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Fact Sheet for the Chairman, Permanent Subcommittee on Investigations, Committee on Governmental Affairs, U.S. Senate

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# WEATHER FORECASTING

# Cost Growth and Delays in Billion-Dollar Weather Service Modernization





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Information Management and
Technology Division

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December 17, 1991

The Honorable Sam Nunn
Chairman, Permanent Subcommittee
on Investigations
Committee on Governmental Affairs
United States Senate

Dear Mr. Chairman:

This report responds to your request for information on the National Weather Service's (NWS) $4.6 billion modernization and restructuring program. NWS believes that the advanced technology being acquired under this program will allow improved weather forecasting and more cost-effective operations. Although primarily an NWS program, other federal agencies are participating in the funding and management of some of the system modernization projects and plan to use the technologies being developed.

As agreed with your office, our objective was to provide information on the status of the four major automated systems under the modernization program, including any cost growth and schedule delays. Because the systems are only a part of the whole modernization and restructuring, we also describe NWS' plans under the program to restructure its field organization. Appendix I provides details on our objective, scope, and methodology.

## Summary

NWS' ability to forecast severe weather affects virtually everyone in the United States. Hundreds of lives and billions of dollars are lost every year as a result of thunderstorms and lightning, tornadoes, hurricanes, blizzards, and floods.

Over the past 10 years, NWS has been modernizing its systems so it can more accurately and quickly predict severe weather. According to NWS, productivity and efficiency gained from these systems will also permit it to reduce its existing number of field offices by over 50 percent and overall staffing levels by a little over 17 percent. More than 90 percent of the costs for this modernization and restructuring, or nearly $4.2 billion, are to acquire four automated systems: the Next Generation Weather Radar (NEXRAD), the Next Generation Geostationary Operational Environmental Satellite (GOES-Next), the Automated Surface Observing System (ASOS), and the Advanced Weather Interactive

Processing System (AWIPS). Each of the systems is at a different stage of completion, ranging from evaluation of vendor full-scale development proposals to limited production of systems for testing in an operational setting.

The systems' cost and deployment schedules have changed dramatically. When the systems were initiated, their estimated cost through deployment was under $2 billion with deployment to be completed by the end of October 1994. NWS' latest cost estimates, however, show that the systems' combined cost has more than doubled. Additionally, NWS estimates that the deployment of all the systems will not be completed until 1998—almost 4 years later. NWS officials attributed the cost growth and deployment delays primarily to expanded system requirements, increased number of units to meet other agency needs, development problems, and inflation. Table 1 presents the initial and current cost and schedule estimates for each of the systems.

**Table 1: Initial and Current Cost and Schedule Estimates to Complete Deployment of the Four Major Systems**

| | Cost[a] (millions) | | Schedule (fiscal year) | |
|---|---|---|---|---|
| System | Initial | Current | Initial | Current |
| NEXRAD | $340 | $1,477 | 1989 | 1996 |
| GOES-Next | 640 | 1,978 | 1989[b] | 1994[b] |
| ASOS | 72 | 298[c] | 1990 | 1995 |
| AWIPS | 350 | 465 | 1995 | 1998 |

[a]The National Oceanic and Atmospheric Administration's (NOAA) initial NEXRAD cost estimate was in 1980 constant dollars, ASOS in 1986 constant dollars, and AWIPS in 1985 constant dollars. NOAA's initial estimate for GOES-Next and all current estimates are in current dollars.

[b]Initial and current dates are for launching the first GOES-Next satellite.

[c]The initial estimate for ASOS was for 250 NWS units. The current estimate is for 868 NWS, Federal Aviation Administration, and Department of Defense units.

## Background

NWS is under the National Oceanic and Atmospheric Administration (NOAA), within the Department of Commerce. Its basic mission is to provide weather and flood warnings, public forecasts, and advisories primarily for the protection of life and property. NWS operations also support other agencies' missions and the nation's commercial interests. For example, NWS provides specialized forecasts to support the Federal Aviation Administration (FAA) and aviation operations, and to support the agricultural and marine industries. To carry out its mission, NWS uses a variety of manual and automated systems to collect, process, and disseminate weather data to and among its network of field offices and regional and national centers.

During the 1980s, NWS undertook a comprehensive program to modernize its systems and restructure its field offices. The goals of the program are to achieve more uniform weather services across the nation, improve forecasts, provide more reliable detection and prediction of severe weather and flooding, permit more cost-effective operations, and achieve higher productivity.

An analysis of the modernization's benefits and costs is currently being prepared by the Department of Commerce's National Institute of Standards and Technology. According to NOAA, when the new technology is in place, the benefits from improved weather information will include

- better warnings and forecasts of hurricanes and winter storms;
- earlier, more reliable, and site-specific warnings of flash floods, the leading cause of weather-related deaths;
- earlier, more site-specific warnings of tornadoes and thunderstorms (an increase from 10 minutes to as much as 30 minutes for tornado warnings);
- improved warnings of general flooding for the increasing numbers of people living in cities and river valleys;
- fewer false alarms of severe weather, resulting in heightened public confidence in weather warnings; and
- improved long-range routine forecasts, out to 10 days, to better serve the general population and the nation's economic interests.

Three other agencies are participating in the development of NWS systems. FAA and the Department of Defense are major users of weather data and have formed tri-agency programs with NWS to manage and fund the development and deployment of NEXRAD and ASOS. The National Aeronautics and Space Administration (NASA), with extensive experience in designing and developing space systems, manages the development and procurement of weather satellites funded by NOAA.

Concerns about NWS' management of the modernization have recently been raised by the Commerce Inspector General and the National

Research Council.[1] In response to these concerns, NOAA established a Systems Program Office in June 1991 to strengthen management of the modernization's major system components. Specifically, it assigned responsibility for the design, procurement, and acceptance of the four systems to a single office reporting directly to the Deputy Under Secretary of NOAA. NOAA believes that this reorganization will improve its ability to manage the system acquisitions and meet critical time schedules and cost estimates.

## Description and Status of the Four Systems

Each of the four major automated systems under the modernization program is briefly described below in terms of its purpose and status, including cost and schedule changes. More detailed information on each of the systems is in appendix II.

## NEXRAD

NEXRAD consists of an advanced doppler weather radar, minicomputers, workstations, and communications equipment. It includes software to operate the radar, process radar signals, and generate, transmit, and display data on the motion of the atmosphere for earlier detection of weather events, such as tornadoes and thunderstorms. NWS, FAA, and Defense plan to buy 175 radar units, 159 of which are needed for nationwide weather operations.

NEXRAD's current project cost estimate through deployment is approximately $1.5 billion, an increase of over $1.1 billion from the original 1980 estimate of $340 million. Further, delays in the schedule will extend NEXRAD's final implementation from fiscal year 1989 to 1996. According to NWS and NOAA officials, reasons for the cost growth are that the initial estimate was for only 95 doppler and 65 non-doppler radar units, and did not include costs for training, logistics, and weather office land acquisition and facilities construction that are included in the current estimate. NWS officials also attributed the cost growth and schedule slips to (1) new system requirements added to support applications such as hydrology; (2) hardware, software, and contractual problems; (3) the change in the number and type of units; and (4) inflation. Currently, NOAA and the NEXRAD contractor are negotiating modifications to the contract that reflect recent agreements made during a settlement of contractual disputes.

[1] Inspector General's Semiannual Report to the Congress, Covering the Period April 1, 1990 - September 30, 1990. United States Department of Commerce, November 1, 1990. Toward a New National Weather Service—A First Report. Committee on National Weather Service Modernization, National Research Council, March 1991.

