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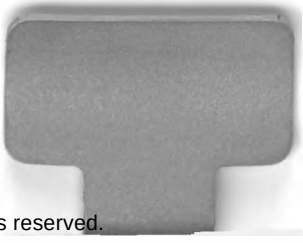
Cover: An image made from radar reflectivity values measured by the prototype Next Generation Weather Radar (NEXRAD) located at Norman, Oklahoma, on March 17, 1989, at 2:52 p.m. The atmosphere was free of clouds at the time of observation and demonstrates the high sensitivity of the new system. This enhanced sensitivity, compared to current operational weather radars, permits the detection of both a cold front and a moisture discontinuity (dry line) oriented NE-SW and located NW of the radar site (represented by the small circle below the center of the image). Four hours after these data were acquired, a thunderstorm developed on the cold front and produced hail the size of baseballs near Tulsa. (Reprinted with permission of the National Weather Service.)



TOWARD A NEW NATIONAL WEATHER SERVICE

-- *A First Report*

Prepared by the
Committee on National Weather Service Modernization

of the
Commission on Engineering and Technical Systems
National Research Council

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the panel responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Notice

Since the completion of this report by the Committee on National Weather Service Modernization, the Department of Commerce (National Oceanic and Atmospheric Administration, NOAA, 1991b) has announced that it is "creating a new advanced system acquisition office which will provide an integrated system development and procurement capability within NOAA. Both the National Weather Service's modernization system procurement and the Next Generation Geostationary Operational Environmental Satellite (GOES-Next) system development and procurement will be the responsibility of the new office." Although details of the reorganization had not been announced by the end of January 1991, the Committee understands that the new advanced system acquisition office will report to the Commerce Deputy Undersecretary for Oceans and Atmosphere. As reflected in this report, the National Weather Service (NWS) is currently responsible for the development and procurement of systems required for the modernization. The National Environmental Satellite, Data, and Information Service (NESDIS), together with the National Aeronautics and Space Administration, is now responsible for the development and procurement of the GOES-Next satellite system. (Both NWS and NESDIS are major line components of NOAA.)

Although this reorganization undoubtedly will affect the future work of the Committee, it believes that the conclusions and recommendations in this report are still germane; however, some of them may now be applicable to the new NOAA systems office rather than to NWS or NESDIS.

Preface

The National Weather Service (NWS) is engaged in a dramatic transformation involving new sources of information about the atmosphere, new ways of using that information effectively and making it available to a wide community of users, and new ways of providing the forecasts and warnings that will lead to enhanced protection of life and property. This effort follows more than a decade of planning based on recent scientific and technological developments.

In its report *Technological and Scientific Opportunities for Improved Weather and Hydrological Services in the Coming Decade*, the Select Committee on the National Weather Service of the National Research Council (NRC, 1980) pointed out scientific and technological opportunities for substantial improvement in the quality and quantity of the nation's weather and hydrological services, including the timely warning of hazardous weather and flooding. According to the National Oceanic and Atmospheric Administration (NOAA), this report encouraged and assisted NOAA in moving toward implementation of plans to modernize and restructure the NWS. Subsequently, a study panel of the NRC (1987) reviewed the status of the development of potential technological components of a modernized NWS and the planning at that time for modernization and the associated restructuring. The report was generally supportive of both the technological developments and the plans for implementation.

In response to Department of Commerce budget requests to move ahead with the modernization and associated restructuring, the U.S. Congress (1988) passed and the President signed Public Law 100-685, Title IV of which set forth guidelines for planning the NWS modernization and restructuring, as well as for reporting and certifying proposed actions to Congress. In accordance with this law, the Department of Commerce issued a *Strategic Plan for the Modernization and Associated Restructuring of the National Weather Service*

(DOC, 1989). In July 1989, NOAA requested that the NRC establish a review committee on the modernization and associated restructuring of the NWS (Appendix A). The NOAA proposed that the review committee function throughout the national deployment of the new technology and the transition to the new structure of the NWS, a period expected to extend into the mid-1990s.

The NRC agreed to establish a committee to help ensure

- the implementation of the most cost-effective levels of technical systems and services by assessing the availability, applicability, and timing of appropriate underlying technological and scientific capabilities; and
- the successful demonstration and acceptance of the modernized and restructured NWS operations by reviewing test, demonstration, and certification plans, and by independently reviewing the data collection and interpretation processes.

The NOAA executed a contract for this activity on December 29, 1989, and the NRC established the Committee on National Weather Service Modernization.

