be at as many as 400 airports.
- Level C service includes the ASOS/AWOS plus augmentation by tower personnel. Tower personnel will add to the report observations of thunderstorms, tornadoes, hail, tower visibility, volcanic ash, and virga when the tower is in operation. Level C service includes about 250 airports.
- Level B service includes all of the weather parameters in Level C service plus Runway Visual Range (RVR) and the following when observed--freezing drizzle versus freezing rain, ice pellets, snow depth and snow increasing rapidly remarks, thunderstorm/lightning location remarks, and remarks for observed significant weather not at the station. Level B service includes about 57 airports.
- Level A service includes all of the weather parameters in Level B service plus 10-minute averaged RVR for long-line transmission or additional visibility increments of 1/8, 1/16, and 0 miles. Level A service includes about 78 airports.

Automated surface weather observing systems will provide aviation-critical weather data (e.g., wind velocity, temperature, dew point, altimeter setting, cloud height, visibility, and precipitation type, occurrence, and accumulation) through the use of automated sensors. These systems will process data and allow dissemination of output information to a variety of users, including pilots via computer-generated voice.

FAA has deployed Automated Weather Observing Systems (AWOS) at over 200 airports to provide the basic aviation weather products directly to pilots approaching the airport. The majority of these systems were 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 previously did not have local weather reporting capability. These systems are built to the standards of quality necessary to ensure the safety of flight operations and are available off-the-shelf as a commercial product.

The FAA has negotiated with the National Oceanic and Atmospheric Administration (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 weather reporting capabilities. A production contract was awarded in February 1991. The FAA will be sponsoring, as part of the reimbursable agreement with NOAA, 537 systems with an option for 228 additional systems. The current buy of FAA-sponsored systems is for 304 of which 208 were installed by August 1996.

The AWOS/ASOS Data Acquisition System (ADAS) will function primarily as a message concentrator and will collect weather messages from AWOS and ASOS equipment located at controlled and non-controlled airports within each air traffic control (ATC) center's area of responsibility. ADAS will distribute minute-by-minute AWOS/ASOS data to the Weather and Radar Processor (WARP) and the Data Link Processor (DLP) within the center in which it is installed. ADAS will also distribute AWOS data to the National Airspace Data Interchange Network (NADIN) which will in turn forward the data to Weather Message Switching Center Replacement (WMSCR) for further distribution. The DLP (via Mode S) will make weather data available, on a timely basis, to pilots and air traffic controllers within the "local" area as well as other users. Field implementation of ADAS has started and will be completed in 1997.

AWOS for Non-Federal Applications. 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 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. 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 five versions of the non-Federal AWOS. An AWOS-A provides only altimeter setting. The AWOS I system contains sensors to measure wind direction and speed, ambient and dew point temperatures, altimeter setting, and density altitude. The AWOS II contains the AWOS I sensors plus a visibility sensor; AWOS III adds a cloud height sensor to an AWOS II. AWOS IV will include AWOS III capabilities plus the option for precipitation identification, thunderstorm detection, and runway surface condition. Most importantly, 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. AWOS III also enables the pilot, as part of their preflight activities, to call the AWOS and obtain the current weather observation. In addition, the observation may be transmitted to the database within the national weather network.

There are more than 275 non-Federal AWOS locations. Some of these are capable of reporting through a geostationary communications satellite, and many more will acquire that capability during the year. These observations will be entered into the national network for use in support of the NAS and the national weather network.

The New Generation Runway Visual Range (RVR) program provides for a new generation RVR sub-element of the NAS. The RVR provides runway visual range information to controllers and users in support of precision landing and takeoff operations. The new generation RVR incorporates state-of-the-art sensor technology and imbedded remote maintenance monitoring. FAA plans to procure and install these RVR systems at all new qualifying locations. FAA plans also call for the replacement of many existing RVRs in the NAS inventory.

The RVR provides for near real-time measurement of visibility conditions along a runway (up to three points along the runway can be measured-- touchdown, midpoint, and rollout) and reports these visibility conditions to air traffic controllers and other users. The system automatically collects and formats data from three sensors: a visibility sensor--forward scatter meters will replace the transmissometers currently in use, a runway light intensity monitor for both runway edges and center-line lights, and an ambient light sensor which controls computer calculations using a day or night algorithm. The data processing unit calculates RVR products and distributes the products to controllers and other users.

A total of 528 RVR visibility sensors will be deployed at 264 airport locations. Delivery of the new RVR sensors began in November 1994, and 45 units have been delivered as of August 1996. Enhancements are planned to interface with the Tower Control Computer Complex and the ASOS by 1997.

Airport Surveillance Radar-9 Weather Modular Enhancement. The Weather Modular Enhancement will be an add-on modification to the existing Airport Surveillance Radar-9 (ASR-9) radars and will provide air traffic controllers with information on low level windshear associated with microbursts and gust fronts in the vicinity of the airport. Presently, the ASR-9 weather data that are available consist of the six intensity levels as defined by the NWS.

En Route Aviation Weather Programs

The FAA is procuring the Operational and Supportability Implementation System (OASIS) to improve weather products, flight information, aeronautical data collection, analysis, and timeliness of dissemination and, thereby, enhance the safety and efficiency of the NAS. OASIS will replace the Model 1 Full Capacity Flight Service Automation System, which includes the Aviation Weather Processor. OASIS will also integrate the Interim Graphic Weather Display System functions. It will also include several automated flight service data handling capabilities. This configuration will be its initial deployment capability.

Future enhancements leading to the full capability deployment will include: interactive alphanumeric and graphic weather briefings, direct user access terminal (DUAT) service functionality, automated special use airspace, and training support. OASIS will support flight planning, weather briefings, NOTAM service, search and rescue, and pilot access terminal services.

Each OASIS will have interfaces with its host Air Route Traffic Control Center (ARTCC) computer, U.S. Customs Service, Treasury Department, foreign ATC facilities, and WMSCR. WMSCR will relay most of

the weather information, data, and pilot reports (PIREP).

The Next Generation Weather Radar (NEXRAD), known operationally as the Weather Surveillance Radar -1988 Doppler (WSR-88D), is a multiagency program that defined, developed, and implemented the new weather radar. Using the principles of the Doppler effect and state-of-the-art software, the WSR-88D is able to detect many properties of the atmosphere that were not heretofore routinely sampled. Departments of Commerce (DOC), Defense (DOD), and Transporation (DOT) jointly fund WSR-88D implementation costs; DOC is responsible for program management. The WSR-88D was developed and acquired under the auspices of the NEXRAD Program Council within the Office of the Federal Coordinator for Meteorology.

Field implementation began in 1990 and was completed in 1996. There are a total of 161 WSR-88D systems deployed within the three agencies. The FAA sponsored 12 systems in Alaska, Hawaii, and the Caribbean. DOC and DOD WSR-88Ds provide coverage over the continental United States.

The FAA emphasized the development of WSR-88D algorithms that take advantage of the improved detection of precipitation, wind velocity, and hazardous storms. The FAA also stressed that these algorithms provide new or improved aviation-oriented products. These improvements in detection of hazardous weather will reduce flight delays and improve flight planning services through aviation weather products related to wind, windshear, thunderstorm detection, storm movement prediction, precipitation, hail, frontal activity, and mesocyclones and tornadoes.

WSR-88D data provided to ATC through the WARP 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 to maximize fuel savings and manpower productivity.

In addition, the three funding agencies support the field sites through the WSR-88D Operational Support Facility (OSF) at Norman, Oklahoma. The OSF provides software maintenance, operational troubleshooting, configuration control, and training. Planned product improvements include a shift to an open architecture and the development of more algorithms associated with specific weather events, such as hurricanes. Field sites continually provide the OSF with suggestions for improvement of existing algorithms and applications of products.

A new Air Route Surveillance Radar (ARSR-4) provides the ARTCCs with accurate multiple weather levels out to 200 nautical miles. The ARSR-4 is the first en route radar with the ability to accurately report targets in weather. The ARSR-4 is used to provide weather information to supplement the WSR-88D in areas such as the Rocky Mountains. The ARSR-4 is a joint FAA/USAF funded project. Forty joint radar sites were installed during the 1992-1995 period.

The Weather Systems Processor (WSP) program will provide an additional radar channel for processing weather returns and de-alias returns from the other weather channel in the ASR-9. The displays of convective weather, microbursts, and other wind shear events will provide information for controllers and pilots to help aircraft avoid those hazards. A prototype has been demonstrated and limited production will commence in the fourth quarter of CY 1997. Full productions deliveries are expected to be completed by 2001.

Aviation Weather Processing Programs

The FAA participates in coordination among federal agencies, concerning Automated Weather Information Systems (AWIS). The OFCM-sponsored Committee for AWIS developed a national plan which integrates requirements, development, and implementation activities associated with AWIS programs and projects of the DOC, DOD, and DOT. Under this plan, the three departments are cooperating in the review, clarification, and allocation of requirements to the various specialized elements of the planned national AWIS. The intent of this activity is to avoid unnecessary duplication of development efforts and to ensure the sharing of information and products in the operational phase. New interface requirements are being defined and plans for product sharing are being developed. Within FAA, new interfaces with elements of the NAS will be developed to support the aviation weather information dissemination function. One interface will enable the DLP to provide WSR-88D mosaics for communication to pilots as well as receive PIREPs from aircraft in-flight.

The Meteorologist's Weather Processor (MWP) is a commercially available, interactive workstation which

was procured through a series of 5-year leases. It is used primarily by NWS meteorologists who are assigned to Center Weather Service Units (CWSU) at each of the ARTCCs. The MWP receives a stream of products and data fields which is controlled by the vendor but originates with the NWS. This system improves the dissemination of aviation weather information throughout the NAS, including pilots, air traffic controllers, flight service specialists, traffic management specialists, and NWS CWSU meteorologists. The MWP provides 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.

The original deployment of MWP was completed in 1992. The MWP, leased in the second 5-year period, will interface with the WARP, which should become operational in the late 1990s. The MWP also interfaces 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 the NWS' Advanced Weather Interactive Processing System (AWIPS).

The Weather and Radar Processor (WARP) will automatically create unique regional, WSR-88D-based, mosaic products. WARP will send these products, along with other time-critical weather information, to controllers through the Advanced Automation System (AAS) and to pilots via the aeronautical data link. WARP will greatly enhance the dissemination of aviation weather information throughout the NAS. It will have interfaces with WMSCR through NADIN, ADAS, OASIS, and DLP.

The Direct User Access Terminal (DUAT) system has been operational since February 1990. Through DUAT, pilots are able to access weather and NOTAMs and also file their IFR and/or VFR flight plans from their home or office personal computer. This system will eventually be absorbed into OASIS.

Aviation Weather Communications

It should be noted that FAA communications systems are multipurpose. Weather data, products, and information constitute a large percentage of the traffic, as do NOTAMS, flight plans and other aeronautical data.

The National Airspace Data Interchange Network (NADIN II) packet-switched network was 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, which provides extremely high data flow capacity and efficiency to the network users. NADIN II consists 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, Utah, and Atlanta, Georgia. It will interface directly to WMSCR, WARP, MWP, ADLP, ADAS, TMS, ACCC, and the Consolidated NOTAM System. NADIN II also may be used as the intra-facility communications system between these (collocated) users during transition to end state.

The Weather Message Switching Center Replacement (WMSCR) replaces the weather message switching center (WMSC) located at FAA's National Communications Center (NATCOM), Kansas City, Missouri, 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 NOTAMs. WMSCR will rely on NADIN for a majority of its communications support. The system will accommodate graphic data and function as the primary FAA gateway to the NWS' National Centers for Environmental Prediction (NCEP)--the principal source of NWS products for the NAS.

To provide for geographic redundancy, the system will have nodes in the NADIN buildings in Atlanta, Georgia, and Salt Lake City, Utah. Each node will support approximately one-half of the United States and will continuously exchange information with the other to ensure that both nodes have identical national databases. In the event of a nodal failure, the surviving one will assume responsibility for dissemination to the entire network.

The Aeronautical Data Link Program (ADLP) will implement the Data Link Processor (DLP) to support weather services for aircraft utilizing the discreetly addressed data link capability of the FAA's Mode Surveillance (MODE S) 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 communication 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 access to these data.

Initially, the data-link services to be implemented will be for automated databases which currently exist or are planned to be operational in the near term. These include alphanumeric products, such as SIGMETs, AIRMETs, surface observations, terminal forecasts, winds aloft, pilot reports, and alphanumeric radar summary information. Installation of this system began in 1991 and is continuing as programmed. The ADLP will be enhanced to support additional weather information (including windshear advisories) and ATC tower applications (including digital ATIS) and to provide expanded data-link communications functions in support of ATC data-link services.

The Worldwide Aeronautical Forecast System (WAFS) is a three geosynchronous satellite-based system for collecting and disseminating aviation weather information and products to/from domestic or international aviation offices as well as in-flight aircraft. The information and products are prepared at designated offices in Washington, D.C., and Bracknell, United Kingdom. The U.S. part of WAFS is a joint project of the FAA and NWS to meet requirements of the member states of the International Civil Aviation Organization (ICAO). FAA funds the satellite communications link, and the NWS provides the information stream.

Two of the three satellites are funded by the United States. The first is located over the western Atlantic with a footprint covering western Africa and Europe, the Atlantic Ocean, South America, and North America (except for the West Coast and Alaska). The second U.S.-funded satellite is positioned over the Pacific and covers the U.S. West Coast and Alaska, the Pacific Ocean, and the Pacific rim of Asia. The third satellite is stationed over the western Indian Ocean and covers the remaining areas of Europe, Asia, and Africa.

The data available via WAFS include flight winds, observations, forecasts, SIGMETs, AIRMETs, and hazards to aviation including volcanic ash clouds.

Aviation Weather Research Program

Working closely with the Integrated Product Team for Surveillance and Weather, the Aviation Weather Division sponsors research on specific aviation weather concerns, such as in-flight icing. This research is performed through collaborative efforts with the National Science Foundation (NSF), the NWS, and the Massachusetts Institute of Technology's Lincoln Laboratory. A primary concern is the effective management of limited research, engineering, and development resources.

The Aviation Gridded Forecast System (AGFS) will capitalize on significant advances in atmospheric sciences and computer technology to develop a four-dimensional database of weather phenomena that is of major importance to aviation. Data inputs from ASOS, radar wind profilers, satellite sensors, ACARS, radiosondes, and ITWS will provide the most accurate current and forecast variables with high spatial and temporal resolution. High technology computers will allow the forecasts to be run more often in a rapid update cycle. AGFS is being designed to generate timely regional and national aviation weather products for immediate use by non-meteorological personnel, such as pilots, air traffic controllers, traffic management personnel, and flight service specialists. The products will be available on the aeronautical data link. AGFS implementation is expected in the late 1990's.

Improved Aircraft Icing Forecasts. The purpose of this initiative is to establish a comprehensive multiyear 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 OFCM by the DOC, DOD, DOT, NSF, and the National Aeronautics and Space Administration to provide the NWS with an improved aircraft icing forecast capability. The objectives of this plan are to develop (1) an icing severity index, (2) icing guidance models, and (3) a better comprehension of synoptic and mesoscale conditions leading to icing. The result of this effort will be an improved icing forecasting capability that provides pilots with more timely and accurate forecasts of actual and expected icing areas by location, altitude, duration, and potential severity.

Convective Weather Forecasting. The purpose of this research effort is to establish more comprehensive knowledge on the conditions that trigger convection and thunderstorms and, in general, the dynamics of a thunderstorm's life cycle. The program will lead to enhanced capability to predict growth, movement, and type of precipitation from thunderstorms. Gaining this

forecast capability will allow better use of the airspace and help aircraft avoid areas with hazardous convective conditions.

Model Development and Enhancement. This research is aimed at developing or improving models to better characterize the in-flight environment and, thereby, deliver superior aviation weather products to end users.

Weather Support to Deicing Decision Making. There is a need to develop products that provide forecasts on the intensity of snow and freezing rain, and how or when these phenomena will change in the short term. This information is needed by airport management to determine when an aircraft will require deicing before take-off. The water content of snow is believed to be an important factor.

Other Aviation Weather Research. Other aviation weather research programs that are continuing, but at a lower level of funding, pertain to ceiling and visibility, turbulence detection, and convective weather detection.

UNITED STATES COAST GUARD

Among the United States Coast Guard's (USCG) activities are: marine and coastal weather observations by ocean-going cutters and at shore stations; collection and transmission of marine weather observations received from ships at sea by Coast Guard communications stations; broadcast of NWS marine weather forecasts, weather warnings, and weather facsimile charts to marine users; monitoring the seasonal iceberg threat to the North Atlantic shipping lanes off the Grand Banks of Newfoundland and the transmission of warning messages defining the iceberg limits; providing facilities and ship support to maintain the National Data Buoy Center (NDBC) network of automated environmental monitoring platforms; and operation of long-range radionavigation systems (OMEGA and LORAN-C), which are used by the meteorological sounding instruments essential to observational networks.