**Figure 1: The Next Generation Weather Radar**

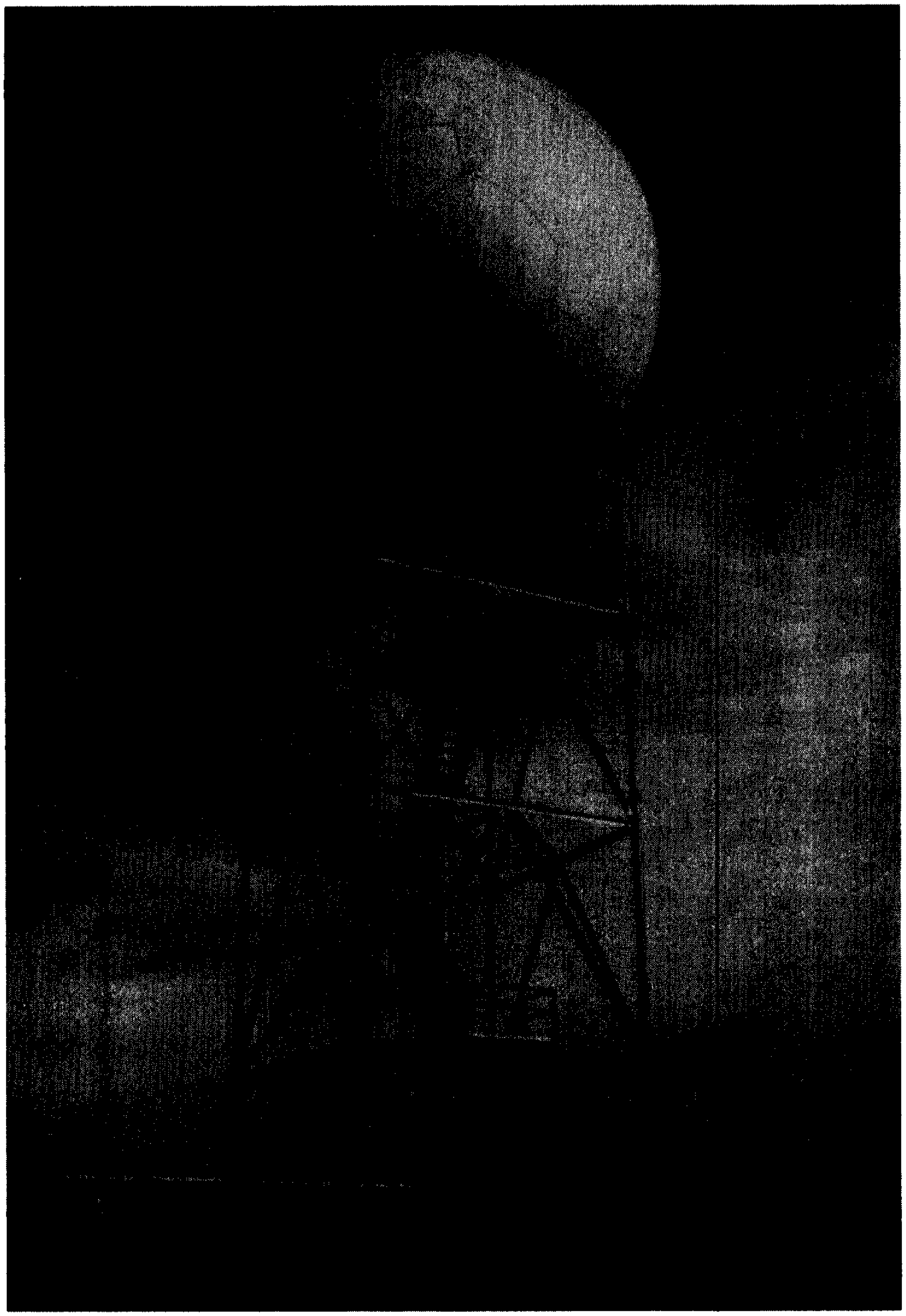


Photo Source: National Weather Service

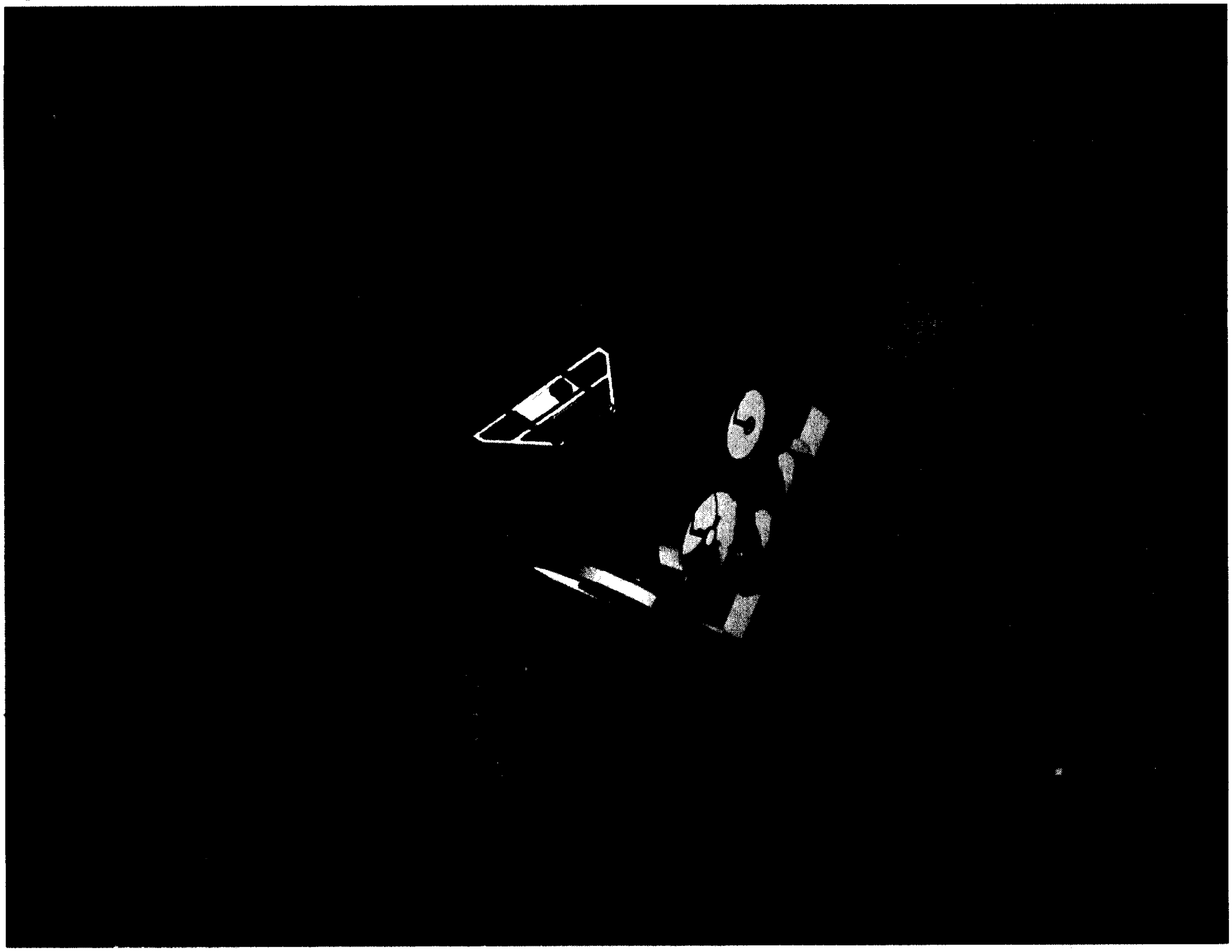
## GOES-Next

The GOES-Next program includes the acquisition of five satellites, launch vehicle services to place the satellites in orbit, and ground systems to command, control, and communicate with the satellites. The satellites are designed to take images of clouds and the earth and analyze atmospheric components to identify and track severe weather events, such as hurricanes.

GOES-Next's current cost estimate of approximately $2 billion represents an increase of more than $1.3 billion over a 1986 estimate of $640 million. The first satellite, currently under development, is experiencing technical problems that have delayed its scheduled launch more than 4 years, from July 1989 to February 1994. The second satellite needed for complete coverage of the United States is planned for launch about 1 year later. In July 1991, we reported that the system's cost growth and schedule slips were due to the complexity of the satellite design, inadequate program management by NOAA and NASA, and poor contractor performance.[2] Continuing technical problems and the need for more extensive testing have caused additional cost growth and schedule delays since our July report.

[2] Weather Satellites: Action Needed to Resolve Status of the U.S. Geostationary Satellite Program (GAO/NSIAD-91-252, July 24, 1991).