The Committee held its first meeting on February 21-22, 1990, and a total of five meetings during that year. Its work is being supported by the Committee on Meteorological Analysis, Prediction, and Research of the NRC Board on Atmospheric Sciences and Climate (Appendix B). The two committees met jointly in June. In addition, individuals and groups of members of both committees, along with NRC staff, have held discussions on specific details with personnel and contractors of the NWS. This first report of the Committee presents the results of its work during 1990. In addition to taking a broad overview of the modernization and associated restructuring, the Committee examined in more detail selected areas in which near-term decisions by NOAA are contemplated or needed. The Committee will continue to examine the planning and implementation of the NWS modernization and associated restructuring, and will present additional conclusions and recommendations in subsequent reports to be issued at least annually during its lifetime.

The members of the National Weather Service Modernization Committee are pleased to be able to contribute to a "new National Weather Service" for this nation.

Acknowledgments

The contributions of members of the Committee, both during its meetings and in carrying out individual assignments, are acknowledged with great

appreciation. The Committee wishes to thank the members of the Committee on Meteorological Analysis, Prediction, and Research for their valuable contributions to this work. I would like to express the Committee's appreciation for the excellent support of the NRC staff in all aspects of its work. Although this report represents contributions by and deliberations of all members of the Committee, I would especially like to note the contributions to its writing by David S. Johnson, Study Director, and to its production by Mercedes Ilagan, Senior Study Assistant. Finally, the peer review by the NRC contributed significantly to the quality of the report.

Charles L. Hosler, Jr.
Chairman, Committee on National
Weather Service Modernization

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Summary

Since World War II, significant improvements have been made in the prediction of large-scale weather features (high pressure areas, large storms) owing to increased knowledge of atmospheric processes, new observational techniques such as radar and satellites, and the advent of large computers and numerical prediction models. However, improvements in the forecasting and warning of smaller-scale phenomena (hurricanes, severe thunderstorms, tornadoes, flash floods) have been less dramatic. Yet recent scientific advances in the understanding of these phenomena and new capabilities to observe and rapidly process information on these smaller scales (from a few to several hundred miles) now permit a major advance in weather service to the nation.

As a result, the United States has launched a bold and innovative program to modernize the National Weather Service (NWS), a major component of the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce. The modernization involves new observational technology, powerful new information and forecast systems, and a new organizational structure. It promises to provide a dramatic improvement in weather services to the nation, including more accurate and timely predictions of those weather events that have regular and dramatic impact on both private and public activities.

Modernization of the NWS thus offers great opportunities to the nation, but it is also a complex undertaking. The National Weather Service Modernization Committee[1] of the National Research Council (NRC) endorses the

[1] At the request of NOAA, the National Research Council established a review committee on the modernization and associated restructuring of the NWS. This first report of the Committee presents the results of its work during 1990. The Committee will continue its review and will present additional findings and recommendations in subsequent reports.

organizational approach and implementation philosophy of the NWS, but recognizes the challenges ahead; success will depend on the continuity of strong leadership, of good management, and of adequate resources. Although the Committee is impressed with the progress made by the NWS, it is also cognizant of the commitment required by the federal government, NOAA, and the NWS to complete successfully the modernization and revitalization of the nation's weather services. The recommendations presented in this report are intended to be supportive of the national effort and to increase the possibilities of success.

- **The success of the National Weather Service modernization requires an increased commitment of resources and personnel to the many scientific, technical, and organizational challenges involved. Parsimony now will be expensive later.**[1]

- **The National Weather Service modernization requires the development and implementation of complex observation and information systems. Rigorous and creative management of the overall structure and of the individual components of each of these systems is essential for success. The system management capabilities of the National Weather Service must be strengthened through the commitment of additional resources and personnel.**

- **Modernization of the National Weather Service involves a variety of scientific and technical issues and challenges. The National Weather Service and the National Oceanic and Atmospheric Administration should create technical advisory panels for each of the major systems that contribute to the technological modernization. However, these panels cannot substitute for the additional resources and personnel recommended.**

- **Modernization must continue beyond the implementation of systems now being procured. Provision should be made to incorporate data from additional new technology, such as wind profilers and a lightning detection network, and to take advantage of scientific developments as well as improved computational and information systems as they become available.**

NEW OBSERVATION SYSTEMS

The Next Generation Weather Radar (NEXRAD) system utilizes Doppler radar technology to provide improved estimates of precipitation amounts; to detect the transition between rain and snow; to track storm

[1] Several specific recommendations appear in the section on human and financial resources in Chapter 6.

movement and intensity; and to allow for earlier detection of the precursors of tornadic activity, thunderstorm development, and other important weather phenomena. The NEXRAD program is currently in a limited production phase. A number of software problems have been encountered and are in the process of being resolved. The Committee cannot judge how well NEXRAD will meet its technical and functional requirements until the test and evaluation phase has been completed.