USCG ocean-going cutters and coastal stations provide weather observations to the NWS. Coast Guard communications stations broadcast NWS marine forecasts, weather warnings, and weather facsimile charts and, also, collect weather observations from commercial shipping for the NWS. In addition, Coast Guard groups broadcast NWS marine forecasts and weather warnings to users.

USCG conducts the International Ice Patrol (IIP) which uses radar-equipped aircraft to patrol the area of the Grand Banks off of Newfoundland during the iceberg season. IIP determines the geographic limits of the iceberg hazard and, twice daily, broadcasts iceberg warning bulletins and daily ice facsimile charts which depict the limits of all known ice. These broadcasts are made to the marine community during the period of iceberg danger. IIP operates an Iceberg Drift and Deterioration Model to predict iceberg distribution between IIP reconnaissance flights. IIP annually archives iceberg data reflecting all targets (both known icebergs and unidentified radar targets). The data is forwarded to the National Snow and Ice Data Center. The listing contains iceberg sighting data along with the last model-predicted position.

Various USCG facilities support NOAA's National Data Buoy Center (NDBC). NDBC's automated network of environmental monitoring platforms in the deep ocean and coastal regions provide accurate and reliable data for NWS and other users. Fifteen Coast Guard personnel fill key technical and operating positions within NDBC; the senior Coast Guard officer assigned serves as the NDBC Deputy Director. Coast Guard cutters provide the deployment and retrieval of data buoys and service visits to both buoys and coastal stations, expending up to 280 cutter days annually. Coast Guard aircraft, boat, and shore facilities also provide NDBC support.

USCG operates navigation stations providing OMEGA and LORAN-C radionavigation signals for the aviation and navigation communities. These signals also support the operation of meteorological sounding instruments essential to observation networks. OMEGA will cease operations September 30, 1997.

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

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

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 total grains has exceeded production in 3 of the last 4 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 weather information and in disseminating that information to them.

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

Historically, the Forest Service (FS) has collected meteorological data to assist in the control of forest fires and in the management of smoke from prescribed burning. Other activities also need weather data to ensure sound management decisions. Therefore, a national weather program was established to coordinate all FS meteorological activities and to meet the increasing need for diverse weather information. The major objectives of the program are to: (1) improve quality control of weather data, (2) improve the design and operation of data collection from networks, (3) increase data recovery from the weather stations, and (4) upgrade station maintenance. Meteorological data collected from 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 are being developed in cooperation with regional climate centers. The FS monitoring network will provide essential data for use in Global Change Research Program (GCRP) work.

The FS currently operates more than 900 RAWS and manual stations, many in the western United States. Air temperature, relative humidity, soil moisture, wind direction and speed, and precipitation are transmitted via NOAA's Geostationary Operational Environmental Satellite (GOES) telemetry. These data are received via a direct-readout ground site in Boise, Idaho, in cooperation with the Bureau of Land Management. The main use of the data is in the calculation of the fire danger rating for the FS and cooperating agencies. These data are also used by other resource managers; such as, road engineers, wildlife biologists, and hydrologists who monitor precipitation; silviculturalists (who are attempting to maximize tree-planting opportunities); and ecologists, soil specialists, and fisheries biologists (who monitor the effects of runoff). The main secondary user of RAWS data is the NWS for fire weather forecasting and flood warnings.

The Natural Resources Conservation Service (NRCS) operates a network of 1,400 manual snow courses and over 550 automated data collection sites in conjunction with the project (SNOTEL) for the western U.S. and Alaska. The primary objective of the project is to forecast water supplies and streamflow for the coming spring run-off 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 U.S. 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, NRCS initiated an upgrade to 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 gauges, antennas, towers, solar panels, battery 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 high quality commodities and products while minimizing any adverse effects of agriculture on the environment. As part of the USDA reorganization, the new Undersecretary for Research, Education, and Economics was created. This includes the merger of the Cooperative State Research Service and the Extension Service, and the transfer of the Economic Research Service and the National Agricultural Statistics Service (NASS).

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 the environment.

The Cooperative State Research, Education, and Extensive Service (CSREES) coordinates research programs in the state agricultural experiment stations, the 1890 Land Grant Distributions, and cooperating forestry schools. These institutions conduct a wide variety of 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, therefore, are the focus of this research. Research on the changes in levels of ultraviolet (UV) radiation as part of the GCRP was significantly expanded through the CSREES competitive grants program in FY 1994. The work is coordinated with EPA's UV radiation program and will support assessment efforts to develop related national policy on the environment.

Investigations by NASS support domestic crop estimating programs for all major commodities. Promising studies are underway to develop models relating weather parameters and associated variables to corn ear weight and wheat head weight. Previous efforts to develop models for short-term forecasting have 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.

A NASS program explores the use of satellite and weather data for assessing crop conditions is continuing. A preliminary investigation using polar-orbiting meteorological satellite data showed a good relationship between crop conditions 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.

FS research includes efforts to: (1) understand and control forest fire initiation by lightning, (2) improve the translation of mid-range forecast elements to describe forestry conditions, (3) incorporate drought information into management decision-making, and (4) 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 GCRP work.

DEPARTMENT OF THE INTERIOR

The Department of the Interior's (DOI) atmospheric science activities are primarily research in nature and historically have been reported through the Subcommittee for Atmospheric Research. The following narrative describes the full range of DOI's meteorological activities.

The Bureau of Land Management (BLM) is one of five Federal Land Management agencies which have centralized wildfire weather operations in the National Interagency Fire Center (NIFC) at Boise, Idaho. BLM's 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 IAMS inputs are Remote Automatic Weather Station (RAWS) meteorological data, Automatic Lightning Detection System (ALDS) information, and vegetation, slope, elevation, and terrain data. The real-time data sources are coupled to advanced fire modeling capabilities to facilitate the BLM's fire and resource management objectives.

The RAWS program collects meteorological data from a network of 3 classes of stations located throughout 12 western states including Alaska; the 3 classes denote the permanence of the site and the density and duration of data collection. All data are recovered via the NOAA's GOES system by the BLM's Direct Readout Ground Station (DRGS) located at NIFC. BLM presently owns 359 RAWS systems with about 300 of these being fielded. The network is designed to ultimately reach 359 fielded systems. Completion of the network, as planned, is contingent upon acquiring the personnel to implement and maintain the total number of planned systems.

The BLM's RAWS support facility at NIFC 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 11 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 U.S. The system provides data via a satellite telecommunications system to 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 DOD installations. The Alaska ALDS is comprised of nine DFs which provide the required coverage for Alaska Fire Service needs.

In addition to the meteorological monitoring conducted primarily in support fire management activities, BLM also conducts site-specific climate monitoring at over 200 locations on public lands in 11 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.

In 1991, the BLM Global Change Research Program (GCRP) established five monitoring sites in BLM wilderness and wilderness study areas to establish baseline conditions for assessment of long-term ecosystem trends. A total of 20 sites are planned to be established over the initial 5-year period. A standardized monitoring platform will make measurements of climate and atmospheric constituents.

The National Park Service (NPS) monitors air quality and visibility in several national parks and monuments. Gaseous pollutant data are collected on a continuous and integrated 24-hour basis. Surface meteorological data are collected and analyzed for hourly averages. Precipitation chemistry is determined on week-long integrated rainfall samples. Twenty-four average particle concentrations (number, mass, and chemical analyses) are measured twice weekly. Atmospheric light extinction is measured continuously and is satellite telemetered to a central location for analysis.

The NPS also conducts and contracts research to develop and test air quality models to assess long-range transport, chemical transformation, and deposition of air pollutants. These models are used to estimate source contributions to, and to identify source regions responsible for, observed pollutant loadings.

The Bureau of Reclamation (BuRec) activities requiring the collection and use of meteorological data include water scheduling, flood hydrology, irrigation project management, and reservoir operations. They also include projects related to the development of wind and solar energy resources. Multiagency work is also proceeding in projecting potential effects of climate change on western water resources and BuRec operations. The BuRec's weather modification research program has not been funded since 1989 except for reimbursable work.

Currently, the BuRec's HYDROMET system collects data from approximately 400 hydrometeorological data collection platforms (DCP) which transmit data in "real time" through the GOES to the DRGS in Boise, Idaho. AGRIMET is another network of 53 DCPs dedicated to analysis of crop water use and water conservation in the Pacific Northwest. Data collected and products created in Boise are electronically transferred to other BuRec, federal, and state offices.

The U.S. Geological Survey's (USGS) Water Resources Division collects streamflow, precipitation, and other climatological data for a number of projects concerning rainfall/runoff, water quality, and hydrologic processes. Currently, the USGS collects hydrometeorological data from approximately 4,000 remote DCPs. The data are transmitted to Wallops, Virginia, via GOES, and rebroadcast to a domestic communication satellite (DOMSAT). Data are received from the DOMSAT by local readout ground stations (LRGS) procured by the USGS under a 1992 contract. The USGS currently operates 10 LRGSs which provide near real-time data to the USGS's computerized National Water Information System.

The Geologic Division, through the National Geomagnetic Information Center (NGIC) in Golden, Colorado, collects data on temporal variations of the Earth's magnetic field from a global network of over 60 geomagnetic observatories. These observatories (which include 13 operated directly by USGS/NGIC) all belong to the INTERMAGNET program. Under INTERMAGNET, data from the global network of geomagnetic observatories are transmitted in near real time via satellites and computer links (E-mail) to collection and dissemination points called Geomagnetic Information Nodes (GIN). Five GINs are now located in Europe, North America, and Asia.

These data are key inputs to the National Space Environment Forecast and Warning Program and to the new interagency National Space Weather Program, which are coordinated through the OFCM, and are used for nowcasting, forecasting, and modeling of "space weather"--particularly the effects of geomagnetic disturbances. These effects range from satellite computer upsets and early reentry, to disruption of radio communications, degradation of navigation systems, e.g., the Global Positioning System, and outages of power distribution grids. The roles and responsibilities of agencies participating in the National Space Environment and Warning Program are detailed in the *National Plan for Space Environment Services and Supporting Research, 1993-1997* (FCM P10-1993), which was prepared by the OFCM Committee for Space Environment Forecasting.

The USGS is continuing a joint research program with NASA to map snowpack water equivalent using satellite passive microwave techniques. Comparisons of data collected by the USDA's Soil Conservation Service Snow Telemetry (SNOTEL) sites, by USGS field teams, and through instrumentation by other agencies, are being made to test the feasibility of making near real-time assessments of snowpack from space.

The USGS also carries out research on past climate change, regional hydrology, the carbon cycle, coastal erosion, volcanic activity, and glaciology. It collects precipitation samples for a number of studies to determine the atmospheric contribution to the chemical constituent loads to runoff and for defining the effect of atmospheric deposition on water quality and the aquatic environment.

The Minerals Management Service's (MMS) Environmental Studies Program gathers offshore environmental data in support of mineral leasing responsibilities. Currently, MMS supports eight data buoys which transmit, via GOES, off the Pacific Coast. Wind data are used in the MMS' Oil Spill

Risk Analysis Model to predict effects of potential spills.

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 NIFC.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The National Aeronautics and Space Administration (NASA) Headquarters Weather Support Office has continued to improve NASA's weather support capabilities for both manned and unmanned space 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 Space Shuttle launches and landings. The goal of the operations program is to provide the specialized meteorological data needed by operational forecasters at Cape Canaveral Air Station of Kennedy Space Center (KSC) and Johnson Space Center to support the Space Shuttle program. The focus is on detecting and forecasting the mesoscale weather events which strongly impact Shuttle ground processing, launches, and landing operations.

The Applied Meteorology Unit (AMU), collocated with the Air Force's Range Weather Operations, provides a facility to evaluate, exploit, and, if warranted, transition new meteorological technology into operations. For instance, the AMU strives to develop techniques and systems to help predict and avoid the impacts of KSC's frequent mesoscale summer thunderstorms which endanger the ground processing, launch, and landing operations of the American Space Program--Space Shuttle, DOD, and commercial. Special attention is given to improving and transitioning mesoscale numerical models. The AMU functions under a joint NASA, Air Force, and National Weather Service (NWS) Memorandum of Agreement.

Forecasts and observations for KSC are provided by Air Force meteorologists and contractors. KSC cost shares with the Air Force the expense of operating and maintaining (O&M) the Eastern Range's extensive meteorological network--KSC contributes 40 percent. KSC funds O&M of the Doppler Radar Wind Profiler (DRWP) and Lightning Detection and Ranging (LDAR) systems.

Further Space Shuttle budget decreases may require reductions in the NASA operational budget. Reduction magnitude and specific items affected will not be known for several months. Technology transition and study items would most likely be impacted. KSC will seek FY 1997 cost-sharing agreements with other users for O&M of KSC's (a) LDAR system and (b) 50 MHz DRWP. The Air Force is considering funding additional labor hours during FY 1996 to further develop, transition and evaluate a toxic diffusion prediction system. A major FY 1996-1997 initiative under contract is to replace the meteorological data display/analysis/distribution system which is becoming obsolete. The Air Force presently plans to pay most of the costs.

Supporting Research

The overall goal of the NASA's Mission to Planet Earth (MTPE) program is to understand the total Earth system and the effects of natural and human-induced changes on the global environment. To preserve and improve the Earth's environment for future generations, people around the world need to base policies and decisions on the strongest possible scientific understanding. The vantage point of space provides information about the Earth's land, atmosphere, ice, oceans, and biota that is obtainable in no other way. In concert with the global research community, the MTPE program is utilizing space to lead the development of knowledge required to support the complex national and international environmental policy decisions that lie ahead. The MTPE Earth Observing System (EOS) will establish the foundation for a new, innovative approach to global environmental monitoring and climate prediction. The outcome of MTPE's policy-relevant, global environmental science focus will help to insure a strategic advantage for American enterprise.

The scientific discipline associated with MTPE's activities is Earth system science which has strong elements in the atmospheric, oceanic, hydrological, ecological, and solid Earth sciences but integrates them in a way that the full-range of couplings in the Earth system can be addressed. Earth system science is a young discipline, and MTPE investigators and programs make a significant contribution to its emergence as a field of scientific endeavor. The collection of global data to characterize the Earth system is a cornerstone of the MTPE program. Comprehensive measurements are being made covering the land, atmosphere, ice, bodies of water, and biota. Data must be collected for extended periods of time due to the long time constants associated with the changing Earth system. Future data will be integrated with previously obtained data to enable study of the long-term evolution of the Earth system. The MTPE program is strongly committed to analysis and interpretation of archived data. Data gathering and analysis will be accompanied by theoretical and modeling efforts which provide the framework for the interpretation of data and for quantitatively testing our understanding of how the Earth system works.

The MTPE program develops Earth observing spacecraft and instruments, acquires and analyzes data, and disseminates these data, information, and scientific understanding throughout the world. Data, information, and knowledge from the MTPE program form the basis for decision-making on complex, environmental policies. NASA brings to the field of Earth system science the ability to observe the Earth globally from space. The MTPE program provides the space-based assets, complimentary aircraft, balloons and in-situ capabilities, and the scientific capabilities to interpret the data for modeling, prediction, and assessment needs. Resultant data, information, and scientific understanding must be provided to all classes of users, including but not limited to the Earth science community. Policy makers, environmental decision-makers and resource managers, industrial planners, social scientists and the general academic community, educators, and interested individuals must have effective access to Earth science data and ideas so that difficult decisions about managing the global environment can be made on an informed basis.

MTPE products form the basis for public education as well as for training future generations of scientists and engineers. Communication to the general public is important so that people can effectively participate in the national decision-making process and can understand the complex economic and environmental tradeoffs that may be required. Training of future generations of Earth scientists, fully representing the diversity of the United States is inspired and facilitated by the data and ideas developed by the MTPE.

The MTPE program contributes directly to American economic growth and competitiveness through the scientific products we deliver as well as by developing and infusing spacecraft instrument and information system technologies to enable new scientific investigations. Methods used by MTPE to obtain, interpret, and distribute Earth system data and information must be cost-effective and be at the cutting edge of science and technology. The MTPE utilizes advanced technology that is currently available and works to develop and infuse needed new technologies. MTPE investigators work to develop technologies and products that have multiple uses including those which will help ensure continued economic competitiveness for the United States. People are benefiting today from MTPE products. This includes farmers, foresters, fishermen, land-use managers, etc., who currently utilize the weather prediction and remote-sensing capabilities. Global environment is playing an increasing role in global business. Leading the international effort on global environment helps ensure a level playing field for enterprise. The MTPE program includes, on a fully reimbursable basis, technical and procurement support for the Nation's civilian weather satellite system on behalf of the National Oceanic and Atmospheric Administration (NOAA).

The MTPE program consists of the EOS, the EOS Data Information System (EOSDIS), a series of Earth probe satellites, additional payloads flown on the Space Shuttle, specialized aircraft and balloons, and a focused scientific investigation program that provides the scientific understanding necessary to accomplish the MTPE goals.