**Figure 2: The Next Generation Geostationary Operational Environmental Satellite System**



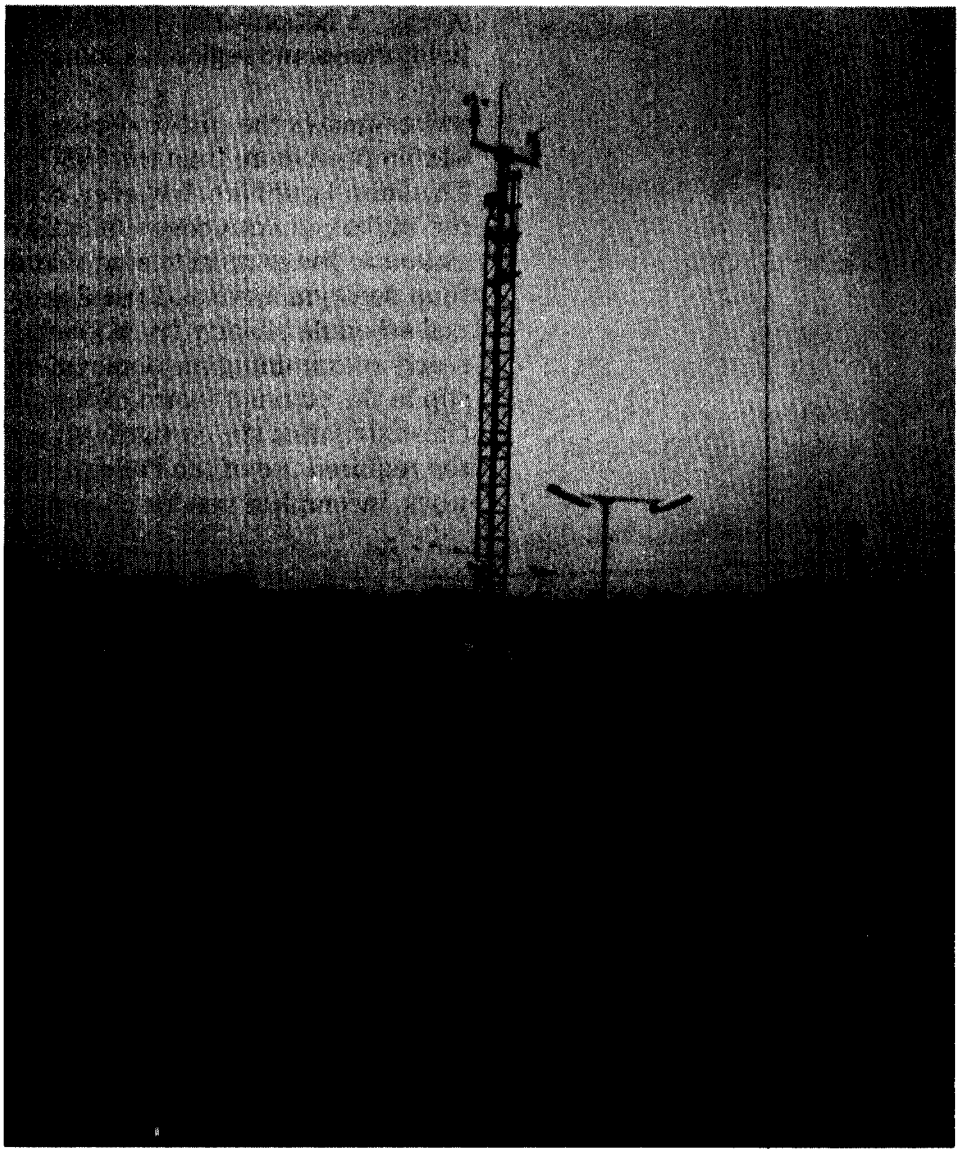
Source: Ford Aerospace Corporation (now Space Systems/Loral)

## ASOS

ASOS is a system of sensors, computers, display units, and communications equipment to automatically collect and process basic data on surface weather conditions, including temperature, pressure, wind, visibility, clouds, and precipitation.

The current cost to deploy 250 ASOS systems at NWS sites is $120 million, an increase of $48 million over an initial 1986 estimate of $72 million. However, FAA and Defense requirements for surface observing systems have been consolidated under the NWS ASOS program, bringing the total number of ASOS systems to 868 at a cost of $298 million. Deployment of the systems has been extended by approximately 5 years, from 1990 to 1995. NWS officials stated that the cost growth and delays resulted from inclusion of FAA and Defense requirements and inflation. In July 1991, NWS deployed the first units and is currently testing them in an operational environment.

**Figure 3: The Automated Surface Observing System**



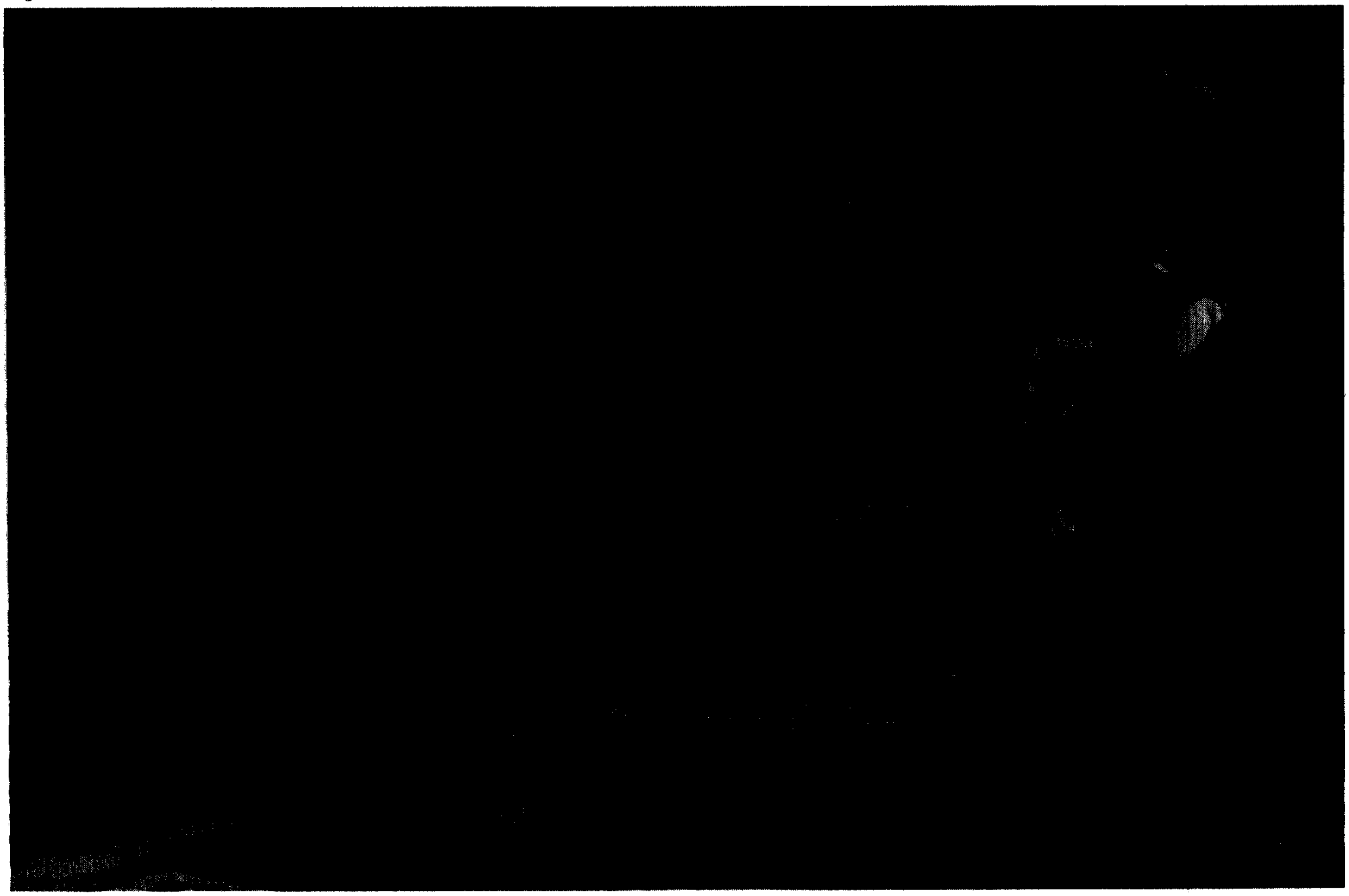
Source: The General Accounting Office

## AWIPS

AWIPS is an information system that includes workstations, associated data processing, and communications to integrate data from NEXRAD, GOES-Next, and ASOS as well as data from field offices, regional and national centers, and other sources. AWIPS systems are planned for installation at 124 locations across the country, primarily at weather field offices. A nationwide AWIPS communications network will interconnect field offices and regional and national centers.