■ **Steps should be taken to ensure the continued development and improvement of Next Generation Weather Radar processing algorithms as new developments and operational experience accumulate. The National Weather Service should develop a continuing comprehensive training and education program so that the skills of the Next Generation Weather Radar maintenance and operational staffs, as well as the meteorologists and hydrologists, reflect the ever-changing state of the art.**

The Automated Surface Observing System (ASOS) network will provide the basic data required for severe weather, flash flood, and river forecasting, as well as for support of aviation operations. However, although the ASOS has some clear advantages over the present surface observation method in operational weather forecasting and warning, serious concerns exist about its use in monitoring climate as discussed in the following section. The ASOS network will substantially increase the spatial resolution of surface observations, but even greater resolution will be needed for additional improvement in small-scale weather forecasting and warnings in the future.

■ **The National Weather Service should identify other local and state surface observation resources; initiate efforts to acquire existing data and, as feasible, to improve the quality and quantity of the data; and promote the development and installation of additional local and state networks in data-sparse regions.**

The Next Generation Geostationary Operational Environmental Satellites (GOES-Next), now under development, will allow higher-quality and more frequent atmospheric soundings and cloud images to be obtained simultaneously (only one or the other can be obtained from the current GOES). These advances are very important for improved prediction of severe storms and flash floods. Improvements now being developed in the free atmosphere temperature and humidity soundings acquired by NOAA polar orbiting satellites will also contribute to improved longer-range numerical forecasts.

Development and funding problems in the GOES-Next program may result in a delay until mid-1994 or later in reestablishment of the full two-GOES constellation, should there be a launch or spacecraft failure. The NOAA polar satellite system is in better condition, but continued funding constraints have decreased the availability of replacement satellites, thereby raising the threat of an interruption in observations in the event of launch or premature satellite failure.

■ **The National Oceanic and Atmospheric Administration, the Department of Commerce, the Office of Management and Budget, and the Congress should provide more realistic budgeting and funding for the National Oceanic and Atmospheric Administration's operational satellite systems in order to realize the full potential benefits of the National Weather Service modernization and associated restructuring.**

Viability and Integrity of the Climate Data Record

The nation's climate record is a valuable resource whose viability must be maintained. Climate information is used in the design of structures, drought assessments, agricultural planning and assessment, and water management. The possibility of climate change as a result of human activity emphasizes the need for a data record from which climate trends over the coming decades can be determined unambiguously (for example, see Committee on Earth Sciences, 1990; NRC, 1990b). The NWS is the primary organization engaged in observing and recording in situ weather information in the United States. It must ensure the accuracy and integrity of the weather information it gathers to fulfill its operational requirements; however, the Committee is concerned about the adequacy of NWS data to meet NOAA's climate requirements. Modernization and restructuring of the NWS will affect the viability and integrity of the U.S. climate data record, but it will also provide the opportunity to enhance this record significantly through the availability of new kinds of data; such opportunities should be examined by NOAA. Because the NWS has traditionally viewed its role as collecting observed data to prepare forecasts and warnings, data quality has been determined largely by these needs. However, the accuracy, continuity, and consistency required of observed data for climate studies are more stringent. The Committee argues that the NWS must be concerned that its data satisfy the needs for consistent climate records as well as for forecasting. Because NWS modernization plans

give little attention to the issues of data management and the quality of the climate record, the Committee recommends[1] the following:

■ **The National Oceanic and Atmospheric Administration should set the requirements for the climate data to be derived from the modernized National Weather Service observations, establish the role of the National Weather Service in generating these data, and ensure the availability of the resources necessary for this purpose. The National Weather Service at all levels should recognize its responsibility to acquire a major portion of the national climate record; the preservation of data quality for climatic purposes should have equal priority with its mission of providing forecasts.**

NEW INFORMATION SYSTEMS

Improved information systems are critical to the NWS modernization and associated restructuring. The key component of each modernized Weather Forecast Office (WFO) will be the Advanced Weather Interactive Processing System (AWIPS) supported by its associated communications system. The AWIPS at each WFO will be the information system used by the meteorologist on duty to prepare warnings and forecasts and to disseminate these products rapidly to the public and other users. The Committee is favorably impressed with the prototypes of AWIPS and the capabilities that are afforded to meteorologists and hydrologists in producing warnings and forecasts. However, it is concerned with the steady slippage of the schedule for full implementation. Without this system, WFOs will be unable to use the new observational technology in an effective manner or to reduce staff through restructuring while increasing service effectiveness. Attention also must be given to providing adequate access by private meteorologists and weather services, and by universities to raw data and information from AWIPS.