During 1995, NASA conducted a comprehensive review of the entire MTPE enterprise. The goal was to adopt an evolutionary approach to program planning which would enable: (1) a focus on near-term science and associated applications; (2) explicit provision for new technology infusion; (3) reduction in life-cycle cost of the EOS program;

(4) provision of new science opportunities through smaller, quicker, and less expensive missions; and (5) closer participation with other federal agencies (especially NOAA), commercial firms, and international partners.

The result of this review is an EOS which is lower in life-cycle cost, more flexible in implementation, and of greater utility to the science and commercial communities. We continue to refine this plan and seek the advice of the National Academy of Sciences (NAS) and other external groups as we progress. Our basic approach has been endorsed by the NAS Board on Sustainable Development.

Upcoming activities over the next 2 years in the MTPE program include, in the Earth probes program, launch of the first Total Ozone Mapping Spectrometer (TOMS) Earth probe in FY 1996, launch of the NASA Scatterometer and TOMS instrument on the Japanese Advanced Earth Observing System (ADEOS) spacecraft in FY 1996, and launch of the Tropical Rainfall Measuring Mission (TRMM) in early FY 1998. The mission operations and data analysis program within MTPE will begin operations of the Earth probe satellites and processing of the data received from them in addition to maintaining activities for currently orbiting satellites, including TOPEX/Poseidon and UARS and recently completed space shuttle missions. The instrument and payloads development program will be focused on Shuttle Imaging Radar C (SIR-C) and Atmospheric Laboratory for Applications and Science (ATLAS-3) post-mission activities. Within the EOS, preliminary design review will be held for PM-1 in FY 1997. Critical design reviews will be held for the Sea Winds spacecraft and Stratospheric Aerosol and Gas Experiment (SAGE-III) in FY 1996. Instruments for AM 1 and Landsat 7 will be delivered in FY 1997. The EOSDIS will release Version 1 in FY 1997 and prepare for the release of Version 2.

The overall goal of the EOS is to advance the understanding of the entire Earth system on a global scale by improving our knowledge of the components of the system, the interactions between them, and how the Earth system is changing. The EOS data will be used to study the atmosphere, oceans, cryosphere, biosphere, land surface, and solid Earth, particularly as their interrelationships are manifested in the flow of energy and in the cycling of water and other chemicals through the Earth system.

The EOS program mission goals are: (1) to create an integrated, scientific observing system emphasizing climate change that will enable multi-disciplinary study of the Earth's critical, life-enabling, interrelated processes; (2) to develop a comprehensive data and information system, including a data retrieval and processing system; (3) to serve the needs of scientists performing an integrated multidisciplinary study of planet Earth and to make MTPE data and information publicly available; and (4) to acquire and assemble a global database for remote-sensing measurements from space over a decade or more to enable definitive and conclusive studies of Earth system attributes.

The EOS will contribute directly to accomplishing the goal of understanding global climate by providing a combination of observations made by scientific instruments which will be integrated with the EOS spacecraft and the data received, archived, processed, and distributed by the EOSDIS. The selection of scientific priorities and data products responds directly to the GCRP global change science priorities and the Intergovernmental Panel on Climate Change's (IPCC) assessment of the scientific uncertainty associated with global change.

The three main EOS spacecraft that will support observations by the scientific instruments include the morning (AM), afternoon (PM), and Chemistry series. Beginning in 1998, 2000, and 2002 respectively, a satellite in each series will be flown for a period of 6 years in order to obtain, at a minimum, a data set that will span 15 years. Additional observations will be provided by the Landsat-7 mission in 1998. Data continuity for the Landsat program will be maintained by flying an advanced technology Landsat instrument on the AM-2 mission in 2004.

The EOS AM 1 will be launched in June 1998. The global climate change research emphasized by the AM instrument data set will include cloud physics, atmospheric radiation properties, and terrestrial and oceanic characteristics. Because the AM series primarily observes terrestrial surface features, a morning equatorial crossing time is preferred to minimize cloud cover over land. The primary contractors associated with the program are Lockheed Martin Astro Space for the AM-1 spacecraft, Hughes Santa Barbara Research Center for the Moderate Resolution Imaging Spectrometer (MODIS) instrument, TRW for the Clouds and Earth's Radiant

Energy System (CERES) instrument, (the instrument will also be flown on the Tropical Rainfall Measuring Mission (TRMM) in 1997 and PM Series spacecraft and as a flight of opportunity), and Lockheed Martin Commercial Launch Services for the AM-1 Atlas Centaur/IIAS launch service. The Multi-Angle Imaging Spectrometer (MISR) instrument is being built in-house at the Jet Propulsion Laboratory (JPL). The Japanese will provide the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument; the Canadians will provide the Measurement of Pollution in the Troposphere (MOPITT) instrument for the AM-1 spacecraft. The Earth Observing Scanning Polarimeter (EOSP) instrument for AM-2 will be built in-house at Goddard Space Flight Center (GSFC), Greenbelt, Maryland.

The research focus of the PM series is atmospheric temperatures and humidity profiles, clouds, precipitation, and radiative balance; terrestrial snow and sea ice; sea-surface temperature and ocean productivity; soil moisture; and the improvement of numerical weather prediction. With the emphasis of the instrument complement being cloud formation, precipitation, and radiative properties, an afternoon equatorial crossing is more suitable for acquiring the data. The primary contractors associated with the program are TRW for the common spacecraft to be used for PM-1 and Chemistry-1; Loral Infrared and Imaging Systems (LIRIS) and JPL for the Atmospheric Infrared Sounder (AIRS) instrument; and Aerojet General Corporation for the Advanced Microwave Sounding Unit (AMSU-A) instrument. We anticipate that the Japanese will be providing the Advanced Microwave Scanner Radiation (AMSR) instrument for the PM-1 spacecraft. We are currently negotiating with Brazil for provision of the Microwave Humidity Sounder (MHS).

With the launch in 1998 of Landsat 7, substantially cloud-free, sun-lit land surface imagery for detecting and characterizing regional and global change will continue. The primary contractors are Lockheed Martin Astro Space for the Landsat-7 spacecraft, Hughes Santa Barbara Research Center for the Enhanced Thematic Mapper Plus (ETM+) and McDonnell Douglas for the Landsat-7 Delta 2 launch service. The Landsat 7 estimate includes funding for ground segment development. NOAA will be responsible for operating the satellite and the United States Geological Survey (USGS) will archive the data.

The AIRS, AMSU, CERES, and MODIS PM-1 instruments remain on schedule for a December 2000 launch. All issues identified in the January AIRS PDR were closed out by the end of FY 1995, and the CDR is scheduled for February 1997. The AMSU PDR was completed in September 1994. Because the build of AMSU instruments for the operational weather satellites was added to the EOS AMSU contract, the AMSU CDR was delayed from mid-FY 1995 to April 1996. Development of the CERES and MODIS instruments for PM 1 are proceeding on schedule in synchronization with the AM 1 program.

The search for an alternative to the MHS instrument, which was originally to be provided by EUMETSAT, is continuing. The Brazilian space agency is currently exploring partnership arrangements for providing an MHS instrument.

The European Space Agency indicated recently that it would not be able to commit to providing a Multifrequency Imaging Microwave Radiometer (MIMR) instrument for the PM-1 spacecraft. Therefore, NASA is pursuing Japan's offer to provide an AMSR instrument. The Japanese engineers and the PM-1 project at GSFC are performing accommodation studies. An in-house build of a PM Microwave Imager is being evaluated as a backup; although this effort will be dropped if an agreement with the Japanese on AMSR can be implemented.

Because of the stop work order on TRW, the PM-1 spacecraft System Concept Review has been delayed. The CDR for the PM-1 AMSU instrument will be held the third quarter of FY 1996. The AIRS and AMSR CDR's are scheduled for FY 1997 and FY 1998, respectively. The CDR's for CERES and MODIS have already been completed. The PM-1 flight instruments (AIRS, AMSU, AMSR, CERES, and MODIS) will be in various stages of fabrication, assembly, integration, and testing throughout FY 1996.

Integration and testing of the AIRS engineering model will begin in FY 1997 with delivery scheduled for the fourth quarter of FY 1997. Fabrication and assembly of the AIRS proto-flight model will continue throughout FY 1997. Fabrication and assembly of the remaining PM-1 flight instruments (AMSU, AMSR,

CERES, and MODIS) will be completed in FY 1997; integration and testing phase will also begin in FY 1997.

The goals for the EOSDIS are: (a) the development and operation of a highly integrated system which can produce the data and information products from the EOS, (b) preserve these and all other MTPE environmental observations for continuing use, and (c) make all these data and information easily available for use by the research, education, and government agencies and all those who can benefit from them in making economic and policy decisions. The EOSDIS is critical to achieving the goals of MTPE by enabling the public to benefit fully from increased understanding and observations of the environment.

The EOSDIS will be based on an evolutionary design to enable adaptation to changes in user needs and technology. The design is also modular allowing the replacement of individual components without costly overall system changes or disruptions in service. NASA is making extensive use of prototypes to assure that EOSDIS will effectively meet the needs of the satellites and users. A limited amount of technology development and adaptation is focused specifically on meeting EOSDIS evolutionary needs while relying on other programs at NASA and other agencies to fund needed technology development efforts of a more generic nature. An initial version of the system, implemented at nine Distributed Active Archive Centers and through cooperative efforts with NOAA, USGS, and international partner space agencies became operational in 1994. Major development of the next two versions of the system are under way to prepare for the first flights of EOS instruments on TRMM in 1997, as well as the EOS AM-1 and Landsat 7 missions in 1998, to improve service to users and incorporate new technologies.

The Earth probes program is the component of MTPE that addresses specific, highly focused mission requirements in Earth science research. The program was designed to have the flexibility to take advantage of unique opportunities presented by international cooperative efforts or technical innovation, and to complement the EOS by providing the ability to investigate processes that require special orbits or have unique requirements. The currently approved Earth probes are TOMS, NASA Scatterometer (NSCAT), TRMM, and the Earth System Science Pathfinders (ESSP).

Because winds are a critical factor in determining regional weather patterns and global climate, NSCAT has been developed to measure near-surface wind direction and speed over the global oceans every 2 days under all weather and cloud conditions. The NSCAT data will be useful for both oceanography and meteorology and will permit the first global study of the influence of winds on ocean circulation. NSCAT will also provide data on the effects of the oceans on the atmosphere and improved marine forecasting of winds and waves. JPL is the lead center for this program, and the Harris Corporation is the main contractor for the instrument development.

When NSCAT was first initiated in October 1984, it was planned for launch aboard the Navy Remote Sensing Satellite (N-ROSS). After final cancellation of N-ROSS in March 1988, NSCAT was selected in August 1989, for flight on the Japanese Advanced Earth Observing System (ADEOS). Since a majority of the instrument design was completed during the period that NSCAT was to fly on N-ROSS, in the past few years, the program has centered on making design changes to the instrument so that it can be accommodated on the ADEOS spacecraft and on completing the instrument. The NSCAT launch is now planned for August 1996. The launch of the Japanese ADEOS spacecraft was slipped from February 1996 when the Japanese experienced anomalies with the spacecraft during integration and testing.

The scientific objectives of the TOMS program are to measure the long term changes in total ozone and to verify the chemical models of the stratosphere used to predict future trends. The TOMS flights build on the experience that began in 1978 with the launch of a TOMS instrument (Flight Model 1) on Nimbus-7 and continues with the TOMS instrument (Flight Model 2) on the Russian Meteor-3, launched in 1991. As with the earlier developments, GSFC has the responsibility for flight project development, and post-launch mission operations and data analysis. Prime contractors are Orbital Sciences Corporation for the TOMS instruments and Pegasus launch services; TRW for the TOMS Earth Probes spacecraft. The TOMS program consists of a set of instruments (Flight Models 3, 4, and 5, designated FM-3, FM-4, and FM-5) and one spacecraft for launch on a Pegasus expendable launch vehicle in mid-FY 1996 (FM-3). The FM-4 is planned for launch on the Japanese ADEOS satellite in

August 1996. The FM-5 was completed in 1995 and is planned for a cooperative mission with Russia in 2000.

The latent heat released during precipitation is a significant factor in the large-scale computer models used to predict weather and climate change, yet two-thirds of the global rainfall occurs over the tropics where ground-based rain measurements are scarce. The TRMM objective is to obtain a minimum of three years of climatologically significant observations of tropical rainfall. In addition, TRMM will provide precise estimates of the vertical distribution of latent heat in the atmosphere. The TRMM data will be used to understand the ocean-atmosphere coupling, especially in the development of El Niño events which form in the tropics but effects of which are felt globally-- causing floods in some areas and droughts in others. GSFC has the responsibility for flight project development, and post-launch mission operations and data analysis. The contractors for the instruments are Hughes Santa Barbara Research Center for the Visible and Infrared Scanner (VIRS) and Hughes Space and Communications for the TRMM Microwave Imager (TMI).

The Japanese space agency is an active partner with all three Earth probes and provides the ADEOS spacecraft and H-II launch vehicle for the TOMS FM-4 and NSCAT as well as the Precipitation Radar instrument and H-II launch vehicle for TRMM. Russia will also be a critical partner for the last of the three TOMS Earth Probes missions and provide the Meteor-3 spacecraft and launch vehicle.

The ESSP is a science-driven program intended to identify and develop small satellite missions to accomplish scientific objectives in response to national and international research priorities not addressed by current programs. ESSP will provide periodic "windows of opportunity" to accommodate new scientific priorities and infuse new scientific participation into the MTPE program. By launching ESSP missions on a frequent, regular basis, NASA will provide a mechanism by which pressing questions in Earth system science may be addressed in a timely fashion and, thereby, permit a continual improvement in our understanding of the Earth system and the processes that affect it.

The ESSP first Announcement of Opportunity (AO) is being formulated with the following programmatic guidelines. The first two ESSP missions will be: focused on high-priority Earth system science research, limited to a total mission life cycle cost from NASA of $120 million, managed by the principal investigator as the single point of contact accountable for total mission implementation and success, developed in less than 36 months from development authority to proceed, and compatible with EOSDIS standards including the immediate release of mission data to the scientific community.

The goal of Applied Research and Data Analysis is to advance our understanding of the global climate environment, the vulnerability of the environment to both human and natural forces of change, and the provision of numerical models and other tools necessary for understanding global climate change.

The applied research and data analysis program is divided into two major components: (1) MTPE Science and (2) Operations, Data Retrieval, and Storage. The activities that support MTPE science include research and analysis, EOS science, and airborne science and applications. Operations, data retrieval, and storage consist of several independent activities responsible for the operation of currently functioning spacecraft and flight instruments, the purchase and management of scientific data, and the provision of computing infrastructure. Each of the major components of applied research and data analysis has its own set of goals, strategies for achieving the goals, performance measures, and accomplishments and plans.

The goal for the MTPE science program is to contribute interdisciplinary scientific understanding of the Earth system and the effects of humankind on the global environment. Major emphasis is placed on providing early warning and fast response to global environmental changes which pose risks to society. The science program also provides the analysis and integration of critical data and models needed for national and international assessments. MTPE Earth system science activities are essential to the design of future operational observing systems and global sustainable development strategies.

The research and analysis science program is essential to the discovery of new concepts and to the design of future missions. The primary mode of research coordination occurs through the GCRP, the Committee on the Environment and Natural Resources (CENR) Subcommittee on Global Change

Research, and the various boards and committees at the National Academy of Sciences. The type of basic research supported by research and analysis is exemplified by the work of Professors Rowland and Molina who received the 1995 Nobel Prize in chemistry for studies of stratospheric ozone. They made their original discoveries as a result of work supported by research and analysis funding.

The strategy of interdisciplinary research is to increase scientific understanding of the global environment and its vulnerability to both human and natural forces of change (e.g., pollution, climate variability, deforestation). EOS Interdisciplinary science consists of both focused research centered around a specific Earth science data set and interdisciplinary research geared toward a broader probe into Earth science systemic functions. The quality of the data utilized is monitored by the scientists at Interdisciplinary Instrument Computing Facilities and the research is supplemented by graduate student participation in the EOS science fellowship program. Modeling and data analysis research will synthesize existing environmental data, build component models, and conduct tests and evaluations of model progress. This approach will provide well-documented and tested disciplinary models and data sets to the interdisciplinary science program where integration into global biogeochemical and Earth system models occurs. The process studies program will help Earth scientists understand and predict global change through planning and support of laboratory and field studies, advanced instrument development, satellite and in-situ data analysis, and the development of process-scale models and numerical tools to aid in diagnosing and predicting natural and human-induced global environmental change. The outcomes of this research will be essential to United States leadership in designing sustainable development strategies for the 21st century.

There are currently over 1,700 scientific activities being funded under the Research and Analysis Program. Approximately 900 are carried out by universities, 100 by national research laboratories, and 700 by the federal government. The distribution of the activities encompasses 45 of the 50 states.