NWS estimates the cost to deploy AWIPS to be $465 million, or $115 million more than the $350 million that was estimated in 1986. This initial estimate, however, did not include an estimated $30 million for additional NOAA communications requirements. The latest official estimates for AWIPS indicated that delays in the schedule will extend the final deployment to mid-fiscal year 1998, about 4 years beyond the original schedule of early fiscal year 1995. However, NOAA and NWS are currently reexamining the deployment schedule in light of a recent 1-year slip in the planned award of the system development contract. NWS officials attributed the cost growth and schedule slips to delays in funding, the required use of the Federal Telecommunications System-2000 network, incomplete vendor proposals, and inflation.

Figure 4: The Prototype Advanced Weather Interactive Processing System



Source: National Weather Service

## Field and Staff Restructuring Plan

NWS' office structure consists of 3 national weather centers, 13 river forecast centers, and 249 field offices (52 forecast offices and 197 smaller service offices). It also consists of about 4,700 staff, the majority of whom are in the 249 field offices. Field office staff include meteorologists, meteorological technicians, and electronic technicians. Under NWS' restructuring plan, the 249 field offices will be consolidated to form 115 forecast offices, and the 13 river forecast centers will be collocated within these offices. Additionally, the overall staffing level will decrease from 4,700 to 3,900, primarily through a reduction in meteorological and electronic technicians. According to NWS, the operational improvements from its systems modernization program will permit this reduction of offices and staff. Moreover, NWS claims that without this restructuring, overall operating costs for the modernized NWS will be higher. Public law prohibits NWS from closing or consolidating any offices until the Secretary of Commerce certifies that weather services to that area will not degrade.[3] Additional information on NWS' field office and staff restructuring plan is in appendix II.

Unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time, we will provide copies of the report to the Secretary of Commerce, the Commerce Under Secretary for Oceans and Atmosphere, the NOAA Assistant Administrator for Weather Services, and other interested parties. Please contact me at (202) 275-9675 if you have any questions concerning this report. Major contributors to this report are listed in appendix III.

Sincerely yours,

JayEtta Z. Hecker
Director, Resources, Community
and Economic Development
Information Systems

[3] Public Law 100-685, The National Aeronautics and Space Administration Authorization Act, Fiscal Year 1989, Section 408 (Nov. 17, 1988).

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## Abbreviations

| | |
|---|---|
| ASOS | Automated Surface Observing System |
| AWIPS | Advanced Weather Interactive Processing System |
| FAA | Federal Aviation Administration |
| GAO | General Accounting Office |
| GOES-Next | Next Generation Geostationary Operational Environmental Satellite |
| IMTEC | Information Management and Technology Division |
| NASA | National Aeronautics and Space Administration |
| NEXRAD | Next Generation Weather Radar |
| NOAA | National Oceanic and Atmospheric Administration |
| NSIAD | National Security and International Affairs Division |
| NWS | National Weather Service |
| PUP | Principle User Processor |
| RDA | Radar Data Acquisition |
| RPG | Radar Product Generator |
| WFO | Weather Forecast Office |
| WSFO | Weather Service Forecast Office |
| WSO | Weather Service Office |

# Objective, Scope, and Methodology

The objective of our review was to provide information on the status of the four major automated systems, including any cost growth and schedule delays, under NWS' modernization and restructuring program. Because the four systems are but a part of the modernization and restructuring, we also describe NWS' plans under the program to restructure its field offices and reduce staffing. To do this, we first discussed NWS' overall modernization program and the status of the four major system development projects with officials in the Washington, D.C., area, at the Department of Commerce's Major Systems Procurement Office; NOAA's Systems Program Office; and NWS' Transition Program Office, Office of Systems Development, and Management and Budget Office.

At NWS, we obtained information on initial cost estimates and schedule changes from interviews with project managers and system and agency acquisition and planning documents. Information on the reasons for cost growth and schedule slips was obtained from the Systems Program Office and NWS' Transition Program Office and Office of Systems Development. To obtain information on the status of each system, we reviewed system development documentation and interviewed officials at NOAA's Sterling Research and Development Center in Sterling, Virginia; Environmental Research Laboratory in Boulder, Colorado; and NEXRAD Operational Support Facility in Norman, Oklahoma. To discuss the use of systems in an operational environment, we interviewed staff at Weather Service Forecast Offices in Sterling, Virginia; Norman, Oklahoma; and Denver, Colorado. We also obtained and analyzed system test reports, external evaluation documents, and interviewed Commerce Inspector General officials and reviewed their reports. Additionally, we reviewed NOAA's budget requests and congressional hearings and testimony on the modernization over the past 10 years.

Our work was performed between June and November 1991 in accordance with generally accepted government auditing standards. We discussed the facts in this report with NWS and NOAA officials, and have incorporated their views where appropriate.

# NWS Modernization and Restructuring Program

Four major automated system development projects are critical components of NWS' modernization and restructuring program. Detailed descriptions of the four major systems and their status are provided below. Also provided is information on the overall program, including NWS' planned restructuring of its field offices and staffing, and legislative requirements for proceeding with the modernization and restructuring program.

## Four Major System Development Projects

NWS is working jointly with FAA, Defense, and NASA to modernize its observation and information systems that collect, process, and communicate weather data. According to NWS, the modernization will replace existing systems that are obsolete and costly to maintain with newer ones that will provide more sophisticated analytical capabilities and enable earlier and more accurate predictions of the most destructive weather events. NEXRAD, GOES-Next, ASOS, and AWIPS are the four major system development efforts.