■ **The Administration and Congress should take the necessary steps to maintain the implementation schedule for the Advanced Weather Interactive Processing System and its associated communications. The National Weather Service, in consort with the university community and private sector users of National Weather Service data and information, should develop viable plans for broad access to the raw data and information that will become available via the Advanced Weather Interactive Processing System,**

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[1] Additional recommendations in this area appear in Chapter 2.

keeping in mind the benefits such collaboration can provide to the government, the public, and the private sector.

Improved numerical forecast and guidance products, with higher space and time resolution, are required by the WFOs to improve their forecasts and warnings of small-scale weather features. In turn, these improvements necessitate continuing enhancement of computer capability and refinement of atmospheric models at the National Meteorological Center.

NEW STRUCTURE OF THE NATIONAL WEATHER SERVICE

A major purpose of the NWS modernization is to improve dramatically the short-term forecasts of significant weather events and warnings of severe weather. To achieve this aim, meteorologists and hydrologists must be able to observe their service domains continuously and must have a workload commensurate with the area covered, the short response time necessary for effective warning, and the effective range of available observations (e.g., Next Generation Weather Radar). These human factors must be paramount in evaluating field service structures proposed for the modernized NWS.

Weather Forecast Offices

The Committee has examined the various configurations of the Weather Forecast Office (WFO) network that have been considered and endorses the proposed network of 115 WFOs, which coincides with the expected effective coverage of the new Next Generation Weather Radars (NEXRADs), a radius of around 200 km from each unit. The efficacy of this network will be validated by the Modernization and Associated Restructuring Demonstration (MARD) to be conducted for one year in the midwestern United States around 1993, a schedule that is in jeopardy because of continued delays in implementation of the Advanced Weather Interactive Processing System. However, the Committee is very concerned about a report that the Department of Commerce has decided to modify the MARD to test the efficacy of using about one-half as many WFOs as now planned while maintaining the current proposed network of 115 NEXRADs.

Attempting to double the area covered by each WFO without a proportional increase in staff on shift could seriously jeopardize the ability of each WFO to deal effectively with small-scale weather events over such a large area. Moreover, coordination of warnings with state and local government would also be degraded by doubling the area of responsibility for each WFO. Furthermore, a two-tier test would surely increase significantly the difficulties

involved in using the MARD results in the certification process required by Congress. Finally, the need to transmit the full-resolution data from two or three remote NEXRADs to a WFO and to merge these data in "real time" for use by meteorologists, although technically feasible, would add significantly to the complexity, cost, and the time required to implement both the MARD and, subsequently, the entire modernization.

■ **The Department of Commerce should carefully reconsider its decision to have the National Oceanic and Atmospheric Administration/National Weather Service conduct a two-tiered Modernization and Associated Restructuring Demonstration because a configuration of significantly fewer than 115 Weather Forecast Offices will lead to serious degradation of weather services. Moreover, such an experiment would be much more complex and expensive, and would probably lead to a serious delay in the National Weather Service modernization.**

Hydrology in the National Weather Service Modernization

The nation's need for improved management of water resources and more accurate flood forecasting will increase during the 1990s. Modernization of the NWS presents opportunities for improving hydrological services on all time scales by taking advantage of the new observational technology and forecasting capabilities, and by enhancing the collaboration between meteorologists and hydrologists.

■ **In light of the National Weather Service modernization and restructuring, the workloads, responsibilities, interactions, and cross-training of meteorological, hydrometeorological, and hydrological personnel planned for Weather Forecast Offices and River Forecast Centers should be examined carefully and redefined.**[1]

NEW AND STRONGER COLLABORATION

Strong and effective collaboration between the NWS and the academic community, the private sector, and public institutions is necessary for the NWS to accomplish its mission to provide weather and flood warnings and public forecasts for the protection of life and property, as well as to improve its

[1] Additional recommendations are included in the section on hydrology in Chapter 4.

services. Thus, planning and fostering these collaborations must be an important part of the NWS modernization.

Universities

The success of the NWS in accomplishing its mission depends on the effective integration of the skills and knowledge of its meteorologists, on employing advancing technology for observing the atmosphere, on continued improvement in its systems for transmitting information and creating numerical simulations and forecasts of atmospheric behavior, and on effective utilization of new and basic scientific understanding of the atmosphere. Clearly then, the effectiveness of the NWS is dependent on education, on technological development, and on scientific advances. Thus the Committee believes that the federal government must take a new view of the relationship among NOAA, the NWS, and the atmospheric sciences community, especially in the universities. An important new component of modernization of the NWS should be a strong commitment by NWS and NOAA to strengthen their research partnership with the academic community.