The airborne science program funds operations of two ER-2's, a DC-8, and a C-130. In FY 1997, the C-130 aircraft will no longer be part of the airborne program. If a C-130 is needed to support Earth science investigations, another NASA C-130 may be used on an as needed basis. The program also funds operation and support of a core of remote sensing instruments and a facility for analyzing and calibrating data from those instruments. The specially modified aircraft serve as test beds for newly developed instrumentation and their algorithms prior to launch by ELV's or the Shuttle. The instrumented aircraft provide remotely sensed and insitu data for many Earth science research and analysis field campaigns, including stratospheric ozone, tropospheric chemistry, and ecological studies throughout the world. The ER-2 aircraft, in particular, are unique in that they are the highest flying subsonic civilian research aircraft and were key in collecting insitu data for our understanding of ozone depletion and stratospheric transport mechanisms.

In FY 1997, NASA will initiate a data purchase program designed to acquire from commercial sources data sets not otherwise available that are necessary to accomplish the broad research goals of Earth system science. The current generation of data purchase to begin in FY 1997 derives from the experience of the Optical Transient Detector and Sea Star/Ocean Color. The current generation data purchase contract will be executed in FY 1997 after broad agency competition. The budget authority will be liquidated only as acceptable data are delivered. Data product generation, data archival, science analysis, and all other NASA requirements are included in other elements of the MTPE budget.

In FY 1997, NASA will initiate a data purchase program designed to acquire data sets rather than hardware to produce the data from commercial sources. Such innovative methods of procurement were suggested in the Vice President's National Performance Review. The budget authority for the data sets purchased will be liquidated only as acceptable data are delivered, and the proposed contract will be executed with FY 1997 funds only after broad agency competition.

An international intercomparison and assessment of global vegetation models was conducted in the summer 1995. The summary report of results of the assessment was delivered in December 1995. Data from the Boreal Ecosystem-Atmosphere Study

(BOREAS) will be analyzed and assessed to improve climate and weather models and to determine whether the study region is a net source or sink of carbon and methane. The BOREAS results will also improve ecological models of the boreal forest biome needed for sustainable forestry. EOS investigators will utilize the data gathered in EOSDIS to perform integrated interdisciplinary studies of the Earth to enhance the capability to predict global climate change. The MTPE interdisciplinary science education strategy will continue to focus on sponsoring global change fellowships for highly qualified graduate students at U.S. universities. In FY 1996, approximately 160 graduate students will be funded under the EOS Interdisciplinary Science Fellowship Program.

The Airborne Visible Infrared Imaging Spectrometer will be used in FY 1997 for land imaging and applications research in preparation for the Small Spacecraft Technology Initiative Lewis mission; data collected by the Lewis spacecraft will be used to classify surface land cover and vegetation types. In FY 1996, we will complete the Multi-center Airborne Coherent Atmospheric Wind Sensor development and science demonstration flights. The LIDAR In-Space Technology Experiment data will be delivered to the Langley Research Center Distributed Active Archive Center for access by the scientific community. A science data workshop will be held with scientific results to be published in the open scientific literature by FY 1997. A TOPEX/Poseidon mission review was held in November 1995. The remarkable accomplishments of the TOPEX/Poseidon, specifically the capability for measuring ocean topography, are significantly improving the understanding of ocean circulation and ocean-climate interactions.

A workshop involving the participating investigators in the interdisciplinary aerosol research program was convened in the fall of 1995. A summary assessment of the impact of aerosols on atmosphere chemistry and climate will be completed and released to the public by August 1996. Surface Radiation Budget (SRB) data will be provided to the International Satellite Land Surface Climatology Project Pathfinder, Global Energy and Water Cycle Experiment and scientific community in FY 1997. The global short-wave and long-wave SRB data sets (covering the period 1992 to 1995) will be extended to 1996. Validations of the satellite-based algorithms using reliable ground truth data, including the global Baseline Surface Radiation Network and Global Energy Budget Archive data sets, will be completed in FY 1997 and results will be published in the open literature. The current International Satellite Cloud Climatology Project (ISCCP) will be extended from the current 1983-1992 interval to the year 2000. The interval 1982-1995 will be completed by FY 1997. The entire ISCCP climatology will be recalculated in FY 1996 using the improved version 2.0 algorithm. A World Climate Research Program biannual ISCCP review workshop will be conducted. The results of the Smoke, Clouds, and Radiation (SCAR)-A (Atlantic), SCAR-C (California), SCAR-B (Brazil) campaigns will be presented in a series of science data workshops and science conferences and the results will be published in the scientific literature beginning in FY 1997. The Pacific Exploratory Mission-Central field campaign will be completed by October 1996. This field campaign will explore fundamental atmospheric chemical processes in the eastern tropical Pacific which is considered to be a "clean" air region.

Savings will be achieved in FY 1997 due to policy changes suggested by the NASA Zero Base Review. One change in policy is that support contractors will no longer perform in-house science, research, and engineering.

The scientific issues of concern to MTPE are among the most complex and most policy relevant of any major scientific research program. The results of MTPE science are critical to the development of sound U.S. and global environmental policy necessary for long-term sustainable development. MTPE Science is focused on the following priorities: Atmospheric Ozone, Seasonal-to-Interannual Climate Prediction, Long-term Climate Variability, Land Cover Change, and Natural Hazards. (See Table D.1)

The Operations, Data Retrieval and Storage (ODRS) program provides the data and data products from EOS precursor missions, including UARS, TOPEX, TOMS, and future missions, such as NSCAT and TRMM, required to understand the total Earth system and the effects of humans on the global environment. The goals of the NASA High Performance Computing and Communications (HPCC) program are to accelerate the development, application, and transfer of high performance computing technologies to meet the engineering and

TABLE D.1 MISSION TO PLANET EARTH PRIORITIES

	FY 1995	FY 1996	FY 1997
Seasonal-To-Interannual Climate Variability	Improved Prediction with Coupled Ocean-Atmospheric Models	Evaluate Role of El Niño in Tropical Droughts	Provide Improved Sea Surface Winds to Prediction Models
Long-Term Climate System Variability	Role of Volcanic Aerosols in Climate	Role of Total Aerosol Burden in Climate	Tropospheric Ozone as a Climate Driver
Atmospheric Ozone Research	Complete Assessment of Stratospheric Chlorine Sources	Ozone Transport Field Campaign	Establish Role of Asian Emissions in Ozone Levels
Land Cover - Land Use	Satellite Methods for Deforestation in South America	Evaluate Hyperspectral Remote Sensing of Land Ecosystems	Tropical Rain forest - Climate: International Field Campaign
Natural Hazards	Dense Array GPS for Earthquake Studies	Strategic Plan for Remote Sensing of Flooding/Droughts	Initiate Program on Flood/Drought Assessment

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science needs of the U.S. aeronautics, Earth science, and space science communities and to accelerate the implementation of a National Information Infrastructure.

The ODRS program supports the observations and data management portion of the activities, including process research, integrated modeling and prediction, and assessments that together produce a predictive understanding of the Earth system. The ODRS program will achieve its goals through the Mission Operations and Data Analysis (MO & DA) and information systems. The data and data products from the ODRS program have or will migrate to the EOSDIS.

The MO&DA program objectives are to acquire, process, and archive long-term data sets and validated data products. These data sets support global change research in atmospheric ozone and trace chemical species, the Earth's radiation budget, aerosols, sea ice, land surface properties, and ocean circulation and biology. Funding provides for operating spacecraft, such as UARS, TOPEX, and Earth Radiation Budget Satellite (ERBS), and for processing of acquired data.

The MTPE MO&DA program has been structured to provide a balanced system of high performance computers, mass storage systems, workstations and appropriate network connectivity between researchers and components of the system. A major portion of the program funding supports operations of the NASA Center for Computational Sciences, a supercomputing center at GSFC. A full range of computational services are provided to a community of approximately 1,400 users from all disciplines of Earth and space sciences. Users of the supercomputer complex select representatives to an advisory committee who are integrally involved in strategic planning for the evolution of the complex. They provide feedback on user satisfaction with services provided and help establish priorities for service and capacity upgrades. Offsite NASA-sponsored users comprise some 25 percent of the total. The program has also been structured to take advantage of new technology as it reaches production maturity. The program monitors and participates in advanced technology programs, such as the HPCC program and National Science Foundation's Gigabit Testbed programs. Program elements at GSFC and the JPL are focused on providing early access to emerging technologies for the Earth and space science communities. The early access to new technology provides the program with the opportunity to influence vendors and system developers on issues unique to the Earth and space science researchers, such as data intensive computation and algorithm development. Early access also prepares a subset of the research community to make needed changes in research methodology to exploit the new technologies and to champion promising technologies to their colleagues and peers.

Data has been acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products for global and/or regional monitoring purposes from all operational spacecraft and instruments. The current emphasis on global modeling in support of policy decision on such matters as the impact of deforestation, ozone depletion, and environmental quality worldwide has led to the acquisition and manipulation of unprecedented amounts of environmental data. The accompanying computational demand has led to a doubling of production computing capacity and quadrupling of mass storage capacity in the last two fiscal years.

In the MO & DA program, responsibility for assigned missions is assumed 30 days after launch. Data are acquired, processed, disseminated, and archived to meet mission requirements for user availability of timely and accurate data products. Additional missions supported will be those scheduled for launch in 1996 (TOMS, NSCAT, and Sea Star), as well as the inauguration of data receipt from ERS-2 and RadarSat at the ASF. The MTPE information systems program will continue to provide a balanced computational environment for NASA science researchers primarily through facilities housed at GSFC and the JPL. Projected demands have led to the establishment of new partnerships with other agencies (i.e. National Security Agency, National Science Foundation, and Department of Energy) and vendors (i.e., International Business Machines, Cray Research, and Convex) to seek solutions to production-related problems in emerging computational environments. SEDAC is now on-line with Internet access and providing limited data products to the research community and the public.

User requirements will be met in 1996 and 1997 by continuing operations of on-orbit spacecraft and instruments, including the UARS, TOPEX, and ERBS missions; continuing support of the SBUV/2 sensor and processing of data from the SSBUV; and continuing receipt of ERS-1 and JERS-1 data at the Alaska SAR Facility. Missions to be supported that are scheduled for launch include the NSCAT and TOMS on ADEOS, TOMS Earth probe, and TRMM.

The measurements to be made by these and other future MTPE missions as well as current on-orbit missions provide data products that are used extensively in the MTPE science program. The program encompasses over 1,700 scientific activities at universities, research laboratories, and government research organizations. These activities are providing an ever increasing scientific understanding of global environment and the effects of natural and human sources of change.

High Performance Computing and Communications (HPCC) - Earth and Space Sciences

The NASA HPCC program consists of four vertically integrated projects. These projects are: Computational Aeroscience, Earth and Space Sciences, Remote Exploration and Experimentation, and Information Infrastructure Technology and Applications (IITA). The ITTA Project focuses on providing the technology base and applications to accelerate the implementation of the National Information Infrastructure.

The implementation of the NASA HPCC program is mainly through coordinated activities at NASA field centers. The Earth and Space Sciences project, lead by GSFC, will work in close partnership with industry, academia, and government. The project used the NASA Research Announcement process to select 8 Product Improvement teams and 21 grand challenge investigations. IITA Remote Sensing Databases project uses remote sensing databases developed by NASA and other federally-funded agencies to expand the application outreach of its programs to traditionally unserved communities. The Internet is used as the primary means of providing access to and distribution of science data and images and value-added products of the data and images.

ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) is responsible for working with state, local, and other federal government agencies to provide user-appropriate and scientifically credible air quality meteorological programs to support regulatory applications. Applied research and meteorological support is furnished primarily by EPA's National Exposure Research Laboratory in Research Triangle Park, North Carolina, through an interagency agreement with the National Oceanic and Atmospheric Administration (NOAA), which provides approximately 50 research meteorologists to the EPA.

Meteorological support to the EPA Office of Research and Development, the EPA Office of Air and Radiation, the EPA regional offices, and to state and local agencies includes: (1) development and application of air quality dispersion models for pollution control, direct and indirect exposure assessments, and strategy creation; (2) preparation and performance of dispersion studies and air quality model evaluations; and (3) review of meteorological aspects of environmental impact statements, state implementation plans, and variance requests. Meteorological expertise and guidance are also provided for the air quality standard, modeling guideline, and policy development activities of the EPA.

In light of the 1990 Amendments to the Clean Air Act, air quality models and the manner in which they are used are expected to evolve considerably over the next few years. In the area of pollutant deposition, the evaluation of nitrogen and oxidant chemistry, in addition to sulfur chemistry, will clarify the role of model formulation, cloud processes, radiative transfer, and surface/vertical exchange in air quality model predictions, along with development of a better understanding of model predictions relative to control strategy assessment. Further development and evaluation of existing air quality models will take place to accommodate the inter-pollutant effects resulting from the variety of control programs that are now or will be in place. These inter-pollutant effects include trade-offs among controls on ozone, sulfur oxides, nitrogen oxides, and volatile organic compounds, as well as developing predictable methods of forecasting the impacts on various measures of air quality.

With respect to inhalable particulate model development, dispersion models are being enhanced to accurately predict aerosol growth from precursors over regional and local transport distances. To assist in the evaluation of the contribution of various sources to regional air degradation, inert tracer and tagged species numerical models are being developed. These models will introduce separate calculations for inert or reactive chemical species emitted from a particular source or region. The calculations will proceed to simulate transport and transformation to a receptor point, where the contribution of the particular source could be isolated.

With respect to oxidant air quality modeling, the role of biogenic volatile organic compounds, rural nitrogen oxides, and vertical transport will be elucidated. A better understanding will be developed of the fundamental aspects of the ozone nonattainment problem such as differences in urban and rural rates of and/or sources of photochemical production and the interaction through transport of these ozone precursors. Much of this research will be performed under the program entitled North American Research Strategy on Tropospheric Ozone (NARSTO).

Atmospheric research in the areas of climate and climate change includes ozone distribution in the global troposphere, the relationship between that ozone distribution and climate (including temporal and spatial aspects), and regional climate studies addressing the interaction of climate with the biosphere. The climatology program involves both analytical and statistical climatology as well as support for regional-scale climate model development. Climate change issues and their feedbacks with the biosphere are being stressed.

Research in human exposure modeling includes microenvironmental monitoring and modeling, and development of exposure assessment tools. Microenvironmental algorithms are being developed based on field data to predict air quality in buildings, attached garages, and street canyons. These improved algorithms are then incorporated into microenvironmental simulation models for conducting human exposure assessments within enclosed spaces in which specific human activities occur.

In addition to these major areas, dispersion models for inert, reactive, and toxic pollutants are under development and evaluation on all temporal and spatial

scales, e.g., indoor, urban, complex terrain, mesoscale, and regional. Other efforts include construction and application of air pollution climatologies, modeling of agricultural pesticide spray drift and of fugitive particles from surface coal mines; modeling of trace metal deposition to the Great Lakes, nutrient deposition to Chesapeake Bay, and mercury deposition to the Florida Everglades; determination and description of pollutant effects on atmospheric parameters; and conversely, determination of meteorological effects on air quality. Measurement data obtained during field programs and from wind tunnel and water channel/towing tank experiments in the EPA Fluid Modeling Facility will be used to continue development and evaluation of these models in the FY 1997-1998 period, along with developing models for pollutant dispersion around natural and manmade obstacles.

EPA participation in the interagency HPCC program is enabling increased efficiency in air quality meteorological modeling through research on parallel implementation of the Mesoscale Meteorological Model (MM5), with the subsequent transfer of these achieved efficiencies to the user community. The HPCC Program is also developing a flexible environmental modeling and decision support tool (Models-3) to deal with multiple scales (urban to regional) and multiple pollutants simultaneously, thus facilitating a more comprehensive and cost-effective approach to related single-stressor and multi-stressor ecosystem problems. Models-3 provides a framework to support the constant evolution of environmental models to handle more complex issues, such as fine particulate, visibility, toxic pollutants, and multimedia (air and water) environmental assessments.

The EPA is a participant in the United States Weather Research Program (USWRP), mainly by providing research-in-kind in the area of meteorological simulation modeling on local, meso, and regional spatial scales for pollutants from fossil-fueled power plants, vehicle exhausts, and other emissions sources. The detailed understanding and modeling of the mesoscale circulations that control the atmospheric dispersal of these pollutants will also be applied to coping with accidental releases of toxic or radioactive materials.

The EPA also maintains relations with foreign countries to promote exchange of research meteorologists and research results pertaining to meteorological aspects of air pollution. One of the most active areas of cooperative research is with Russia under the 1972 Nixon-Podgorny Agreement forming the US/USSR Joint Committee on Cooperation in the Field of Environmental Protection and under the 1993 Gore/Chernomyrdin Agreement forming the US/Russia Commission on Economic and Technical Cooperation. Other agreements are in place with Canada, Japan, China, Mexico, and several European countries.

DEPARTMENT OF STATE

The Department of State (DOS) plays an active role in international climate/meteorological policy making as a result of the growing worldwide concern with global environmental issues, including the depletion of the stratospheric ozone layer and global warming. The role of DOS has principally revolved around preparation and negotiation of the United States position in three fora: (1) the Conference of the Parties to the Vienna Convention and its Montreal Protocol on Substances that Deplete the Ozone Layer, (2) the Intergovernmental Panel on Climate Change (IPCC); and (3) negotiation under the United Nations Framework Convention on Climate Change.