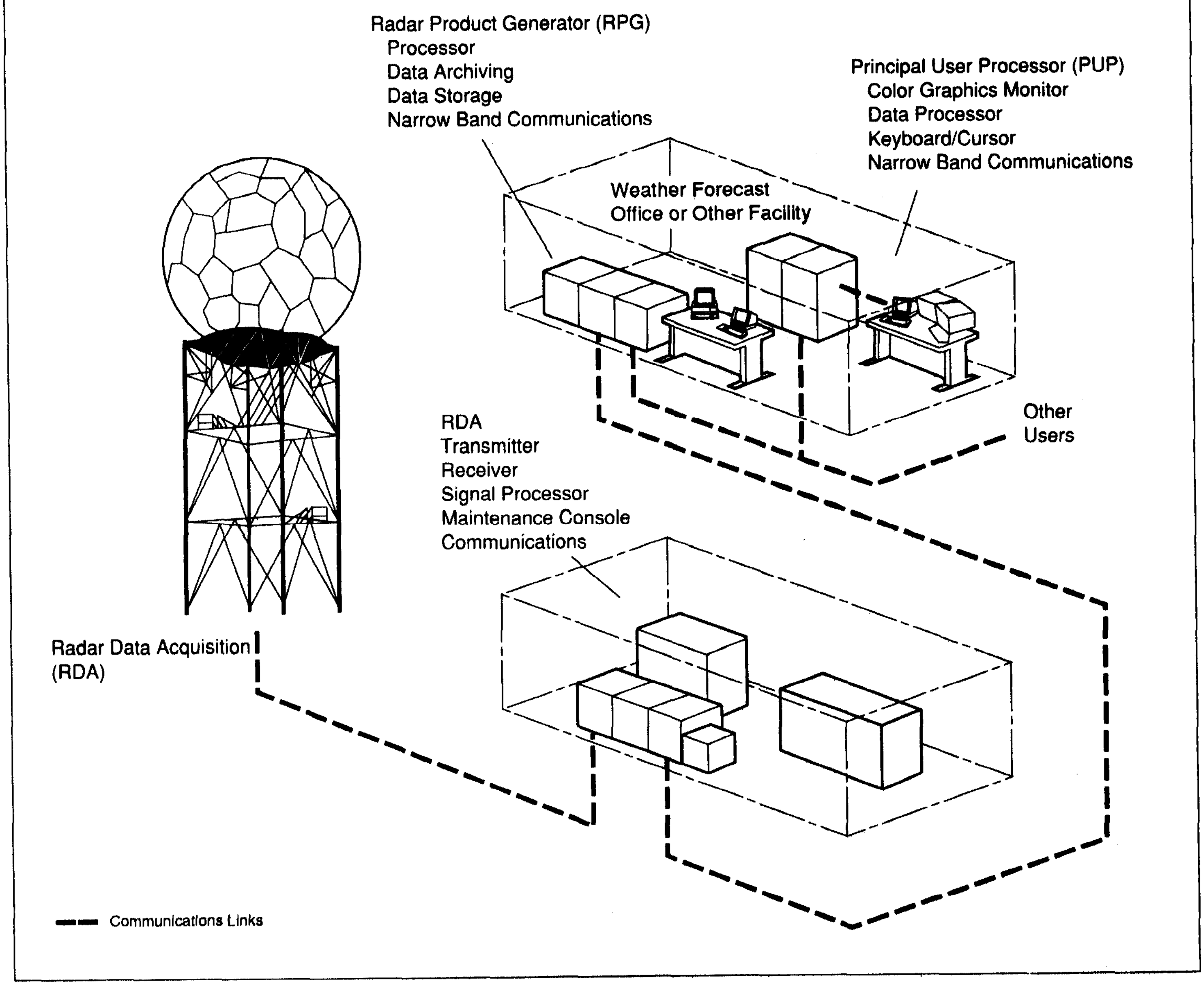
## NEXRAD

NEXRAD is expected to allow earlier detection of tornadoes, thunderstorms, and other important weather phenomena. In addition to providing better data, the NEXRAD system is being designed to replace the existing network of aging weather radars, many of which were deployed in the 1960s and 1970s, and are increasingly difficult to maintain, frequently break down, and lack spare parts. NWS records show that during a 1-year period ending July 1991, there were 72 incidents in which a radar was out of service for 2 or more days. In one case, the radar experienced multiple problems and was out for over 2 months.

## NEXRAD Components

NEXRAD consists of three major subsystems—a radar data acquisition (RDA) subsystem, a radar product generator (RPG) subsystem, and a principal user processor (PUP) subsystem—and associated communications capabilities (see fig. II.1 for a description of key NEXRAD components). Each radar system includes about 400,000 lines of code for operating the radar, processing radar signals, generating and transmitting data, and displaying the data products.

**Figure II.1: Key Components of NEXRAD**




Radar Data Acquisition (RDA) subsystem consists of the tower, radome, antenna and pedestal, associated facilities, support equipment, and the electronic hardware and software for receiving and transmitting the radar data.

Radar Product Generator (RPG) subsystem consists of the computer hardware and software necessary to produce real-time NEXRAD data.

Principle User Processor (PUP) subsystem is a workstation composed of hardware, software, and displays necessary to view and evaluate the radar information.

RDA consists of a 10 centimeter wavelength Doppler weather radar that collects the raw data to, among other things, (1) measure wind velocity in severe weather, such as thunderstorms, (2) provide improved estimates of precipitation amounts, (3) detect the transition between rain and snow, and (4) track storm movement and intensity. The technology needed to perform this function includes an antenna, pedestal, radome, transmitter, and receiver. Included in the RDA unit is hardware and software necessary for a variety of control functions including signal processing, monitoring and error detection, and archiving of the radar data. A computer processes the radar signals to create digital base data that can be further processed by the RPG.

RPG includes all hardware and software necessary for turning the base data into displayable product images. More specifically, the RPG has the capability for real-time generation, storage, and distribution of products for operational use by forecasters and other users. It also includes hardware and software required for system control, status monitoring and error detection, archiving, and data processing.

PUP is a workstation that consists of the hardware and software required for the request, display, local storage and annotation, and distribution of products by forecasters. It also includes the hardware and software required for local control, status monitoring, archiving, and communicating with other users. PUP will maintain a dedicated communication link to the RPG located on site and will routinely receive NEXRAD products. PUP will also have the capability to access data from RPGs at other NEXRAD sites. In addition, under a NEXRAD information dissemination service, NWS has set aside four communications ports to allow access by commercial companies that provide data to the public and other government agencies.

## NEXRAD Status

NEXRAD is being developed jointly by NWS, FAA, and Defense. Under the joint agreement signed in 1980, the three agencies will purchase 175 radars; 159 are necessary for nationwide weather forecasting operations, while the remaining radars will be deployed at overseas military bases to support Defense operations.

In 1987, limited production of ten NEXRAD units was approved. However, by 1990, NOAA officials had serious concerns about the ability of the Unisys Corporation to complete the NEXRAD contract. Their concerns focused on continuing schedule delays, an ongoing Department of Justice investigation of Unisys' involvement in Defense procurements, Unisys' financial condition, and Unisys' protest of the full production contract award. Their disputes with Unisys led to a suspension of the NEXRAD deliveries in early 1991.

To address this dilemma, NOAA considered alternatives to continuing with its existing contract and selected two for detailed evaluation: (1) reach a comprehensive settlement with Unisys to deliver both limited and full production radar systems, or (2) terminate the existing contract after receiving the ten limited production units and contract with another vendor for the NEXRAD full production units. After weighing the pros and cons of these choices, NOAA and Unisys signed a comprehensive settlement of contractual issues in August 1991, and delivery of the limited production radars resumed.

By December 1991, NOAA officials expect to have modified the contract to reflect the terms of the settlement. According to the NEXRAD contracting officer, the precise impact of the settlement will not be known until the contract modifications are completed. A key provision of the settlement requires Unisys to replace the minicomputers currently used in NEXRAD. NWS believes the current minicomputers will make the systems difficult to maintain over their 20-year expected life. Under the settlement, over one-half of the NEXRAD units will receive new minicomputers. The settlement required the replacement to occur by the 73rd full production unit. NOAA officials explained that the replacement was occurring by the 73rd unit because it would take that long for Unisys to rewrite the software to run on the new minicomputers.

Currently, three of the ten limited production units have been installed. During testing in March and July of 1991, officials reported that NEXRAD demonstrated the capability to significantly enhance the ability of operators to issue timely and accurate weather forecasts and warnings. However, according to a recent Inspector General report,[1] poor software development practices on NEXRAD create a high risk that the software will not be reliable, maintainable, or fit for use in an operational environment. According to the report, Unisys developed the NEXRAD software without a well-managed and disciplined software engineering process, and without adequate specification of software requirements and design.

[1] Final Inspection Report on NEXRAD Software Risks (TA-100), U.S. Department of Commerce, Office of Inspector General, Technical Support Staff, August 1991.

## GOES-Next

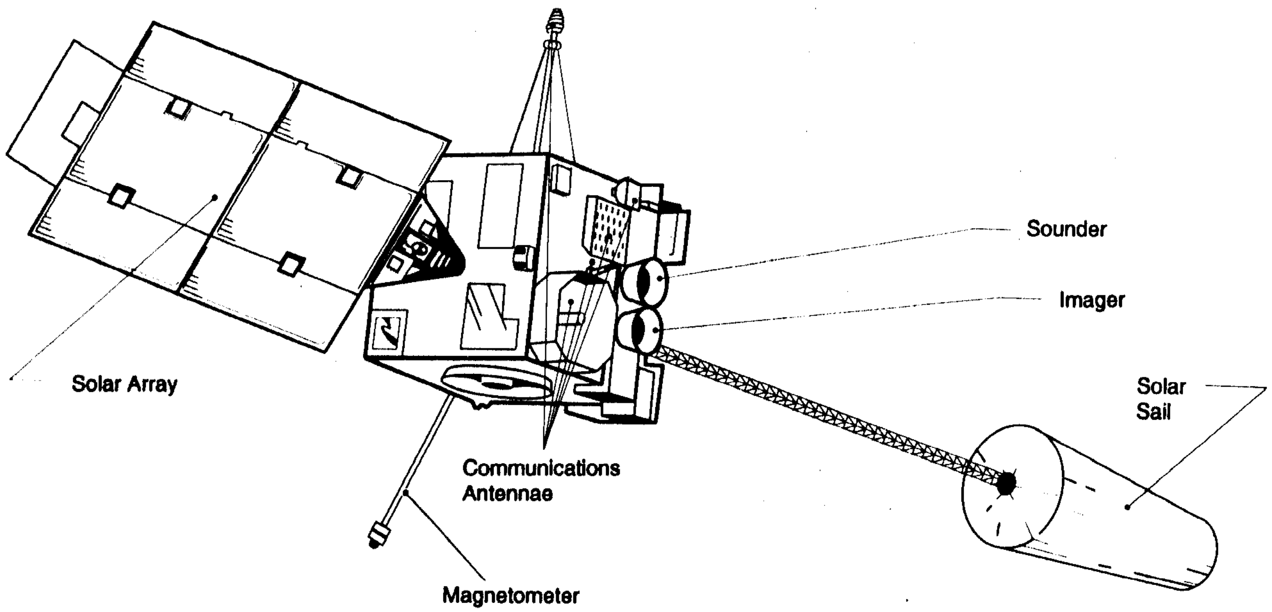
GOES-Next satellites are expected to replace an existing series of satellites that provide imagery of clouds and the earth's surface, and measurements of the atmosphere. Such data are valuable for (1) issuing severe weather and flood warnings and other short-range forecasts and (2) tracking hurricanes over ocean areas where other observations are sparse. In addition to providing higher resolution and more frequent data, GOES-Next satellites are expected to allow simultaneous images and measurements that were not possible on the current GOES series.