The Committee agrees with the NWS intent to collocate, to the extent possible, Weather Forecast Offices with universities offering undergraduate and graduate education in meteorology. Unfortunately, NWS efforts to implement this ideal situation are being impeded by lack of a high-level federal policy on collocation and by ponderous procurement procedures that delay and mitigate against the necessary commitments.

- **The Administration and Congress should adopt a policy that fosters the collocation of as many Weather Forecast Offices as possible on university campuses with atmospheric science departments.**

The Committee believes that more intimate and effective collaboration between the NWS and the universities in education and research would greatly benefit both parties and the nation.

- **The National Oceanic and Atmospheric Administration and the National Weather Service should implement enhanced collaboration with universities in the atmospheric and hydrologic sciences, in both education and research.**

Private Sector

The private sector provides much of the new technology now being implemented in the NWS modernization and also contributes to the technological advances on which operational improvements are based. The primary sources of weather forecasts and warnings for the general public are the mass media: television, radio, and newspapers. Clearly, maintaining effective collaboration with the mass media is crucial, and any inadvertent actions that might impair linkages between the NWS and the media would have serious impacts on the safety and well-being of the populace and on the commercial sector as well. Private weather services, which provide a variety of services regionally, nationally, and even worldwide, constitute another major interface between the NWS and the general public or other elements of the private sector. Thus although these components of the private sector are providing many important services today, they will become even more important in the era of the modernized NWS. Increased attention to collaboration with the private sector will be required as modernization of the NWS continues.

■ **To ensure that the association between the National Weather Service and the private sector functions smoothly and efficiently to the best advantage of all parties, including the general public, the constituent affairs activities of the National Weather Service should be strengthened; the Constituent Affairs Officer should act as an ombudsman for the private sector to the Assistant Administrator of the National Oceanic and Atmospheric Administration for Weather Services, coordinate program changes with the private sector, obtain its inputs to National Weather Service planning and evaluation, and arbitrate or resolve conflicts as they arise.**[1]

Public Institutions

Community preparedness is essential to save lives and minimize property damage during severe weather situations. The critical role of the NWS is to participate actively in preparedness planning and then communicate both to state and local governments, and to the public, the seriousness of specific weather situations. A leadership role is necessary, and the Committee believes that a limited, part-time approach to this key function is entirely inadequate.

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[1] Additional recommendations appear in the section on private weather services, Chapter 5.

■ **To ensure adequate community preparedness, professional staff time equivalent to a full-time person should be provided at each Weather Forecast Office to work with state and local governments and other involved agencies in preparing plans for the community's response to severe weather. To maintain liaison with public institutions and to assist in community preparedness, the federal government should consider retaining, with limited staff, most Weather Service Offices now planned for closure.**

IMPLEMENTATION PROCESS

The NWS has done a commendable job in planning its modernization. A new matrix organization is in place and top management staffing is complete. However, both NOAA and the Department of Commerce appear to have a shortage of staff to provide administrative support, such as procurement and personnel, and to handle the external contacts with Congress, user groups, and the public that are essential for implementation of the modernization and associated restructuring. Moreover, the Committee is concerned that the project management, engineering, and support staff may not be as strong as required for an effort of this magnitude.[1]

It appears to the Committee that the NWS lacks an overall policy for configuration control of large systems and for the development and maintenance of complex software. System engineering in the NWS environment is vital because of the phased development and because NWS systems must remain operational during upgrading and modernization.

■ **The National Weather Service should establish overall policies and procedures for the development of major systems, including consideration of the interaction between systems, and establish software development and maintenance standards.**

Overall, the Committee is impressed with the progress that has been made in developing hardware and preparing for field installation. Delays in procurement and funding constraints for the Advanced Weather Interactive Processing System (AWIPS) are the most serious concerns involving hardware, although there are some troublesome delays in software and hardware for the Next Generation Weather Radar. The AWIPS situation poses a major

[1] Several specific recommendations regarding staff increases appear in the section on human and financial resources in Chapter 6.

problem in the Modernization and Associated Restructuring Demonstration and certification process that must precede restructuring of the NWS.

The Committee's study to date has not reviewed the system security and resiliency issues involved in modernization. It is apparent, however, that the NWS has concentrated on physical security and has not paid sufficient attention to the security of electronic access.