Stratospheric ozone depletion has been recognized as a critical health and environmental problem for more than a decade. Under DOS leadership, the United States worked to negotiate international agreements to phase-out ozone-depleting substances, which should lead to a recovery of the ozone layer in the next century. To date, these treaties have been signed and ratified by more than 130 countries (including the United States), representing 99 percent of the world's production of ozone depleting substances.

The IPCC, which is jointly sponsored by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), held its first session in 1988. This organization serves as a government forum to assess the state of scientific, technical, and economic information regarding climate change. The IPCC is currently organized in three working groups, examining: (1) the state of the science; (2) impacts and possible response strategies,

including mitigation and adaptation; and (3) economics and other cross-cutting issues. The IPCC released its first assessment report in 1990; supplementary reports were released in 1992 and 1994. A full second assessment report from each of the working groups was scheduled for publication in late 1995.

The Framework Convention on Climate Change was negotiated beginning February 1991; the convention was open for signature in Rio de Janeiro at the Earth Summit in June 1992. As of April 1995, it had been ratified by 129 countries, including the United States. The first meeting of the Conference of the Parties to the Convention was held in Berlin in March/April 1995. The convention calls for all countries to develop inventories of their emissions and sinks of greenhouse gases and calls upon developed countries to aim to return these emissions to their 1990 levels by the year 2000. At its first session, the conference decided to begin negotiations on next steps under the convention to elaborate policies and measures and to set quantified limitation and reduction objectives for greenhouse gases.

In addition to its primary role in the fora listed above, DOS is active on the Committee on Environment and Natural Resources (CENR) of the National Science and Technology Council (NSTC). The CENR was established in 1993 to coordinate scientific domestic programs. Furthermore, while the emphasis on global environmental issues is a key new component of the department's focus, traditional DOS responsibilities, described in earlier federal plans, continue. These include, but are not limited to, international aspects of food policy, disaster warnings and assistance, WMO and UNEP activities, and international meteorological programs.

NUCLEAR REGULATORY COMMISSION

The U.S. 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 these nuclear facilities require the identification of meteorological and climatological 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, reviews of facility siting, design, construction, and operation are conducted by the Office of Nuclear Reactor Regulation and the Office of Nuclear Material Safety and Safeguards. These reviews include consideration of meteorological factors. The NRC Office for Analysis and Evaluation of Operational Data and the NRC regional offices assure that commitments by NRC applicants, permittees, and licensees are carried out, and also conduct NRC responses to nuclear facility emergencies. The Office of Nuclear Regulatory Research develops regulations, guides, criteria, and other standards related to the protection of public health and safety and the environment in the licensing and operation of nuclear facilities. The 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.

The primary meteorological area in which the NRC will have an interest during FY 1997 and beyond is improvements in the meteorological capabilities of the NRC and the operators of nuclear facilities to cope with emergencies involving the unplanned releases of radioactive materials. The NRC also maintains an interest in the transport and dispersion of airborne, hazardous non-radioactive materials and their potential effects on the safe operation of nuclear facilities.

DEPARTMENT OF ENERGY

For nearly 50 years, the Department of Energy (DOE) and its predecessors, the Atomic Energy Commission and the Energy Research and Development Administration, have supported meteorological operations and atmospheric research at the DOE field offices. The need for meteorological services began with the development, fabrication, and testing of atomic weapons and the national security and safety issues associated with them. In addition, environmental protection legislation specifies requirements for meteorological services to protect public health and safety and the environment.

Meteorological services at DOE facilities range from complex research to daily operational support. Some examples of research are investigations of potential global climatic change, ultraviolet and infrared radiation studies, and studies of atmospheric boundary layer processes. Operational support includes daily weather forecast services, special project support, on-site meteorological monitoring, climatological services, and emergency response assistance. Some sites maintain 24-hour weather watches for severe weather conditions that could impact site operations, damage property, or threaten lives.

Several DOE field offices cover large areas, and some sites contain complex topography and heterogenous surface characteristics, creating locally driven conditions that influence on-site weather. For these reasons and to protect the environment and public health and safety, on-site meteorological monitoring has been and remains an essential part of DOE atmospheric science programs.

Some of the DOE sites contribute to the national weather observing network by taking standard surface and upper-air observations. Many of these sites are in remote areas where weather observations would be sparse if not for the presence of DOE meteorological monitoring programs. Weather observations taken at several of the DOE field sites are input to the national weather database via the NWS Automation of Field Operations and Services (AFOS) system--the NWS' primary meteorological data distribution and display system. AFOS also interconnects field offices and serves as the distribution system for NWS meteorological products that are centrally produced by the National Centers for Environmental Prediction (NCEP). DOE facilities with AFOS units are connected to the NWS AFOS network through NOAA's Air Resources Laboratory (ARL) that supports the DOE/Nevada Operations Office in Las Vegas, Nevada, which serves as the hub for the NWS/DOE AFOS network.

An accidental release of radioactive or toxic material into the atmosphere can have potentially serious health and environmental consequences. Meteorological processes play a key role in determining the fate of pollutants released into the atmosphere. For example, the processing, fabricating, and underground testing of nuclear weapons all have the potential for industrial accident scenarios. In addition to these activities, the use of nuclear material in the generation of electric power and the storage of nuclear waste from power generation, weapons complexes, and medical and commercial processes are all potential sources of nuclear material that could be accidentally released into the atmosphere. Consequently, a central theme within the DOE community has been to protect public health, safety, and the environment on and around DOE facilities. Therefore, DOE has required and supported on-site meteorological monitoring, directed the development of emergency response capabilities at DOE facilities, funded research on the modeling of the transport, dispersion, deposition, and resuspension of radioactive and toxic materials, and advocated on-site weather forecasting services tailored specifically for the special operational and emergency management requirements at each DOE facility. Much of the research and most of the operational support has been provided by the atmospheric research programs at the six major field offices directly involved in national defense programs. Over the years, these programs have grown to address numerous environmental, safety, and health issues. Due to the complexity of these activities, it was recognized that efforts should be made to coordinate meteorological operations and research among the field offices to enhance cost effectiveness.

Based on a need to facilitate more coordination and cooperation among the meteorological activities at the DOE field offices, the DOE Meteorological Coordinating Council was created in 1994. The mission of the council is to coordinate meteorological support and research to meet DOE objectives. The

objectives of the council are to: (1) promote cost effective support for all DOE facilities; (2) plan for future needs, requirements, and missions; (3) advocate awareness of atmospheric science applications and benefits to DOE; and (4) facilitate the use of common methods, procedures, and standards. The council is composed of senior DOE personnel and managers of DOE meteorological programs. The following narrative highlights the meteorological activities of the DOE field offices.

The Idaho National Engineering Laboratory (INEL) is managed by the Idaho Operations Office and is located on 890 square miles of rolling, arid terrain in southeastern Idaho at the foot of the Lost River and Lemhi mountain ranges. Meteorological services and supporting research are provided by ARL's Field Research Division (FRD) with the mission to support emergency response exercises and INEL operations with meteorological data, weather predictions, dispersion calculations, and consultation. ARL/FRD designs, arranges, and conducts field studies as needed to evaluate the performance of transport and dispersion models over local, regional, and continental scales, and to obtain high quality databases for the model improvement. They are recognized for their unique field experimentation capabilities, for expertise in conducting tracer studies, and for using direct and remote sensing technologies in support of tracer experiments.

To meet other mission requirements, ARL/FRD operates and manages a large meteorological monitoring network to characterize the meteorology and climatology of the INEL site. The network consists of 30 wind towers that provide wind and temperature data. The overall Meteorological Monitoring Program is designed to provide representative data for the INEL area to meet specific operational and potential emergency response situations. Most towers are 15 meters tall; however, four towers range from 45 to 75 meters in height. All towers are instrumented at multiple levels. Eleven have relative humidity, precipitation, and solar radiation sensors. Continuous wind and temperature profiles are obtained from a 915 MHz Doppler wind profiler and a Radio Acoustic Sounding System (RASS). Wind profiles generally extend to 5,000 feet above ground; temperature profiles extend to 1,500 feet. All meteorological data are quality-controlled and archived for future use. Additional use of this database is made in operational weather forecasts tailored to meet INEL and contractor requirements and to prepare climatological summaries that are distributed to users.

DOE operations at the Nevada Test Site (NTS) are managed by the Nevada Operations Office (NV). NTS is the Nation's underground nuclear weapons testing facility and occupies 1,350 square miles of south central Nevada. The topography of the NTS is complex with a system of dry lake beds and mountains. Elevations range from nearly 2,700 feet above mean sea level (MSL) to 7,600 feet MSL; the climate is arid.

Meteorological services are provided by ARL's Special Operations and Research Division (SORD). Over the last 40 years, ARL/SORD personnel have built a solid technical reputation in meteorological operations in the nuclear weapons testing arena. They are recognized for expertise in the transport, dispersion, and deposition of radioactive materials and for developing a rapid emergency response capability for the unlikely occurrence of an accident resulting from the release of radioactive material into the atmosphere.

Both basic and applied research are carried out on problems of mutual interest to DOE and to NOAA. Emphasis is on the maintenance of meteorological support to national defense projects and to the stewardship of nuclear weapons. These capabilities focus on those facets of meteorology having a direct bearing on the transport, dispersion, deposition (fallout), and resuspension of radioactive and/or toxic materials.

ARL/SORD provides full meteorological support to all DOE/NV operations on and off the NTS. The staff is responsible for conducting a modern program in support of nuclear and non-nuclear projects authorized by NV. Furthermore, ARL/ SORD provides technical support to the NV emergency preparedness and response activities, operates a thorough meteorological monitoring program for the NTS, and provides meteorological and climatological services required in support of NV and contractor programs at the NTS and elsewhere, as necessary. ARL/SORD personnel also consult with senior scientists and engineers at the DOE National Laboratories, NASA, private contractors, EPA, USGS, USFS, and other NOAA laboratories.

The SORD meteorological monitoring network consists of thirty-one 10-meter towers and two 30-meter towers. Wind direction and speed are measured at the 10-meter level on all the towers and temperature and relative humidity are sampled at the 2-meter level.

Data from these towers are transmitted via microwave radio to a central processor that checks the data, creates data files, and archives the data every 15 minutes. The data files are accessed by microcomputers to create graphics products for operational use and for immediate display at 15 minute intervals.

ARL/SORD is the DOE node for distribution of NWS AFOS products. Other weather products supplied to DOE contractors, the National Laboratories, NWS, and Nellis Air Force Base include real-time cloud-to-ground lightning flash graphical products and local forecast products. ARL/SORD also provides meteorological monitoring support and weather forecast services to Nuclear Emergency Search Team (NEST) and Federal Radiological Monitoring and Assessment Center (FRMAC) activities. Monitoring support includes surface and upper-air data collection and analysis. Weather forecast service entails maintaining a constant weather watch for conditions that might impact NEST/FRMAC operations and personnel, issuing site-specific, mesoscale wind, stability, and weather forecasts, and providing consultation to the on-scene commander and to National Laboratories personnel.

The DOE Oak Ridge Operations Office (OR) is located on nearly 100 square miles of hilly and heavily vegetated terrain in eastern Tennessee and is supported by ARL's Atmospheric Turbulence and Diffusion Division (ATDD). ARL/ATDD's primary mission is atmospheric research, and their scientists conduct research on matters of atmospheric diffusion and turbulent exchange, concerning air quality. Attention is focused on the physics of the lower atmosphere, with special emphasis on the processes contributing to atmospheric transport, dispersion, and deposition, and on the development of predictive capabilities using the results of this research. Research is directed toward issues of national and global importance, related to the missions of DOE and NOAA. The research program is divided into five major projects; namely, plume transport and diffusion in the planetary boundary layer, complex topography, canopy micrometeorology, dry deposition, and wind-tunnel modeling. The objectives of the research are: (1) to develop better methods for describing atmospheric transport, diffusion, and deposition in numerical simulations; (2) to extend the applicability of these techniques to non-ideal situations such as non-stationary conditions, complex terrain, and dense vegetation; and (3) to develop and test improved numerical models incorporating these new methods. Research programs are undertaken with the assistance of personnel of the Energy/Environment Systems Division of Oak Ridge Associated Universities (ORAU), and in close collaboration with scientists from the Oak Ridge National Laboratory and various other organizations, universities, government agencies, and private research institutions working in their area of expertise.

Operationally, ARL/ATDD personnel provide meteorological consultation and supplemental data to local OR users for air quality analyses, environmental reports, and emergency preparedness. They also work closely with the ORAU to enhance educational opportunities in atmospheric science.

Meteorological services to the DOE Richland Operations Office has been provided by Battelle Pacific Northwest Laboratories (PNL) for nearly 50 years. Not only has operational support been provided, but also supporting research into atmospheric processes has been a key part of PNL's support to DOE-Richland. The facility covers 560 square miles within the arid and sparsely vegetated Columbia River basin in south-eastern Washington. Key DOE research activities at PNL's Environmental Science Research Center include the Global Change Research Program (GCRP), the Atmospheric Radiation Monitoring (ARM) program, the Core Carbon Dioxide Research program, the Computer Hardware Advanced Mathematics and Model Physics (CHAMMP) program, the Atmospheric Studies in Complex Terrain (ASCOT) program, and the Processing of Emissions by Clouds and Precipitation (PRECP) program.

GCRP focuses on the study of basic geophysical processes and development of databases that are critical for understanding global and regional climatic change. The ARM program is designed to characterize empirically the radiative processes in the atmosphere with high spatial, temporal, and spectral resolution and accuracy at four to six climatologically important sites distributed worldwide. The goal of the CHAMMP program is to produce a climate modeling system having 10,000 times the capacity of the current generation of models and computers. In addition, carbon dioxide emissions research is aimed at providing a scientific basis for forecasting future emissions of carbon dioxide and other radiatively important gases.

Other research at PNL includes large field experiments and modeling efforts in collaboration with other laboratories and universities. The focus is on processes of transport, dispersion, transformation, and deposition. The ASCOT program involves research

into atmospheric transport and dispersion, focusing experimental, theoretical, and modeling efforts on atmospheric boundary-layer and mesoscale processes, and the PRECP program has already completed experiments leading to improvements in source-receptor models for acid deposition.

PNL's Meteorological and Climatological Services Project (MSCP) office provides meteorological monitoring and operational support on a 24-hour basis. The monitoring system consists of an array of twenty-three 10-meter towers and three 60-meter towers instrumented with temperature and wind direction and speed sensors. Data from this network are transmitted via UHF radio to a computer that decodes the data and plots graphics products for immediate display and use by Hanford Meteorological Station personnel. Other meteorological data are received via the NWS/DOE AFOS network. Meteorological services include emergency response functions, weather forecasting for on-site operations and special projects, and climatological support. MSCP support to the Hanford site includes: (1) extensive data acquisition via a site-wide meteorological monitoring network, (2) around-the-clock weather forecasting services, (3) hourly surface observations, 6-hourly synoptic observations, and twice-daily pilot balloon releases, and (4) monthly and annual climatological data summaries, plus meteorological input to annual environmental reports.

Support to the Rocky Flats Office (RFO) is provided by EG&G, Rocky Flats, Inc. This facility is located along the eastern slopes of the Rocky Mountains, approximately 15 miles northwest of Denver, Colorado, and is one of the smaller sites, covering only 10 square miles. Part of the former Rocky Flats nuclear weapons facility has been transformed into the National Wind Technology Center as a research facility to aid industry in developing advanced wind energy systems for the future.

EG&G scientific and technical personnel provide meteorological and climatological services in support of RFO site operations. Weather forecasts are issued twice daily to support on-site operations and other weather-sensitive activities. A constant weather watch is maintained during routine working hours for severe thunderstorms, lightning, winter storms, and strong winds. In addition, EG&G manages and operates a meteorological monitoring program that uses local NOAA/ERL meteorological data. They also conduct dose assessments, run dispersion models, and support an emergency response preparedness program. The Colorado Department of Public Health has formally approved the Rocky Flats emergency response program. On-site meteorological monitoring is provided by wind and temperature data collected from a 60-meter tower. This tower is equipped with standard meteorological sensors located at the surface, 10 meters, 25 meters, and 60 meters above the ground. Data are transmitted to the forecast office and to the Emergency Operations Center every 15 minutes. These data are also archived for future use. EG&G plans to have a SODAR/RASS system operational on-site, and there are plans to access meteorological data from five Colorado Department of Public Health and Environment 10-meter towers located near the plant.

The Savannah River Operations Office (SR) is located in extreme southwestern South Carolina, along the banks of the Savannah River. The Savannah River Site (SRS) covers an area of approximately 300 square miles and is managed by the Westinghouse Savannah River Company--the primary producer of tritium for use in nuclear weapons. The climate is typical of the southeastern U.S. with hot, humid summers and mild, wet winters. SRS is heavily vegetated with evergreen trees and contains many streams, a swamp, and a 2,700-acre reservoir built as a cooling pond for the plant reactors.