## GOES-Next Components

The three major elements of the GOES-Next program are the satellites and their instruments, the launch services, and the ground systems. The two primary instruments carried by the satellites will be an imager and a sounder (see fig. II.2 for a description of the GOES-Next satellite). The imager will produce visual and infrared images of the earth's surface, oceans, cloud cover, and severe storm developments. The sounder will produce various temperature and moisture measurements of the atmosphere. Two satellites need to be in orbit for full coverage of the United States. The satellites are positioned in space about 22,238 miles above the equator. From this vantage point, they can remain in the same relative position above the earth at all times. The satellites will be placed in orbit with an expendable launch vehicle.

Ground-based hardware and software will provide monitoring, supervision, and data acquisition and processing functions for the satellites. The ground system will be physically divided between two locations, The Satellite Operations Control Center at Suitland, Maryland, and the Command and Data Acquisition station at Wallops, Virginia. The Satellite Operations Control Center is responsible for continuous monitoring and supervision of the spacecraft and data acquisition system. The Command and Data Acquisition station will provide the primary communication interface with the satellites, as well as data acquisition and processing functions. Raw data from the satellites are transmitted to the ground stations where initial processing occurs. The data are then relayed to a computer center for further processing into weather forecasting products. Both satellite and land-based communications are used to distribute the products to the users.

**Figure II.2 GOES-Next Satellite**




Solar Array generates power for the satellite.

Magnetometer is part of a set of sensors designed to measure solar activity.

Antennae provide communications for telemetry, commands, data relay, and data collection and transmission.

Sounder provides measurements of the temperature and moisture levels of the atmosphere.

Imager provides visible and infrared images of clouds and the Earth's surface.

Solar Sail balances torque caused by solar radiation pressure.

## GOES-Next Status

Under a 1973 cooperative agreement, NOAA and NASA share responsibility for weather satellites. NOAA establishes program requirements; operates and maintains the satellites; acquires, processes, and distributes the data products; and funds satellite development, acquisition, launch, and operations. NASA prepares program implementation plans; designs, engineers, and procures the satellites and instruments; provides for launch services; and conducts on-orbit check-out of the satellites before transferring them to NOAA for routine operations. In 1985 NASA selected Ford Aerospace Corporation to build five GOES-Next satellites.[2]

The satellites' development has been plagued by technical problems. We reported on these problems in June 1989 and again in July 1991.[3] Since our last report, additional technical problems have been discovered. A panel tasked with studying the GOES-Next program evaluated the known problems and the proposed approach for completing the satellite development effort. In September 1991, the panel concluded that changes to the development approach and more extensive testing were needed. NOAA and NASA are following an approach and a schedule recommended by the panel that delays the first launch until February 1994.

According to NWS officials, deploying an operational satellite soon is critical because the only U.S. weather satellite in orbit will reach the end of its expected mission life in early 1992 and run out of fuel by 1993, although it may continue to provide useful data while it drifts. To prevent a total loss of satellite coverage, NOAA has arranged to use an older orbiting weather satellite no longer needed by the Europeans and is considering ways to collect additional data from other observing systems.

## ASOS

ASOS is designed to automate the collection of weather data currently obtained by human observations. These measurements provide the basic data for severe weather, flash flood, and river forecasting, as well as for support of aviation operations. The system is designed to continuously monitor and update the weather information each minute and automatically transmit hourly and special observations. As ultimately envisioned, ASOS will relieve staff of taking manual observations and will provide uniform and continuous weather data.

[2]In 1990 the Ford Aerospace Corporation was acquired by the Loral Corporation and renamed Space Systems/Loral.

[3]Weather Satellites: Cost Growth and Development Delays Jeopardize U.S. Forecasting Ability (GAO/NSIAD-89-169, June 30, 1989). Weather Satellites: Action Needed to Resolve Status of the U.S. Geostationary Satellite Program (GAO/NSIAD-91-252, July 24, 1991).

## ASOS Components

Each ASOS system includes sensors and the hardware and software for data collection, processing, and reporting of surface weather conditions, including temperature, pressure, wind speed and direction, visibility, cloud cover and ceiling heights, and precipitation types and intensity (see fig. II.3 for a description of the ASOS sensors). These functions are provided by the data collection package, acquisition control unit, and a variety of data reporting devices including an operator interface device and other video display units, printers, voice messages, and external communication devices.

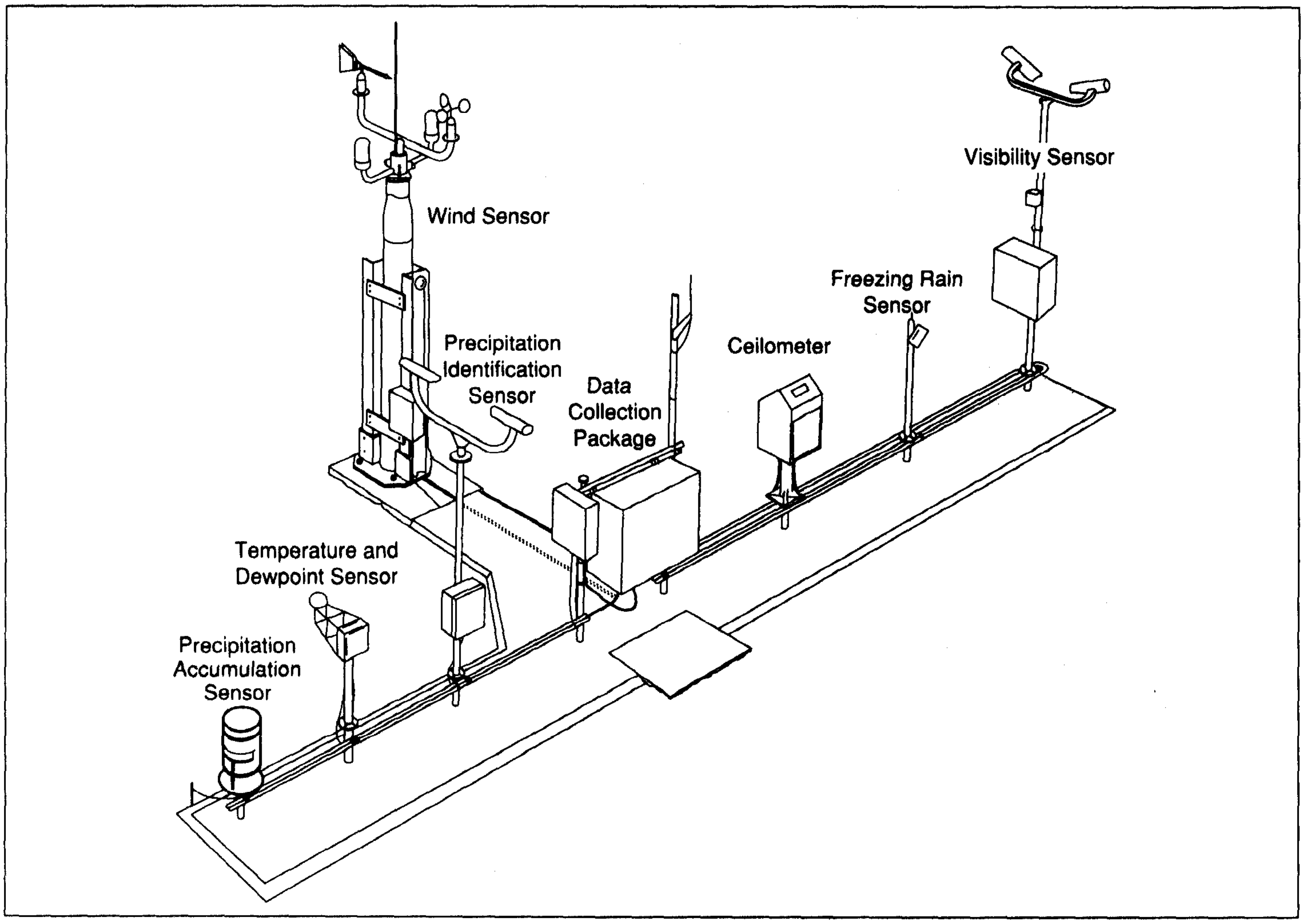
The data collection package collects sensor data and provides some processing functions before sending the data to the acquisition control unit. The acquisition control unit is located in an office environment and is the central processing unit for ASOS. It accepts data from the data collection package, as well as other sources, and performs final processing, formatting, quality control, storage and retrieval functions, and makes the data available to users through the various data reporting devices. Forecasters can access the ASOS data through the operator interface device—a monitor and keyboard that provide the forecaster with interactive access to the acquisition control unit.