■ **The National Weather Service should satisfy itself that the security of its data systems will be adequate to preclude a breakdown of critical services in the event of improper intervention, either intentional or inadvertent, in its data and communications systems.**

The Committee is concerned about the plan to have only one meteorologist on duty during the night shift at each Weather Forecast Office (WFO). The weather is no less life-threatening and damaging at night than during the day and evening. The concept upon which the NWS bases the feasibility of the proposed night shift staffing has not been tested successfully. Therefore, the Committee recommends:[1]

■ **The proposal to produce operational forecasts by computer that are equal to or better than current manually produced forecasts and warnings should be demonstrated for a variety of weather conditions and locations. The new procedures should be operational and their efficacy established before the meteorological staff at a Weather Forecast Office is reduced to the proposed one person on the night shift. An alternate operational plan for staffing the night shift should be formulated for use until the proposed concept has been fully developed and proven.**

The Committee recognizes that many of the suggestions made in this report have a potential impact on the budget for the NWS modernization and associated restructuring. The additional personnel required temporarily to assist in modernization activities could save money in the long term. Although the solution proposed for the problem of limited forecast staff on the night shift at the WFOs may reduce the overall savings visualized from restructuring the NWS until the effectiveness of automation can be demonstrated satisfactorily, the Committee believes that this would be compensated by savings to the

[1] A related recommendation appears in the section on operational staff in Chapter 6.

public and governments from reduced loss of life and destruction of property. The phasing of funds for NOAA satellites to ensure their continuity and for rectifying the current low incremental funding of the Advanced Weather Interactive Processing System program would also require an increase in near-term budgets but would probably reduce the overall cost of implementation.

Although the Committee has not received detailed plans for certification to review, it offers two initial observations. First, specific comparisons of the quantity and quality of weather information, forecasts, warnings, and their prompt dissemination must be obtained, both during the Modernization and Associated Restructuring Demonstration and during the process of certifying the capabilities of any WFO to serve its area of responsibility. The Committee believes that carefully constructed and unbiased comparisons will demonstrate a noteworthy improvement in the quality and accuracy of service. Second, to increase the credibility of the certification process in the eyes of user groups and Congress, it may be appropriate, at some stage, to involve an independent evaluation of the statistical and analytical measures developed during the initial operations of the WFOs as applied to each specific certification.

1

Introduction

BACKGROUND

The United States has launched a bold and innovative program to modernize the National Weather Service (NWS), a major component of the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce. The modernization involves new observational technology, both at the surface and with weather satellites; powerful new information and forecast systems; and a new organizational structure. It promises to provide a dramatic improvement in weather services to the nation, including more accurate and timely predictions of those weather events that have regular and dramatic impact on both private and public activities.

Modernization of the NWS thus offers great opportunities to the nation, but it is also a complex undertaking. The National Research Council's National Weather Service Modernization Committee endorses the organizational approach and implementation philosophy of the NWS, but recognizes the challenges ahead; success will depend on the continuity of strong leadership, of good management, and of adequate resources. Although the Committee is impressed with the progress the NWS has made, it is also cognizant of the commitment required by the federal government, NOAA, and the NWS to complete successfully the modernization and revitalization of the nation's weather services.

BROAD RECOMMENDATIONS

Recommendation: *The success of the National Weather Service modernization requires an increased commitment of resources and personnel to the many scientific, technical, and organizational challenges involved. Parsimony now will be expensive later.*

Recommendation: *The National Weather Service modernization requires the development and implementation of complex observation and information systems. Rigorous and creative management of the overall structure and of the individual components of each of these systems is essential for success. The system management capabilities of the National Weather Service must be strengthened through the commitment of additional resources and personnel.*

Recommendation: *Modernization of the National Weather Service involves a variety of scientific and technical issues and challenges. The National Weather Service and the National Oceanic and Atmospheric Administration should create technical advisory panels for each of the major systems that contribute to the technological modernization. However, these panels cannot substitute for the additional resources and personnel recommended.*

GOALS AND COMPONENTS OF THE MODERNIZATION

In its *Strategic Plan for the Modernization and Associated Restructuring of the National Weather Service*, the Department of Commerce (DOC, 1989) set the following goal:

> "To modernize the NWS through the deployment of proven observational, information processing and communications technologies, and to establish an associated cost effective operational structure. The modernization and associated restructuring of NWS shall assure that the major advances which have been made in our ability to observe and understand the atmosphere are applied to the practical problems of providing weather and hydrologic services to the Nation."

The more specific goals set forth in the *National Implementation Plan for the Modernization and Associated Restructuring of the NWS* (DOC, 1990) are:

- "Operational realization of a predictive warning program focusing on mesoscale meteorology and hydrology;
- "Advancement of the science of meteorology and hydrology;
- "Development of NWS human resources to achieve maximum benefit from recent scientific and technological advances;
- "User acceptance and support of NWS modernization and associated restructuring service improvement objectives;
- "Strengthening cooperation with the mass media, universities, the research community and the private hydrometeorological sector to collectively fulfill the nation's weather information needs from provision of

severe weather warnings and general forecasts for the public as a whole, which is a Government responsibility; to the provision of detailed and customer specific weather information, which is a private sector responsibility;

- "Achievement of productivity gains through automation and replacement of obsolete technological systems; and
- "Operation of the optimum NWS warning and forecast system consistent with service requirements, user acceptability, and affordability."