Support to SR operations is provided by the Westinghouse Savannah River Meteorological Program and includes daily weather forecast services for the SRS. Meteorological data is obtained from a local network of eight 200-foot towers with sensors at the 200 foot level, a 200-foot tower instrumented at four levels, and a 1,000-foot tower. Additional local upper-air data are collected from three acoustic Doppler radars, a Beukers rawinsonde system, and an airsonde and tethersonde system. Other meteorological data are received via the NWS/DOE AFOS network. Research on atmospheric transport and dispersion is also conducted to provide SRS with the best modeling capability available to support emergency response operations and other programs.

FEDERAL EMERGENCY MANAGEMENT AGENCY

The Federal Emergency Management Agency (FEMA) is the central agency within the federal government responsible for emergency preparedness training and exercises, mitigation, response, and recovery. Working closely with state and local governments, FEMA funds emergency programs and offers technical guidance and training. FEMA also coordinates federal disaster relief resources in a catastrophic disaster. These coordinated activities ensure a broad-based program to protect life and property and provide recovery assistance after a disaster. The agency was formed in 1979 by Presidential Executive Order 12127, replacing five former agencies and consolidating the Nation's emergency-related programs, including meteorological emergencies.

In carrying out its role, FEMA works with all of the agencies to assure that the delivery of meteorology-related information is conducted in keeping with established goals and objectives. As administrator of the National Flood Insurance Program, FEMA publishes Flood Insurance Rate Maps for all flood-prone communities, which serve as the official demarcation for flood risk. FEMA also publishes hurricane evacuation maps based on model simulation results from NWS's National Hurricane Center for regions subject to hurricanes.

FEMA's priority interests with the Office of the Federal Coordinator for Meteorology (OFCM) are in promoting standards and procedures which will enhance the ability of the Nation to mitigate and recover from emergencies and disasters. These interests extend to national standards for geographic information systems (GIS) used for delivery of meteorological products and services by other agencies. FEMA also actively supports the OFCM-sponsored Working Group for Post-Storm Data Acquisition (WG/PSDA) and the WG/PSDA's efforts to develop a *National Plan for Post-Storm Data Acquisition* to coordinate and support the collection, by the federal agencies, of perishable data after major storms. For meteorologically-related matters, the Hazard Identification and Risk Assessment Division, Mitigation Directorate, is the principal contact point within FEMA.

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 for coordinating 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, obviating 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.

GOALS AND ORGANIZATION

The goals of the WWP are to extend the time, accuracy, range, and scope of weather prediction and to understand the physical basis of climate and climatic change. The ability of the U.S. 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 are inadequately observed over 80 percent of the Earth's surface and mostly over the oceans; coverage over the remaining 20 percent is barely adequate.

Development of the technology and the systems to obtain these observations, especially over the oceans, presents formidable problems. With the use of satellites, aircraft, ships, radar, anchored and drifting buoys, and balloons, however, a system can be developed to observe and collect comprehensive daily data about the atmosphere over the entire globe. This system is too complex to be implemented by a single nation--a fact clearly recognized by the leaders of many nations whose international cooperation in meteorology has been a tradition for more than a century. In 1961, this continuing need for international cooperation prompted the President of the United States to propose to the United Nations (UN) the establishment of an international effort in weather prediction. The UN 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 the knowledge of the basic physical forces that determine climate.

The WMO, with 184 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.

More recently, the WMO, through its commission structure, is working towards the design and implementation of improved observations for a Global Climate Observing System (GCOS) through enhancements to the Global Observing System (GOS) and other appropriate measures. These efforts are expected to yield an enhanced GOS for both operational and research purposes and are part of the effort to strengthen the WMO's commitment to improve the understanding of climate and related environmental matters, as articulated by the Second World Climate Conference in 1990 and repeated at the United Nations Conference on the Environment and Development.

The responsibilities of U.S. federal agencies in the WWP are as follows:

- Department of Commerce (DOC). Represents the U.S. at WMO and, through NOAA, provides the focal point 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.
- Department of State (DOS). Maintains relations with developing nations and, through the WMO, assists developing nations in improving their national weather services. DOS also 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 DOD weather services is basically internal, the nature of DOD's operations is global. As such, the observation, telecommunications, 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. DOT's observation and telecommunications programs also provide significant indirect support to the WWW through DOT's interaction with the NWS.

- 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--the 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: (1) 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; (2) The systems-support activity provides guidance, technical and scientific information, and training to those involved in the planning, development, and operation of WWW components. (3) 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 automated, for both surface and upper-air observations.

- Fixed sea stations, composed of ocean weather stations, fixed and anchored platform stations, and island and coastal stations.

- Mobile sea stations, including moving ships and drifting buoys.

- Aircraft meteorological stations, including automated aircraft reporting systems.

The space-based (satellite) subsystem provides vital support for meteorological and hydrological predictions and warnings. The use of satellites enables the routine collection of environmental observations from even the most remote locations. Two categories of satellites are used: those in polar orbits and those in geostationary orbits.

Presently, operational meteorological satellites in polar orbits are operated by Russia (the METEOR-3 series) and the United States. The United States operates the civilian NOAA POES (Polar-orbiting Operational Environmental Satellite) series along with the defense DMSP (Defense Meteorological Satellite Program) series of polar-orbiting spacecraft. NOAA currently launches satellites, alternately, into afternoon and morning orbits to maintain an uninterrupted stream of polar data. The current operational NOAA polar-orbiting satellites are

NOAA-14 (launched in an afternoon orbit in December 1994) and NOAA-12 (launched in a morning orbit in May 1991). The current operational DMSP polar-orbiting satellites are F-12 (launched in August 1994) and F-13 (launched in March 1995).

Operational geostationary weather satellites are currently operated by Japan, India, Russia, EUMETSAT (Europe), and the United States. Japan's Geostationary Meteorological Satellite (GMS) is positioned at 140°E, India's Indian National Satellite (INSAT) is at 74°E, Russia's GOMS/Elektro #1 satellite is at 76°E (operational since June 1996), and EUMETSAT's METEOSAT is at 0°. The U.S. normally operates two Geostationary Operational Environmental Satellites (GOES)--one at 75°W and the other at 135°W. GOES-8, launched in April 1994, is operational at 75°W and GOES-9, launched in May 1995, is operational at 135°W.

To help ensure data continuity from geostationary orbit, NOAA has signed a long-term mutual back-up agreement with EUMETSAT.

In the future, NOAA's POES will be combined with the DMSP to form a converged system called NPOESS (National Polar-orbiting Operational Environmental Satellite System). NOAA, DOD, and NASA are working together to implement NPOESS and have created an Integrated Program Office (IPO). NOAA heads the IPO and is responsible for operating the NPOESS and for relations with national and international civilian users of the system. The DOD has the lead responsibility for NPOESS acquisitions, launch, and systems integration. NOAA will facilitate the development and incorporation of new, cost-effective technologies to enhance the NPOESS capabilities. Negotiations continue with the Europeans for their assumption of NOAA's morning polar orbit mission just after the turn of the century. This complements longstanding plans by NOAA and the meteorological operational satellites.

Broadcast of data from both the NOAA and GOES series of U.S. satellites is free, unrestricted, and does not require any prior notification. Data can be received directly by any properly-equipped ground station within the satellites' line-of-sight. The United States, through NOAA, develops information and products from these data for further distribution over the 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.

Over the last few years, several systems intended to improve the operation of the GOS have continued to undergo development and deployment. Among these systems is the family of automated aircraft reporting systems known as the Automated Meteorological Data and Reporting (AMDAR) systems. This family of systems includes the Aircraft to Satellite Data Relay (ASDAR) System and the ARINC Communications Addressing and Reporting System (ACARS). ARINC is Aeronautical Radio Incorporated--a wholly owned subsidiary of the airlines.

To date, 23 ASDAR systems have been purchased. Nineteen have been installed aboard B-747 (14) and DC-10 (3), and B-767 (2) aircraft. Of these 19, there are 17 units flying operationally. Ten units are being flown aboard British Airways aircraft with the United Kingdom being the end owner of six of the units. The end ownership of three of the remaining four units rests with Switzerland. The Netherlands retains maintenance responsibility for the other unit. Three operational units are installed on KLM aircraft and currently reporting (one unit belongs to the U.S., the second unit had been previously flown on Continental Airlines, but is now being maintained by the U.S., and the third unit belongs to the Netherlands.) Two units are installed and operating on South African Airways aircraft (one unit being maintained by the Netherlands and the other by the UK). Of the two remaining operational units, one is installed and operating aboard an aircraft of Germany's Lufthansa Airlines, while the last unit is installed and operating aboard an aircraft of Saudi Arabia's Saudi Airlines. Finally, two units, provided by the UK to Mauritius, have recently been installed aboard B-767 aircraft of Air Mauritius. These two units are awaiting completion of certification by the Federal Aviation Administration prior to being placed into operation. Two of the remaining purchased units, one owned by Spain and the other by the UK, remain unallocated. However, current negotiations between Spain and Argentina are proceeding well for carriage of Spain's unit aboard an Aerolineas Argentinas aircraft. Lastly, two of the purchased units are maintained as operational spares to limit downtime resulting from unit failure. It has always

been the intent to employ different airlines for ASDAR carriage in order to expand the overall geographic coverage of the operational ASDAR units.

A cooperative effort among ARINC, NWS, and the FAA is providing thousands of automated meteorological reports from ACARS-equipped aircraft flying over the U.S. The ARINC meteorological data collection and reporting system collects, organizes, and disseminates automated position/weather reports to the NWS. The standardized weather data is being sent to the NWS in the Binary Universal Form for the Representation of Meteorological Data (BUFR) code. Twelve thousand reports a day in varied formats and internal codes are received by ARINC and the quantity is expected to increase to 150,000 (mostly automated ACARS) reports by the late 1990's.

Large quantities of weather reports, particularly over oceanic and other data-sparse areas, will be realized via satellite communications and navigation systems. This source of data is of prime interest to the U.S. and other members of the International Civil Aviation Organization (ICAO) and the WMO's Automatic Aircraft Reporting study group. The group developed amendments to the ICAO Technical Regulations and made substantial progress toward standardizing meteorological down-link codes (automatic binary, automatic character, manual routine, and special air-reports).

In addition to these aircraft-based systems, other observation systems are being deployed to improve the GOS. For example, the Automated Shipboard Aerological Program (ASAP) has about 12 systems reporting regularly; one U.S. ASAP ship is now operating with a second expected in FY 1996. There has also been deployment of substantial numbers of drifting buoys. A number of nations including the U.S. are implementing test networks or single sites of ground-based Doppler radars called wind profilers to provide nearly continuous soundings of wind. During the past year, there were approximately 88 systems in use worldwide. A demonstration network of 29 wind profilers is being operated principally in the central part of the U.S. to assess the utility of the data in operational and research meteorological analysis and prediction. A report on the multiyear meteorological and engineering assessment was completed in November 1994. Data continues to be made available on the GTS to those countries requesting it.

To improve the methodology used in developing and deploying observing systems, NOAA is developing the North American Atmospheric Observing System (NAOS) program. NAOS objectives are to: (1) define a cost-effective, requirements-driven "best mix" of observing platforms and instruments and (2) reduce observing system risks and uncertainties. While the initial focus of the program will be to modernize the composite upper-air network, NAOS is expected to guide the resource-allocation process for most future observing systems developed and/or fielded by NOAA.

The concept of the Operational World Weather Watch Systems Evaluation (OWSE) has also been developed as a framework for regional implementation. The OWSE-Africa, which was created 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, has been completed. It was designed to implement and test the data collection system for receipt of meteorological observations from various countries in Africa. Thus far, approximately 100 data collection platforms have been installed in Kenya, Ethiopia, Ghana, Sudan, Nigeria, Sierra Leone, Zaire, Egypt, Madagascar, St. Helena, Guinea, and Cape Verde. Evaluations have been carried out to gauge the improvement of observation receipt, and preliminary results show that high-receipt rates are achieved when systems are operating. Further, results indicate that high-receipt rates may be achieved for data originating in Africa, but infrastructure and maintenance issues remain for full operational deployment to be successful.

Efforts are underway to design and implement a GCOS, building upon the WWW, Global Atmospheric Watch, Integrated Global Ocean Services System, and other existing systems to further the knowledge and understanding of climate and the prediction of climate and climate change. Efforts to date have established planning groups to address needs and requirements for atmospheric, oceanic, and land-surface data. Upper-air and surface-observing networks are being defined to provide basic measurements for the GCOS. Links to existing organizational structures are being established, and a high priority has been given to making observational enhancements.

Global Data Processing System (GDPS)

The purpose of GDPS is to make available all processed information required for both real-time and non-real-time applications. GDPS provides products and processed information, based on recent advances in atmospheric science, using powerful numerical computer methods. Members have real-time, unrestricted 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 (WMC), Regional/Specialized Meteorological Centers (RSMC), and National Meteorological Centers (NMC). NMCs carry out GDPS functions at the national level. In general, real-time functions of the system involve preprocessing of data including real-time quality control, analysis, and prognosis, including derivation of appropriate meteorological parameters. The non-real-time functions include data collection and archival, and additional quality control, storage, and retrieval, to include cataloging 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 with geographical specialization are located at Algiers, Algeria; Antananarivo, Malagasy; Beijing, China; Bracknell, United Kingdom; Brasilia, Brazil; Buenos Aires, Argentina; Cairo, Egypt; Dakar, Senegal; Darwin, Australia; Jeddah, Saudi Arabia; Khabarovsk, Russia; Lagos, Nigeria; Melbourne, Australia; Miami, Florida; Montreal, Canada; Moscow, Russia; Nairobi, Kenya; New Delhi, India; Novosibirsk, Russia; Offenbach, Germany; Rome, Italy; Tashkent, Uzbekistan; Tokyo, Japan; Tunis, Tunisia; Washington, D.C.; and Wellington, New Zealand.

RSMCs with activity specialization are found at The European Center for Medium Range Forecasts; Réunion Island (France); Toulouse, France; and Washington D.C.

The regional centers at Bracknell, Miami, Montreal, New Delhi, and Tokyo have dual geographical and activity specialization responsibilities. These centers provide regional products used for short and medium-range forecasting of small, mesoscale, 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.

In the World Area Forecast System (WAFS), two centers (Washington and London) are designated by the ICAO as World Area Forecast Centers (WAFC). They issue upper-wind and temperature forecasts with global coverage to associated Regional Area Forecast Centers (RAFC). The regional centers also prepare and distribute forecasts of weather elements defined by ICAO as significant weather.

In the planned implementation of the final phase, the two WAFCs 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 will be realized in the near future through forecaster-initiated graphic interaction.

The dissemination of aeronautical information via global satellite broadcast began in 1995. The U.S. provides the links to two of the three satellites specified in the system.

Global Telecommunication System (GTS)

The GTS provides communication services for the collection, exchange, and distribution of observational data and processed information among the WMCs, RSMCs, and NMCs of the WWW to meet the member needs for real-time or quasi-real-time exchange of information for both operational and research purposes. The GTS also supports other WMO programs, joint programs with other international organizations, and environmental programs as decided by the WMO Congress and 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 the telecommunications functions of the WMCs, Regional

Telecommunications Hubs (RTH), RSMCs, and NMCs.

The MTN links the WMCs at Melbourne, Moscow, and Washington with the RTHs at Algiers; Beijing; Bracknell; Brasilia; Buenos Aires; Cairo; Dakar; Jeddah; Maracay, Venezuela; Nairobi; New Delhi; Norrköping, Sweden; Offenbach; Prague; Rome; Sofia; Tokyo; Toulouse; and Wellington. 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 member nations.

In summary, the GTS enables the NMCs to receive and distribute observational data and meteorological information to meet the requirements of members. Ongoing WWW activities for FY 1996-1997 include:

- GTS network redesign to take into consideration new technical opportunities, such as Internet-like services.
- Improvement of the capacity of MTN links and inclusion of graphics (e.g., Washington-Brasilia, Washington-Buenos Aires, Washington-Tokyo).
- Continued implementation of satellite-serviced 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 Cooperation Program (VCP)

From the beginning of WWW, it was clear that all countries need better weather observations and improved communications systems. To help remedy deficiencies and to fully implement the WWW, the WMO established a Voluntary Assistance Program in 1967. The name of the program was changed to Voluntary Cooperation Program (VCP) in 1979.

The WMO-VCP helps the developing countries to implement the WWW program by providing equipment, services, and long-term 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 and electrolytic hydrogen generators, and 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 48 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 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 1996, DOS funding for WWW/VCP programs was cut to $1.3 million.

VCP Projects for FY 1996-1997 include:

- Implementation and updating of surface and upper-air observational programs in the tropics, the Southern Hemisphere, and Africa as resources and priorities permit.
- Support of WAFS implementation and utilization.
- Continued support for the implementation of VCP projects in Latin America and the Caribbean areas in support of the hurricane and tropical storm programs.