About 10,000 lines of code will be used for processing and displaying the sensor data. In addition, over 20,000 lines of code will be used for continuous system self-test and diagnostics. Digital data output will permit a full range of communication options from phone line to radio to computer-generated voice messages. Output can also be displayed on a terminal or a printer.

## ASOS Status

In 1980, NWS, FAA, and Defense signed a joint program agreement to develop sensor units. According to the agreement, each agency was to collaborate on researching and developing automated surface observation systems. FAA and NWS became the primary participants, both designing and developing their own systems. In 1986 the President's Council on Integrity and Efficiency evaluated the two developments and advised FAA to purchase the more complete NWS ASOS units to meet its needs. NOAA contracted with AAI Corporation in 1988 to provide the ASOS systems. Currently, NWS, FAA, and Defense plan to procure 868 ASOS units, and could potentially buy as many as 1,700 units to meet additional FAA and Defense needs.

**Figure II.3: ASOS Sensors**




Precipitation Accumulation Sensor measures the amount of liquid precipitation.

Temperature and Dewpoint Sensor measures the temperature and dewpoint.

Precipitation Identification Sensor detects light to moderate drizzle or light to moderate to heavy rain or snow, and mixed precipitation.

Data Collection Package collects sensor data and sends data to a central processing unit.

Wind Sensor measures wind speed and direction.

Ceilometer measures cloud cover and height.

Freezing Rain Sensor detects when rain freezes. It is not part of the initial ASOS deployment.

Visibility Sensor measures visibility.

In July 1991, NWS tested and began deployment of a limited number of ASOS units. According to an August 1991 Interagency Test Review Board report, spring and summer testing indicated that the system would satisfy agency requirements. The report also stated that recent software testing generated 66 trouble reports, which were all corrected, and that system acceptance testing is ongoing.

The Test Review Board supported a decision to continue with the limited production and deployment; however, it indicated that the sensors needed to be tested over a wider range of climate conditions and an extended time frame. An NWS official told us that NWS plans to use the winter months to further test the sensors, as well as test solutions to sensor problems. For example, during winter testing NWS will check to see if a new temperature sensor, designed to correct the problem of inaccurately high temperature readings, functions correctly in cold temperatures, and whether an enhanced precipitation identification sensor can distinguish between rain and snow. If the testing is successful, NWS plans to retrofit units already deployed with the new sensors. NWS is still working on other sensor problems. For example, the precipitation identification sensor currently mistakes insects and spider webs for precipitation.

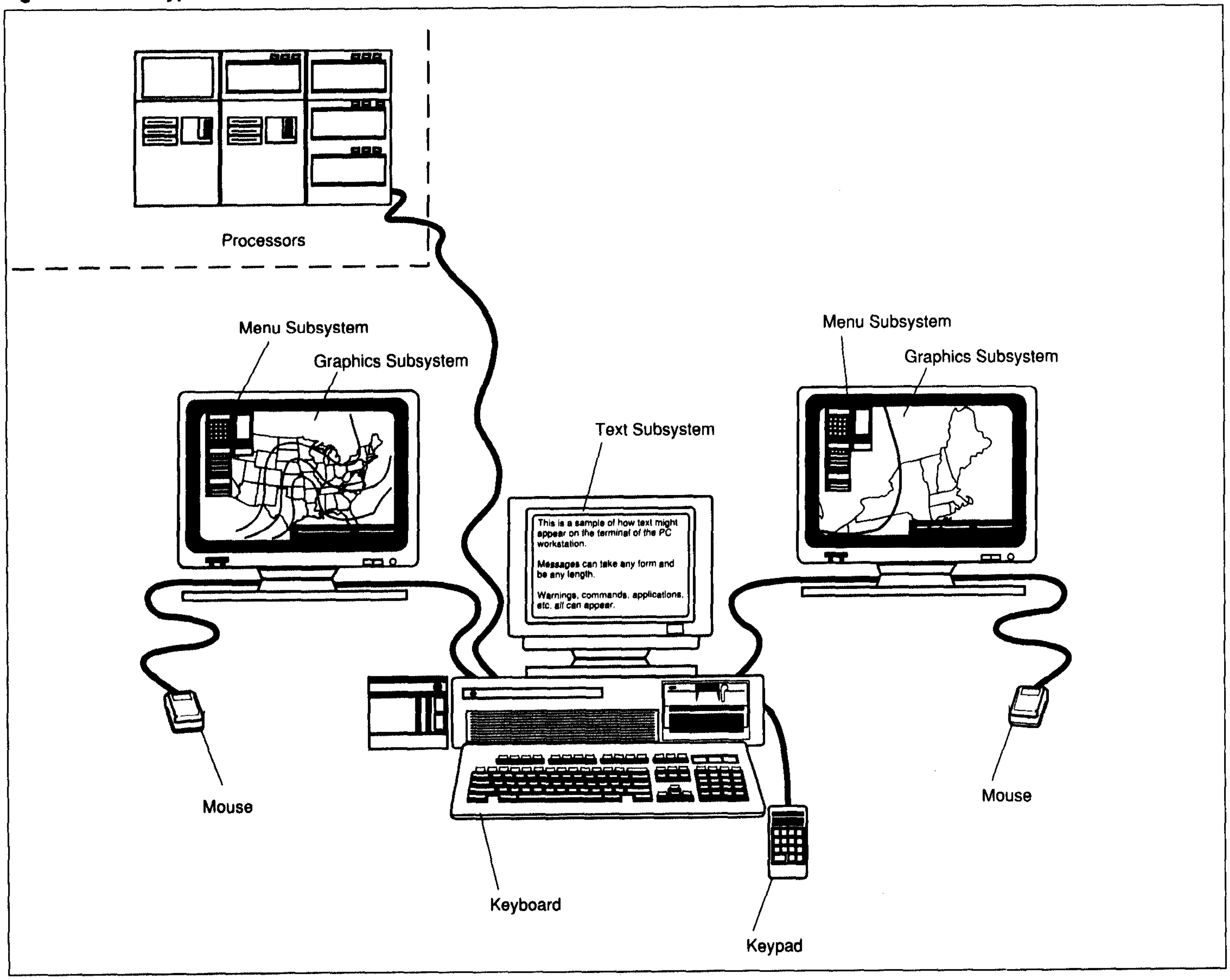
## AWIPS

AWIPS is an information processing and communications system designed to assist forecasters in efficiently assimilating data from NEXRAD, GOES-NEXT, and ASOS, as well as guidance from the national and regional centers and data from neighboring weather offices. NWS' current processing and communication system was developed in the mid-1970s and is based on computer, communications, and display technology that is now obsolete. Currently, one system is used to handle and display radar data, a second for satellite data, and a third for surface and upper air data, model output graphics, and text products. According to NWS, there is little or no capability for integrating data. Further, data from NEXRAD, GOES-Next, and ASOS are expected to overwhelm existing processing and communications capabilities.

## AWIPS Components

The two major elements of the AWIPS design are (1) the workstations and associated data processing and the communication, interface, and storage devices that are to be deployed at offices throughout the nation and (2) the AWIPS communication network, which will interconnect the field offices and link these offices with the regional and national centers. Forecasters will use the workstation to display, interpret, analyze, enter, and manipulate data and to prepare and transmit forecast products. (See fig. II.4 for a description of the key components of the prototype AWIPS workstation.)

**Figure II.4: Prototype AWIPS Workstation**




Processors are computers used for storing, processing, and communicating data.

Menu Subsystem provides for ease and speed in the selection of data sets, products, and applications.

Graphics Subsystem is used for display and overlay of data from national centers, radars, satellites, surface sensors, and other sources.

Mouse allows for quick and precise positioning of the cursor.

Text Subsystem is used for entering commands, weather warnings and advisories, and remarks.

Keypad allows quick access to products, i.e., radar or satellite data, without going through layers of menus.