Since World War II, significant improvements have been made in the prediction of large-scale weather features (high pressure areas, large storms) owing to increased knowledge of atmospheric processes, new observational techniques such as radar and satellites, and the advent of large computers and numerical prediction models. However, improvements in the forecasting and warning of smaller-scale phenomena (hurricanes, severe thunderstorms, tornadoes, flash floods) have been less dramatic. Yet recent scientific advances in the understanding of these phenomena and new capabilities to observe and rapidly process information on these smaller scales (from a few to several hundred miles) now permit a major advance in weather service to the nation.

As a result, the NWS is engaged in a dramatic transformation involving new sources of information about the atmosphere, new ways of employing that information effectively and making it available to a wide community of users, and new ways of providing the forecasts and warnings that will lead to enhanced protection of life and property. This modernization of the NWS offers great opportunity to the nation.

The successful implementation of four key components of the modernization initiative is essential to realize its full potential. Modernization requires:

- more powerful observation technology, including Doppler radar, automatic observing systems, and enhanced satellite systems now being developed, as well as new systems such as wind profilers and a lightning detection network, that together will produce unprecedented, high-resolution, continuing information on the state of the atmosphere;
- more powerful systems and concepts for transmitting this information, converting it into forecasts and warnings, and making timely information about the atmosphere available to a variety of users in the public and private sectors;

- a new organizational structure that enhances the potential for service to the public by taking advantage of the collective skills of a highly trained cadre of professional meteorologists; and
- a new commitment to collaboration with the universities and the private sector in meteorology to enhance the understanding of the atmosphere, along with the development of effective new applications of atmospheric knowledge to ensure the continuing evolution of weather service capabilities in the decades ahead.

The NWS plans for modernization, which are summarized below, provide for all four of these key components.

NEW OBSERVATION SYSTEMS

Next Generation Weather Radar (NEXRAD) units utilize Doppler radar technology to measure the radial wind velocity in severe weather elements such as thunderstorms, to provide improved estimates of precipitation amounts, to detect the transition between rain and snow, and to track storm movement and intensity. The new radars also will allow for earlier detection of the precursors of tornadic activity, thunderstorm development, and other important weather phenomena. The NWS will operate 121 NEXRAD systems, and the FAA and DOD will operate another 39, for a total of 160 systems in a national network. This is a significant improvement in coverage and quality compared to today's radar network, in which most of the units are more than 30 years old. The NEXRAD program is currently in a limited production phase; full-scale production is expected to begin in 1991,[1] with completion of all installations planned for 1995.

Automated Surface Observing System (ASOS) units will be installed initially at more than 1000 locations in the United States in a cooperative program with the Federal Aviation Administration (FAA) and the Department of Defense (DOD). These units will provide surface weather information on a nearly continuous basis and in a uniform manner. The ASOS network will provide the basic data required for severe weather, flash flood, and river forecasting, as well as for support of aviation operations. The automation will free personnel for other activities and allow future expansion of the network at much less cost than presently required with manual observations. The

[1] This and subsequent schedule dates in this chapter are from *The National Implementation Plan for the Modernization and Associated Restructuring of the National Weather Service* (DOC, 1990).

ASOS units now are being produced and installed in the field with completion expected in fiscal year 1995.

Next Generation Geostationary Operational Environmental Satellites (GOES-Next) are under development, with the first launch officially scheduled in 1992. The new GOES will allow atmospheric soundings and cloud images to be obtained simultaneously (only one or the other can be obtained from the current GOES). Both observations will also be of higher quality and resolution. New images can be provided as frequently as every six minutes during severe weather conditions. These advances are very important for improved prediction of severe storms and flash floods.

Recommendation: *Modernization must continue beyond the implementation of systems now being procured. Provision should be made to incorporate data from additional new technology, such as wind profilers and a lightning detection network, and to take advantage of scientific developments as well as improved computational and information systems as they become available.*

NEW INFORMATION SYSTEMS

The Advanced Weather Interactive Processing System (AWIPS) will be the key component of each of the new Weather Forecast Offices (WFOs) and River Forecast Centers (RFCs) of the NWS. The AWIPS unit and its associated communications will be the data integrator at each WFO, receiving high-resolution data from the observation systems; centrally collected data, analyses, and guidance products from the National Meteorological Center (NMC) in Suitland, Maryland; and products from the National Hurricane Center in Miami, Florida, and the National Severe Storms Forecast Center in Kansas City, Missouri. This integrated and continuously updated data base is the source from which all warnings and forecasts issued by the WFO will be prepared. The AWIPS, by providing fast-response interactive data analysis and display, will be the information system used by the meteorologist on duty to prepare warnings and forecasts and to disseminate these products rapidly to the public and other users.