BILATERAL AND REGIONAL INTERNATIONAL COOPERATIVE PROGRAMS

United States - Peoples Republic of China (PRC) Protocol in the Field of Atmospheric Science and Technology

For more than 15 years, this protocol has covered a broad area of research and operational activities in the field of atmospheric science and technology. Program areas include the following:

- Climate Studies (which includes scientific experiments and research on monsoons and Tropical Ocean Global Atmosphere (TOGA)).

- Mesoscale Meteorology (which includes operational techniques for forecasting torrential rains).
- Training and Participation.
- Atmospheric Chemistry.
- Satellite Meteorology and Meteorological Satellites.
- Modernization Activities.

The cooperative activities between the U.S. and China under this program have decreased over the past 2 years. The main cooperative activity has been within the Training and Participation Program with a dozen Chinese scientists and trainees working at NOAA facilities for up to 18 months.

U.S.-Mexico Meteorological and Hydrologic Program

The U.S. and Mexico have signed a new cooperative agreement enhancing the scope of their cooperation in the fields of meteorology, hydrology, and climatology which began over 50 years ago. The new agreement facilitates the following activities:

- The establishment, operation, maintenance, and repair of meteorological and hydrologic observation systems in Mexico.
- The international dissemination of observations from these systems.
- The exchange of meteorological, hydrologic, and related data and products between the U.S. and Mexico.
- The cooperation necessary to assure prompt transmission through telecommunications networks of these data and products.
- The coordination and training related to the exchange of data and products between the National Meteorological Services of both countries.

Over the past few years, the Mexican Meteorological Service has undergone an impressive modernization effort, which included upgrading upper-air observation systems, installing Doppler weather radars, and establishing hundreds of automatic weather stations. This cooperative agreement will facilitate the exchange of data and information to the benefit of both countries.

APPENDIX F

ACRONYMS AND ABBREVIATIONS

ABCS	Army Battle Command System (Army)
AC	Active Component (DOD)
ACARS	ARINC Communication Addressing and Reporting System
ACE	Aviation Combat Element (USMC)
ACFP	Advanced Computer Flight Plan (AF)
ACP	Atmospheric Chemistry Program (DOE)
ACRIM	Active Cavity Radiometer Irradiance Monitor (NASA)
ACU	Acquisition Control Unit
ADAS	AWOS/ASOS Data Acquisition System (FAA)
ADEOS	Advanced Earth Observing System (Japan)
ADFC	Altimetry Data Fusion Center (Navy)
ADLP	Aeronautical Data Link Program (FAA)
ADWS	Automatic Digital Weather Switch (AF)
AF	Air Force (USAF)
AFB	Air Force Base
AFCCC	Air Force Combat Climatology Center
AFGWC	Air Force Global Weather Center
AFOS	Automation of Field Operations and Services (NOAA/NWS)
AFSS	Automated Flight Service Station (FAA)
AGFS	Aviation Gridded Forecast System (FAA)
AIP	Airport Improvement Program (FAA)
AIRS	Atmospheric Infrared Sounder (NASA)
AL	Aeronomy Laboratory (NOAA/ERL)
ALDARS	Automated Lightning Detection and Reporting System (DOI)
ALDS	Automatic Lightning Detection System (DOI)
AMA	AWIS Meteorological Applications (OFCM)
AMC	Army Materiel Command (Army)
AMDAR	Automatic Meteorological Data and Reporting
AMOS	Automated Meteorological Observing System
AMSR	Advanced Microwave Scanner Radiation (NASA)
AMSS	Automatic Meteorological Sensors System (Army)
AMSU	Advanced Microwave Sounding Unit
AMU	Applied Meteorology Unit (NASA)
ANC	Air Navigation Commission (ICAO)
ANG	Air National Guard
AOC	Aircraft Operations Center (NOAA)
AOML	Atlantic Oceanographic and Meteorological Laboratory (NOAA/ERL)
APT	Automatic Picture Transmission
ARGOS	French Satellite Data Collection System
ARINC	Aeronautical Radio Incorporation
ARL	Army Research Laboratory (Army)/Air Resources Laboratory (NOAA)
ARM	Atmospheric Radiation Monitoring (DOE)
ARNG	Army National Guard
ARO	Army Research Office
ARS	Agricultural Research Service (USDA)
ARSR	Air Route Surveillance Radar (FAA)
ARTCC	Air Route Traffic Control Center (FAA)
ARTYMEY	Artillery Meteorological (Army)

ARSPACE	Army Space Command
ASAP	Automatic Shipboard Aerological Program (WWP)
ASCOT	Atmospheric Studies in Complex Terrain (DOE)
ASDAR	Aircraft to Satellite Data Relay
ASOS	Automated Surface Observing System
ASR	Airport Surveillance Radar (FAA)
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATC	Air Traffic Control (FAA)
ATCOS	Army Tactical Command and Control System
ATM	Asynchronous Transfer Mode
ATDD	Atmospheric Turbulence and Diffusion Division (NOAA/ARL)
AVAPS	Atmospheric Vertical Profiling System
AVHRR	Advanced Very High Resolution Radiometer (NOAA)
AWC	Aviation Weather Center (NOAA/NCEP)
AWDS	Automated Weather Distribution System (AF)
AWE	Advance Warfighting Experiment (Army)
AWIPS	Advanced Weather Interactive Processing Systems (NOAA)
AWIS	Automated Weather Information Systems
AWN	Automated Weather Network (AF)
AWOS	Automated Weather Observing System (FAA)
AWS	Air Weather Service (AF)
BBS	Bulletin Board System
BE	Battlefiedl Environment (Army)
BED	Battlefield Environment Directorate (Army)
BOREAS	Boreal Ecosystem-Atmosphere Study (NASA)
BLM	Bureau of Land Management (DOI)
BUFR	Binary Universal Form for the Representation of Meteorological Data
BUREC	Bureau of Reclamation (DOI)
C4I	Command, Control, Communications, Computer and Information
CARDS	Comprehensive Aerological Reference Data Set (NOAA/NCDC)
CAWIS	Committee for Automated Weather Information Systems (OFCM)
CDA	Command and Data Acquisition
CDAS	Command and Data Acquisition Station
CDCL	Climate Diagnostics Center Laboratory (NOAA/ERL)
CDFS	Cloud Depiction and Forecast System (AF)
CDMS	Centralized Data Management System (AF)
CDR	Critical Design Review
CECOM	Communications and Electronics Command (Army)
CEMSCS	Central Environmental Satellite Computer System (NOAA/NESDIS)
CENR	Committee on Environment and Natural Resources
CERES	Clouds and Earth's Radiant Energy System (NASA)
CFEP	Communications Front-End Processor (AF)
CGCP	Climate and Global Change Program (NOAA)
CHANCES	Climatological and Historical Analysis of Clouds for Environmental Simulations (AF)
CHAMMP	Computer Hardware Advanced Mathematics and Model Physics (DOE)
CIDE	Communications Interfaces and Data Exchange (OFCM)
CINC	Commanders-in-Chief
CIRA	Cooperative Institute for Research in the Atmosphere (NOAA)
CMDL	Climate Monitoring and Diagnostics Laboratory (NOAA/ERL)
COADS	Comprehensive Ocean-Atmosphere Data Set (NOAA/NCDC)

COAMPS	Coupled Oceanographic and Atmospheric Model (Navy)
COARE	Coupled Ocean-Atmosphere Response Experiment
COE	Corps of Engineers (Army)
COMEDS	CONUS Meteorological Data System (AF)
COMET	Cooperative Program for Operational Meteorology, Education and Training
CONUS	Continental United States
COPC	Committee for Operational Processing Centers (OFCM)
COTS	Commercial Off-the-Shelf
CPC	Climate Prediction Center (NOAA/NCEP)
CRREL	Cold Regions Research and Engineering Laboratory (Army)
CS	Climate Services (OFCM)
CSA	Chief of Staff of the Army
CSREES	Cooperative State Research, Education, and Extensive Service (USDA)
CY	Calendar Year
DCP	Data Collection Package
DCS	Data Collection System (NOAA/NESDIS)
DDN	Defense Data Network
DF	direction finder
DISS	Digital Ionospheric Sounding System (AF)
DLP	Data Link Processor (FAA)
DMSO	Defense Modeling and Simulation Office
DMSP	Defense Meteorological Satellite Program
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOMSAT	Domestic Communications Satellite
DOS	Department of State
DOT	Department of Transportation
DPS	Distributed Processing System
DRGS	Direct readout ground stations (DOI)
DRWP	Doppler Radar Wind Profiler
DTR	Diurnal Temperature Range
DTSS	Digital Topographic Support System (Army)
DUAT	Direct User Access Terminal (FAA)
E2DIS	Environmental Effects for Distribution Interactive Simulation
EDIS	Environmental Data and Information Service (NOAA)
EMC	Environmental Modeling Center (NOAA/NCEP)
ENSO	El Niño-Southern Oscillation
EO	electro-optical
EOS	Earth Observing System (NASA)
EOSDIS	EOS Data and Information System (NASA)
EOSP	Earth Observing Scanning Polarimeter (NASA)
EOTDA	electro-optical tactical decision aid (AF)
EPA	Environmental Protection Agency
ERB	Earth Radiation Budget
ERC	Extended Research Checkout
ERL	Environmental Research Laboratories (NOAA)
ESD/IPC	Environmental Satellite Distribution/Interactive Processing Center
ESSP	Earth System Science Pathfinders (NASA)

ETL	Environmental Technology Laboratory (NOAA/ERL)
ETM+	Enhanced Thematic Mapper Plus (NASA)
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EUSA	Eighth U.S. Army
EUV	Extreme Ultraviolet
EXCIMS	Executive Council for Modeling and Simulation
FAA	Federal Aviation Administration
FCMSSR	Federal Committee for Meteorological Services and Supporting Research
FEMA	Federal Emergency Management Agency
FMF	Fleet Marine Force
FMH	Federal Meteorological Handbook (OFCM)
FNMOC	Fleet Numerical Meteorology and Oceanography Center (Navy)
FOSDIC	Film Optical Sensing Device for Input to Computer
FORSCOM	U.S. Army Forces Command
FRD	Field Research Division (NOAA/ARL)
FRMAC	Federal Radiological Monitoring and Assessment Center (DOE)
FS	Forest Service (USDA)
FSAS	Flight Service Automation System (FAA)
FSDPS	Flight Service Data Processing System (FAA)
FSL	Forecast Systems Laboratory (NOAA/ERL)
FTE	Full-time Equivalent
FTP	File Transfer Protocol
FSS	Flight Service Station (FAA)
FU	Forecast Unit
FY	fiscal year
GAC	Global Area Coverage
GAO	General Accounting Office
GCCS	Global Command and Control System
GCOS	Global Climate Observing System
GCPS	Global Climate Perspectives System
GCRP	Global Change Research Program
GDPS	Global Data Processing System (WWP)
GFDL	Geophysical Fluid Dynamics Laboratory (NOAA/ERL)
GFMPL	Geophysical Fleet Mission Program Library (Navy)
GHCN	Global Historical Climatology Network
GIN	Geomagnetic Information Nodes (DOI)
GIS	Geographic Information System
GMS	Geostationary Meteorological Satellite (Japan)
GODAR	Global Oceanographic Data Archaeology and Rescue
GOES	Geostationary Operational Environmental Satellite (NOAA)
GOS	Global Observing System (WWP)
GPCP	Global Precipitation Climatology Program
GPS	Global Positioning System
GRIB	Gridded Binary (FM 92-X Ext.)
GSFC	Goddard Space Flight Center (NASA)
GTS	Global Telecommunications System (WWP)
GTSPP	Global Temperature-Salinity Pilot Project
GTWAPS	Global Theater Weather Analysis and Prediction System (AF)
GWDS	Graphics Weather Displays Systems (FAA)

HDSS	Hierarchical Data Storage System
HF	high frequency
HFRB	high frequency radio broadcast
HIRS/2	High-resolution Infrared Sounder (NOAA/NESDIS)
HPC	Hydrometeorological Prediction Center (NOAA/NCEP)
HPCC	High Performance Computing and Communications
HRD	Hurricane Research Division (NOAA/ERL)
HRPT	High Resolution Picture Transmission (NOAA/NESDIS)
IAMS	Initial Attack Management System (DOI)
ICAO	International Civil Aviation Organization
ICMSSR	Interdepartmental Committee for Meteorological Services and Supporting Research
ICSU	International Council of Scientific Unions
IEW	Intelligence and Electronic Warfare (Army)
IFM	Ionospheric Forecast Model (AF)
IHC	Interdepartmental Hurricane Conference (OFCM)
IIP	International Ice Patrol (USCG)
IITA	Information Infrastructure Technology and Applications (NASA)
IIP	International Ice Patrol
IMDES	Interdepartmental Meteorological Data Exchange System
IMETS	Integrated Meteorological System (Army)
IMS	Ionospheric Measuring System (AF)
INTEL	Idaho National Engineering Laboratory (DOE)
IPCC	Intergovernmental Panel on Climate Change (WWP)
IPO	Integrated Program Office
IR	infrared
ISCCP	International Satellite Cloud Climatology Program
ITWS	Integrated Terminal Weather System (FAA)
IWRS	Improved Weather Reconnaissance System
IWRPC	Improved Weather Reconnaissance System Program Council
JAG	Joint Action Group
JASL	Joint Archive for Sea Level
JAWOP	Joint Automated Weather Observation Program (OFCM)
JCRMOD	Joint Center for Research in the Management of Ocean Data
JEDA	Joint Environmental Data Analysis
JGOFS	Joint Global Ocean Flux Study
JMFU	Joint METOC Forecast Unit
JMOC	Joint METOC Operations Center
JPL	Joint Propulsion Laboratory (NASA)
JTWC	Joint Typhoon Warning Center (AF/Navy)
KMR	Kwajalein Missile Range (Army)
KSC	Kennedy Space Center
LAC	Local Area Coverage
LAN	local area network
LCD	Local Climatological Data
LCM	life-cycle management
LDAR	Lightning Detection and Ranging (NASA)
LITE	Lidar In-space Technology Experiment (NASA)
LLWAS	Low Level Wind Shear Alert System (FAA)
LOD2	Lightweight Omega Digital Dropwindsonde
LRGS	local readout ground stations (DOI)

MACOM	Major Army Command
MAGTF	Marine Air Ground Task Force
MAJCOM	Major Command (AF)
MARD	Modernization and Associated Restructuring Demonstration (NOAA)
MC	Meteorological Codes
MCDW	Monthly Climate Data for the World
MCSST	Multichannel Sea Surface Temperature
MDS	Meteorological Distribution System (Army)
MEPED	Medium Energy Proton and Electron Detector
MES	Marine Environmental Services (OFCM)
MET	Mobile Environmental Teams (Navy)
METAR	Aviation Route Weather Report
METMF	Marine Corps Meteorological Mobile Facility
METOC	Meteorological and Oceanographic
MHG	Meteorological Hydrogen Generator (Army)
MHS	Microwave Humidity Sensor (NASA)
MIMR	Multifrequency Imaging Microwave Radiometer (NASA)
MISR	Multi-Angle Imaging Spectrometer (NASA)
MME	Mobile Meteorological Equipment (OFCM)
MMS	Meteorological Measuring System (Army)
MMS	Mineral Management Service (DOI)
MMW	Millimeter Wave (Army)
MPS	Meteorological Profiler System (Army)
MOA	Memorandum of Agreement
MO&DA	Mission Operations and Data Analysis (NASA)
MODIS	Moderate Resolution Imaging Spectrometer (NASA)
MOPITT	Measurement of Pollution in the Troposphere (NASA)
MOU	Memorandum of Understanding (Army)
MOSS	Mobile Oceanography Support System
MRS	Miniature Rawinsonde System
MS	Monitoring the Stratosphere (OFCM)
MSCP	Meteorological and Climate Services Project (DOE)
MSL	mean sea level
MSM	Magnetospheric Specification Model (AF)
MSU	Microwave Sounding Unit
MTF	Model test facility
MTN	Main Telecommunications Network (WWP)
MTPE	Mission to Planet Earth (NASA)
MWP	Meteorologist's Weather Processor (FAA)
MWSS	Marine Wing Support Squadron
M1FC	Model 1 Full Capacity (FAA)
NADIN	National Airspace Data Interchange Network (FAA)
NAOS	North American Atmospheric Observing System (NOAA)
MARSTO	North American Research Strategy on Tropospheric Ozone (EPA)
NAS	National Airspace System (FAA)
NASA	National Aeronautics and Space Administration
NASS	National Agricultural Statistics Service (USDA)
NAVAF	Navy-Air Force
NAVICECEN	Naval Ice Center
NAVOCEANO	Naval Oceanographic Office
NAWPC	National Aviation Weather Program Council (OFCM)