According to the system acquisition documents, each AWIPS unit should provide a variety of data acquisition, storage, and archiving functions. The data acquisition function includes receiving weather data from observations taken by humans as well as those taken by automated observing systems. The data from human observers will be provided via telephone and entered into the system by an AWIPS operator, or may arrive directly via other user communications networks. The data from the automated observation systems will be received electronically by AWIPS. For example, AWIPS is to interface with both NEXRAD and ASOS units located on and off site.

Each AWIPS site must also be able to store sets of selected observational data, official forecast and warning products, guidance products, and graphics for immediate access to support operational requirements. Additional storage is necessary to accommodate other operational items, such as computer programs, map backgrounds, and forecast models. In addition, each site must maintain a capability for archiving historical data to perform a variety of legal, analytical, and other functions.

The AWIPS communications network will support the acquisition, distribution, and dissemination of weather forecast data. The network will interconnect all AWIPS offices and provide three types of communication: (1) point to multipoint distribution of centrally produced guidance, satellite imagery data and sounding products, and centrally collected products and observations that are generated at local AWIPS offices or external user offices; (2) point to point distribution of data and products among AWIPS offices; and (3) multipoint to point distribution of selected data products that are locally collected or produced from AWIPS offices to a central office. The AWIPS network will also support dissemination of data to external users; acquisition of observational data from external systems; and links with computer systems of other government agencies, the public, and news media.

A fully functional AWIPS unit is estimated to require about 1 million lines of code to allow for interactive analysis and display of data to prepare and disseminate forecasts and warnings. Current plans call for implementing an initial operational capability (about 700,000 lines of code) to support data distribution; quality control and management; interactive data processing, display and analysis; and product preparation, formatting, and dissemination functions necessary to support system operations and restructuring the NWS field offices. Another 300,000 lines of code will be developed to improve forecaster efficiency and productivity.

## AWIPS Status

Currently, two vendors, Computer Sciences Corporation and Planning Research Corporation, are competing for the AWIPS development contract. The development contract award date, originally scheduled for September 1991, was changed to March 1992 due to deficiencies with the system design proposals received from the vendors. According to NWS officials, the insufficient design information prevented them from evaluating whether the proposed systems complied with all functional and performance requirements and whether the development phase schedule could be achieved. Modified proposals from the vendors were received in late July 1991 and are being reviewed. According to the AWIPS program manager, schedules for development are being revised and the March 1992 contract award date will probably slip to October.

# Field Office Restructuring

In tandem with the implementation of new technologies, NWS intends to restructure its field office organization. The Strategic Plan for the Modernization and Associated Restructuring of the National Weather Service submitted to the Congress in 1989 cited two primary reasons for restructuring field offices. First, new operational concepts, data sets, and scientific understanding of dangerous weather phenomena required an increase in the number of meteorologists. Second, productivity and efficiency gains from new technology would allow a fewer number of offices. The strategic plan states that if NWS deployed its new technology on the basis of the current field office structure, required staffing levels and overall costs would be higher than those expected under the new structure.

NWS operates a nationwide office structure comprised of 3 national centers, 13 River Forecast Centers, 52 Weather Service Forecast Offices (WSFO), and 197 Weather Service Offices (WSO). The WSFOs combine information from national and regional centers with local data to prepare and issue severe weather and flash flood warnings, as well as aviation, marine, agriculture, forestry, and public forecasts. The WSOs issue more focused, shorter-term warnings and forecasts, using WSFO-provided information and meteorological and hydrological data they collect for an area covering about 10 counties.

The national centers are (1) the National Meteorological Center, which primarily collects national and global data used for weather prediction modeling, and issues forecasts and global pressure patterns to WSFOs and River Forecast Centers; (2) the National Severe Storms Forecast Center, which issues directions necessary to support severe weather and flood warning activities; and (3) the National Hurricane Center, which is responsible for the analysis, prediction, and tracking of tropical storms and hurricanes. The 13 River Forecast Centers provide regional hydrologic forecasts and guidance for river and flood forecasts and flash flood warnings, and long-term seasonal estimates of melting snow and water supply outlooks.

According to NWS' modernization and restructuring plan, the 249 WSFOs and WSOs will be consolidated into 115 Weather Forecast Offices (WFO). The WFOs are expected to provide all of the services now provided by the WSFOs and WSOs. The 13 River Forecast Centers will be collocated with WFOs.

## Staffing Reductions

The consolidation of field offices will also involve changes in the number and type of staffing. NWS currently employs about 4,700 people, the majority of whom work in the 249 field offices. Field office staff are comprised of meteorologists who prepare forecasts and warnings, meteorological technicians who take observations and disseminate weather information, and electronic technicians who maintain equipment. In the future field office structure envisioned by NWS, the number of meteorologists will increase substantially to prepare forecasts and warnings at 115 WFOs, rather than at 52 WSFOs, but overall staffing will be reduced to about 3,900 employees. The overall staff reductions will be achieved by decreasing the number of meteorological and electronic technicians. Many of the manual, labor-intensive procedures currently performed by these staff are to be automated or contracted out.

While the total number of staff will decrease, the skill level of the remaining staff will need to be upgraded to operate, apply, and maintain the new technology systems. Meteorologists will have to be trained to use new technology for detecting new small-scale weather events. Meteorological technicians will require different skills to support the new technologies and increasingly sophisticated operations. System maintenance requirements will also place increased demands on electronic technicians who will require advanced training to support and maintain a variety of complex equipment.

Although NWS' goal is to eventually reduce staff and associated costs, during the transition from the old to the new field structure staffing levels will actually increase as new offices are opened prior to closing old offices. At its peak, NWS estimates its staffing will increase by over 600 people. NWS estimates the cost of staff augmentation to be about $200 million. Under current planning, staff reductions below the current levels will not occur until fiscal year 1998. The staffing goal of 3,900 is to be reached by the year 2000. NWS' goal is to achieve the staff reductions primarily through attrition.

## Legislative Requirements and NWS Plans for Addressing Them

In November 1988, Congress enacted Public Law 100-685, which specified certain requirements to be followed in planning for and carrying out the modernization and restructuring. The law directed the Secretary of Commerce to submit to the Congress a 10-year strategic plan for the comprehensive modernization of NWS. The Secretary is also required to submit and annually update a National Implementation Plan that details the requirements, resources, and schedules for the modernization program. The implementation plan must also include special measures to test, evaluate, and demonstrate key elements of the modernized NWS operations prior to national implementation, including a multi-station operational demonstration that tests the performance of all components of the modernization in an integrated manner for a sustained period.

The law further provides that the Secretary shall not close, consolidate, automate, or relocate any WSO or WSFO unless the Secretary certifies to the Congress that such action will not result in any degradation of weather services provided to the affected area. The certification must include (1) a detailed comparison of services before and after the action, (2) any recent or expected modernization of operations that will enhance services, and (3) evidence, based on operational demonstration of modernized NWS operations, supporting the conclusion that no degradation in services will result from such action. NWS also committed to maintaining its current level of services without disruption as it modernizes and restructures.

NWS is planning a Modernization and Associated Restructuring Demonstration to address the operational demonstration requirements of Public Law 100-685. The 1-year demonstration will occur at the new WFOs, located primarily in Kansas and Oklahoma, using the new systems. NWS' implementation schedule indicates that demonstration will occur during fiscal year 1995.

Prior to the demonstration, NWS plans to carry out several risk reduction activities to validate the capabilities or identify deficiencies of new technologies and operational concepts. For example, risk reduction projects in the Denver, Colorado, area were initiated to provide a test-bed for determining and validating advanced systems technology requirements. The Denver program has focused on prototyping and evaluating the

AWIPS workstations. Risk reduction activities in Norman, Oklahoma, are intended to evaluate (1) the interface between NEXRAD and the prototype AWIPS workstations; (2) the integration of data from multiple sources, such as satellites, radars, and National Meteorological Center guidance; and (3) office processes using modernized workstations and observing systems. Risk reduction activities in Topeka, Kansas, assessed the effectiveness of the ASOS system and evaluated issues, such as the use of lightning data, and the capability to collect observation data without human involvement.

# Major Contributors to This Report

## Information Management and Technology Division Washington, D.C.

Randolph C. Hite, Assistant Director
Richard D. Eiserman, Assignment Manager
Heidi L. Alves, Evaluator-in-Charge
Tonia L. Johnson, Computer Scientist

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