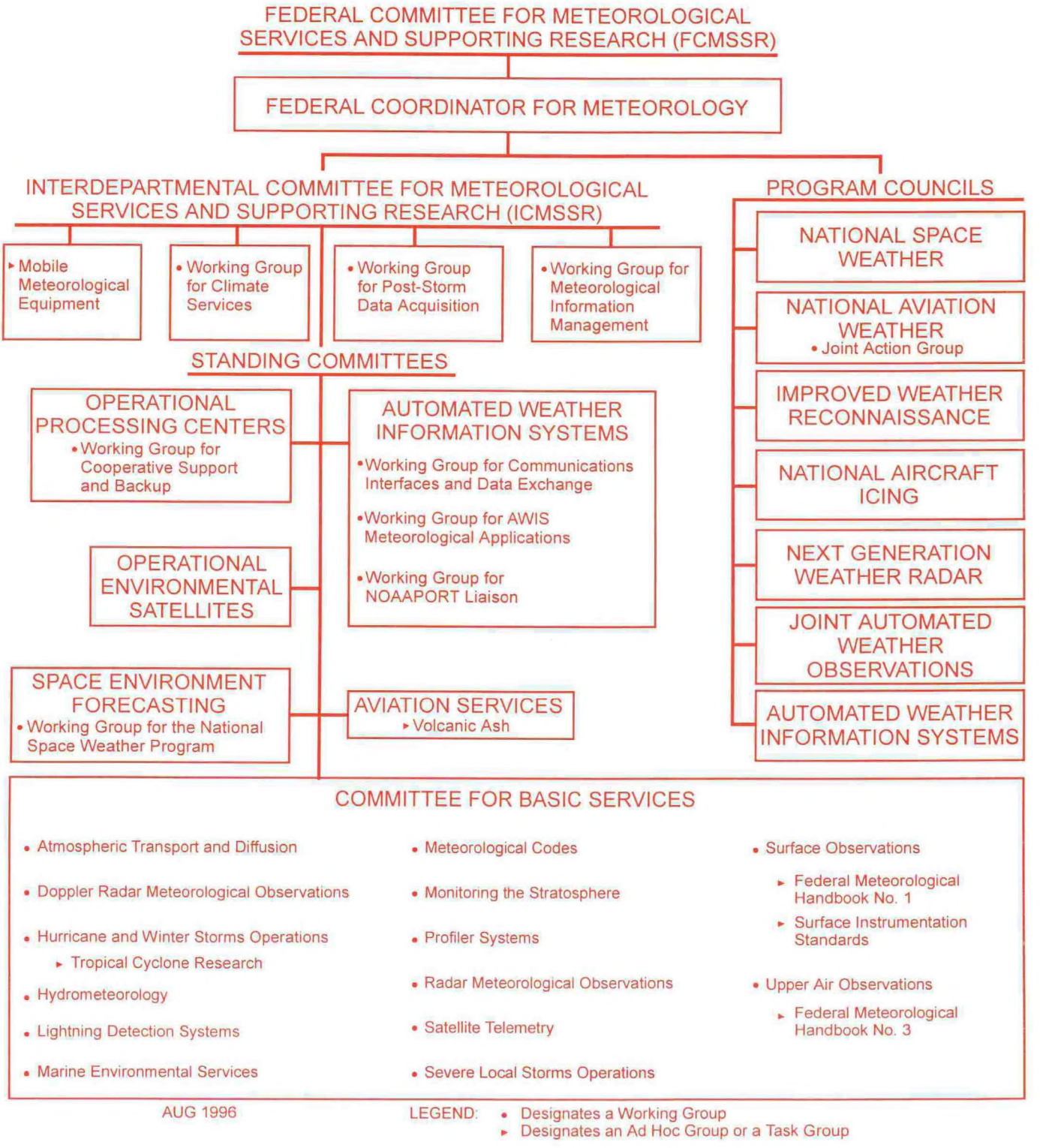
NAWPP	National Aviation Weather Program Plan
NBC	Nuclear, Biological, and Chemical (Army)
NC	NOAA Corps Operations
NCAR	National Center for Atmospheric Research
NCDC	National Climatic Data Center (NOAA/NESDIS)
NCEP	National Center for Environmental Prediction (NOAA/NWS)
NCO	NCEP Central Operations (NOAA/NCEP)
NDBC	National Data Buoy Center (NOAA/NWS)
NDI	non-developmental item
NEMOC	Naval European Meteorology and Oceanography Center
NESDIS	National Environmental Satellite, Data, and Information Service (NOAA)
NESS	National Environmental Satellite Service (NOAA)
NEST	Nuclear Emergency Search Team (DOE)
NEXRAD	Next Generation Weather Radar (WSR-88D)
NGDC	National Geophysical Data Center (NOAA/NESDIS)
NGIC	National Geomagnetic Information Center (DOI)
NHC	National Hurricane Center (NOAA/NWS)
NHOP	National Hurricane Operations Plan (OFCM)
NIC	National Ice Center
NIFC	National Interagency Fire Center (DOI)
NITES	Naval Integrated Tactical Environmental Subsystem
NLMOC	Naval Atlantic Meteorology and Oceanography Center
NMC	National Meteorological Center(s) (NOAA/WWP)
NMOC	Naval Meteorology and Oceanography Command
NMP	New Millenium Program (NASA)
NMTN	National Telecommunications Network (WWP)
NPMOC	Naval Pacific Meteorology and Oceanography Center
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center (NOAA/NESDIS)
NODDES	Naval Oceanographic Data Distribution and Expansion System
NODDS	Naval Oceanographic Data Distribution System
NOGAPS	Navy Operational Global Atmospheric Prediction System
NORAPS	Navy Operational Regional Atmospheric Prediction System
NOS	National Ocean Service (NOAA)
NOTAM	Notice to Airmen
NOWS	NVG Operations Weather Software (AF)
NPL	NOAAPORT Liaison (OFCM)
NPMOC	Naval Pacific Meteorology and Oceanography Center
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPS	National Park Service (DOI)
NRC	Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service (USDA)
NRL	Naval Research Laboratory
N-ROSS	Navy Remote Sensing Satellite
NSCAT	NASA Scatterometer (NASA)
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NSSFC	National Severe Storms Forecast Center (NOAA)
NSSL	National Severe Storms Laboratory (NOAA)
NSTC	National Science and Technology Council
NSWP	National Space Weather Program

NTS	Nevada Test Site (DOE)
NTSB	National Transportation Safety Board
NV	Nevada Operations Office (DOE)
NVDS	NOAA Virtual Data System
NVG	night vision goggle
NWLON	National Water-Level Observation Network (NOAA/NOS)
NWS	National Weather Service
OAML	Oceanographic and Atmospheric Master Library (Navy)
OAR	Office of Oceanic and Atmospheric Research (NOAA)
OASIS	Oceanographic and Atmospheric Support and Information System (Navy)/ Operational and Supportability Implementation System (FAA)
ODCSINT	Office of the Deputy Chief of Staff for Intelligence (Army)
ODCSOPS	Office of the Deputy Chief of Staff for Operations (Army)
OFCM	Office of the Federal Coordinator for Meteorology
OGP	Office of Global Programs (NOAA)
OMB	Office of Management and Budget
ONR	Office of Naval Research
OPARS	Optimum Path Aircraft Routing System (Navy)
OR	Oak Ridge Operations Office (DOE)
ORA	Office of Research and Applications (NOAA/NESDIS)
ORD	Operational Requirements Documents (Navy)
ORAU	Oak Ridge Association Universities
OSDPD	Office of Satellite Data Processing and Distribution (NOAA/NESDIS)
OSF	Operational Support Facility
OSO	Office of Satellite Operations (NOAA/NESDIS)
OTIS	Optimum Thermal Interpolation System (Navy)
OTSR	Optimum Track Ship Routing (Navy)
OWSE	Operational World Weather Watch Systems Evaluation (WWP)
P3I	Preplanned Product Improvement
PACS	Polar Acquisition and Control Subsystem
PC	Program Council (OFCM)
PCGRAFAX	PC-based High Frequency Facsimile System (Navy)
PD	Project Director (Army)
PICS	PC Imaging Communications System (Navy)
PIREP	Pilot report
PIREP	Pilot Report
PL/GP	Phillips Laboratory, Geophysics Directorate (DOD/AFSC)
PMEL	Pacific Marine Environmental Laboratory (NOAA/ERL)
PNL	Pacific Northwest Laboratories (DOE)
POM	Princeton Ocean Model (Navy)
POPS	Primary Oceanographic Prediction System (Navy)
PORTS	Physical Oceanographic Real-Time System (NOAA/NOS)
PRC	Peoples Republic of China
PRECP	Processing of Emissions by Clouds and Precipitation (DOE)
PSDA	Post-Storm Data Acquisition (OFCM)
PW	Precipitable water
R&D	Research and Development
RAFC	Regional Area Forecast Center (WWP)
RAMDIS	RAMM Branch Advanced Meteorological Satellite Demonstration and Interpretation System (NASA)

RASS	Radio-Acoustic Sounding System
RAWS	Remote Automatic Weather Station (USDA/DOI)
RC	Reserve Component
RDTE	Research and Development, Test and Evaluation (Army)
RFC	River Forecast Center (NOAA/NWS)
RFO	Rocky Flats Office (DOE)
RFP	Request for Proposal
RMTN	Regional Telecommunications Network (WWP)
RSMC	Regional/Specialized Meteorological Centers (WWP)
RTH	Regional Telecommunications Hub (WWP)
RVR	Runway Visual Range (FAA)
SAA	Satellite Active Archive
SAMS	Surface Automated Meteorological System
SAO	Surface Aviation Observation (also known as Airways)
SARSAT	Search and Rescue Satellite Aided Tracking
SATCOM	Satellite Communications System (NOAA)
SBUV	Solar Backscatter Ultraviolet Instrument (NOAA/NESDIS)
SCAR	Smoke, Clouds, and Radiation (NASA)
SDHS	Satellite Data Handling System (AF)
SEC	Space Environmental Center (NOAA/NCEP)
SELDADS	Space Environmental Laboratory Data Acquisition and Display System (NOAA)
SEM	Space Environment Monitor (NOAA)
SEON	Solar Electro-Optical Network (AF)
SERCAA	Support of Environmental Requirements Cloud Analysis and Archive
SERDP	Strategic Environmental Research and Development Program
SETT	Space Environmental Technology Transition
SEU	Single event upsets
SFDF	Satellite Field Distribution Facility (NOAA/NWS)
SFMR	Stepped Frequency Microwave Radiometer
SMOOS	Shipboard Meteorological and Oceanographic Observing Sensor (Navy)
SNOTEL	Snow Telemetry
SOCC	Satellite Operations Control Center (NOAA/NESDIS)
SOF	Special Operations Forces
SORD	Special Operations and Research Division (NOAA/ARL)
SPAWARS	Space and Naval Warfare Systems Command
SPC	Storm Prediction Center (NOAA/NCEP)
SPECI	Aviation Selected Special Weather Report
SPOSC	Shared Processing Operations Steering Committee
SR	Savannah River (DOE)
SRBL	Solar Radio Burst Locator (AF)
SRDC	Surface Reference Data Center
SSDC	Space and Strategic Defense Command (Army)
SSM/I	Special Sensor Microwave (NASA)
SRS	Savannah River Site (DOE)
SSU	Stratospheric Sounding Unit (NOAA)
STIWG	Satellite Telemetry Interagency Working Group (OFCM)
STT	Small Tactical Terminal (AF)
SWIM	Solar Wind Interplanetary Measurements (AF)
SWO	Staff weather officer
SXI	Solar X-Ray Imager (AF)

T^2	Technology transfer
TAF	Aerodrome Forecast
TAMSS	Target Area Meteorological Sensor System (Army)
TAO	Tropical Atmosphere Ocean
TACWX	Tactical weather (DOD)
TDA	Tactical Decision Aid (Army)
TDWR	Terminal Doppler Weather Radar (FAA)
TEC	Topographic Engineering Center (Army)
TECOM	Test and Evaluation Command (Army)
TED	Total Electron Detector
TESS	Tactical Environmental Support System (Navy)
TF	Terminal Forecast
TIROS	Television Infrared Observation Satellite (NOAA/NESDIS)
TOGA	Tropical Ocean and Global Atmosphere
TOMS	Total Ozone Mapping Spectrometer (NASA)
TOVS	TIROS N Operational Vertical Sounder (NOAA/NESDIS)
TPC	Tropical Prediction Center (NOAA/NCEP)
TRADOC	Training and Doctrine Command (Army)
TRB	Test Review Board
TRMM	Tropical Rainfall Measuring Mission (NASA)
TWR	Tactical Weather Radar (AF)
UAV	unmanned aerial vehicle (Army)
UN	United Nations
UNEP	United Nations Environment Program (WWP)
URI	University Research Institute (Army)
USA	U.S. Army
USAF	U.S. Air Force
USAFAS	U.S. Army Field Artillery School
USAIC	U.S. Army Intelligence Center
USAIC&FH	U.S. Army Intelligence Center & Fort Huachuca
USAR	U.S. Army Reserve
USAREUR	U.S. Army, Europe
USARPAC	U.S. Army, Pacific
USARSO	U.S. Army, South (Army)
USASSDC	U.S. Army Space and Strategic Defense Command
USASOC	U.S. Army Special Operations Command
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USHCN	U.S. Historical Climatology Network
USIABP	U.S. Interagency Arctic Buoy Program
USMC	U.S. Marine Corps
USN	U.S. Navy
USWRP	U.S. Weather Research Program
URC	Coordinated Universal Time (Zulu)
VA	Volcanic Ash
VAS	VISSR Atmospheric Sounder
VCP	Voluntary Cooperation Program
VISSR	Visible and Infrared Spin Scan Radiometer
VORTEX	Verification of the Origins of Rotation Experiment
VOS	Voluntary Observing Ship (WWP)

WAFC	World Area Forecast Center (WWP)
WAFS	World Area Forecast System (WWP)
WAM	Wave model (Navy)
WAOB	World Agricultural Outlook Board (USDA)
WARP	Weather and Radar Processor (FAA)
WDC	World Data Center (WWP)
WEFAX	Weather Facsimile
WES	Waterways Experiment Station (Army)
WETM	Weather Team (Army)
WFO	Weather Forecast Office (NOAA/NWS)
WG	Working Group
WIDA	Weather Impact Decision Aids (AF)
WMC	World Meteorological Center(s) (WWP)
WMO	World Meteorological Organization
WMSCR	Weather Message Switching Center Replacement (FAA)
WOCE	World Ocean Circulation Experiment
WPDN	Wind Profile Demonstration Network (NOAA)
WSC	Warfighting Support Center (Navy)
WSFO	Weather Service Forecast Office (NOAA/NWS)
WSMO	Weather Service Meteorological Office (NOAA/NWS)
WSMR	White Sands Missile Range (Army)
WSO	Weather Service Office (NOAA/NWS)
WSR-88D	Weather Surveillance Radar-1988 Doppler (NEXRAD)
WSU	Weather Support Unit
WWP	World Weather Program
WWW	World Weather Watch (WMO); World wide web


FEDERAL COMMITTEE FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH (FCMSSR)
FEDERAL COORDINATOR FOR METEOROLOGY
INTERDEPARTMENTAL COMMITTEE FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH (ICMSSR)
▸ Mobile Meteorological Equipment
• Working Group for Climate Services
• Working Group for Post-Storm Data Acquisition
• Working Group for Meteorological Information Management
STANDING COMMITTEES
OPERATIONAL PROCESSING CENTERS
• Working Group for Cooperative Support and Backup
AUTOMATED WEATHER INFORMATION SYSTEMS
• Working Group for Communications Interfaces and Data Exchange
• Working Group for AWIS Meteorological Applications
• Working Group for NOAAPORT Liaison
OPERATIONAL ENVIRONMENTAL SATELLITES
SPACE ENVIRONMENT FORECASTING
• Working Group for the National Space Weather Program
AVIATION SERVICES
▸ Volcanic Ash
PROGRAM COUNCILS
NATIONAL SPACE WEATHER
NATIONAL AVIATION WEATHER
• Joint Action Group
IMPROVED WEATHER RECONNAISSANCE
NATIONAL AIRCRAFT ICING
NEXT GENERATION WEATHER RADAR
JOINT AUTOMATED WEATHER OBSERVATIONS
AUTOMATED WEATHER INFORMATION SYSTEMS
COMMITTEE FOR BASIC SERVICES
• Atmospheric Transport and Diffusion
• Doppler Radar Meteorological Observations
• Hurricane and Winter Storms Operations
▸ Tropical Cyclone Research
• Hydrometeorology
• Lightning Detection Systems
• Marine Environmental Services
• Meteorological Codes
• Monitoring the Stratosphere
• Profiler Systems
• Radar Meteorological Observations
• Satellite Telemetry
• Severe Local Storms Operations
• Surface Observations
▸ Federal Meteorological Handbook No. 1
▸ Surface Instrumentation Standards
• Upper Air Observations
▸ Federal Meteorological Handbook No. 3
AUG 1996
LEGEND: • Designates a Working Group
▸ Designates an Ad Hoc Group or a Task Group