The AWIPS also will include a new communications system to support NWS operations; it will provide for:

- Point-to-multipoint distribution of centrally collected or produced conventional and satellite data, analyses, and guidance products to the WFOs. This function is part of the NOAAPORT data access concept whereby NWS and other NOAA products, including oceanographic and environmental data, will be delivered to external users, both private and public.

- Point-to-point networking of the WFOs, RFCs, National Centers, Automated Surface Observing System, and other observation sites.
- Multipoint-to-point collection at the NMC of the locally produced data and products for use in numerical weather forecasting, international data exchange, and data archiving.

The AWIPS definition phase is drawing to a close; the two-year development phase will start in fiscal year 1992. The deployment phase is expected to begin in fiscal year 1994 and to extend well into the latter half of the decade. The key pacing item for full implementation of the NWS modernization and associated restructuring is AWIPS.

More powerful super computers at the NMC are critical to improving the accuracy of numerical weather forecasts, particularly at the smaller scales of atmospheric motion. Numerical models of the atmosphere must run on large, high-speed computers to have the spatial resolution and timeliness needed in today's weather forecasting. The requirements for computer-generated guidance products in support of forecasting severe storms are significantly increased over those previously needed. For example, a high-resolution model, with a horizontal resolution of 30 km and improved physics, is now being developed that requires a much larger computer capability than the Class VI computers previously used at the NMC for models with a resolution of 85 km. The first Class VII computer was installed at the NMC in 1990. The NWS hopes to obtain budget approval soon for a second super computer at NMC.

NEW STRUCTURE OF THE NATIONAL WEATHER SERVICE

At present the main field forecast offices of the NWS are 52 Weather Service Forecast Offices (WSFOs) whose responsibilities are organized on a geographical basis; in many cases there is one WSFO per state. In addition, there are 197 smaller offices, including Weather Service Offices (WSOs) and Weather Service Meteorological Observatories, that take manual weather observations and, in the case of WSOs, issue local area forecasts and warnings based on the products of the WSFOs. Thirteen River Forecast Centers (RFCs), which primarily provide flood warnings and river stage and water supply forecasts, are located to cover the contiguous 48 states and Alaska. Six RFCs are collocated with WSFOs. The hydrologic forecasts and warnings prepared by the RFCs are disseminated by the WSFOs and selected WSOs. The work of these operational field facilities is supported by the National Meteorological Center, the National Hurricane Center, and the National Severe Storms Forecast Center.

A fundamental change in the structure of the NWS is planned as part of the proposed modernization. There will be 115 Weather Forecast Offices (WFOs) at locations determined primarily by the coverage of Next Generation Weather Radar systems to be installed nearby and not by political (e.g., state) boundaries. All the remaining WSOs and Weather Service Meteorological Observatories, other than those that will be converted to WFOs, will be closed. The observing functions at these WSOs and Weather Service Meteorological Observatories will be automated. The forecast and warning responsibilities of the WSOs to be closed will be assumed by the appropriate WFOs using the improved observation, information processing, and dissemination systems. The NWS expects that services to be provided to areas now covered by WSOs scheduled for closure will be at least as good as those provided today. As at present, the field forecast offices will be supported by the three national centers (National Meteorological Center, National Hurricane Center, and National Severe Storms Forecast Center) and the 13 RFCs. All of the RFCs will be collocated with WFOs.

Concern about possible deterioration in local forecast and warning services with the closing or relocation of many of the existing NWS offices led the U.S. Congress (1988) to include in Public Law 100-685 the provision: "The Secretary [of Commerce] may not close, consolidate, automate, or relocate any [WSO or WSFO] unless the Secretary has certified...that such action will not result in any degradation of weather services provided to the affected area."

NEW AND STRONGER COLLABORATION

The current modernization of the NWS and its continuing improvement in the future are vitally dependent on collaboration with both the university community and the private sector.

Universities are the prime sources of new meteorologists for the NWS and play a key role in training these future meteorologists in the use of new scientific and technological developments. They are also the leading national source of the scientific and technological advances upon which future improvements in NWS services depend. To perform these critical functions, the academic community requires access to data, analysis products, and the technology used in the Weather Forecast Offices (WFOs). To facilitate this collaboration, the NWS is collocating several WFOs with university campuses. The NWS also proposes to increase collaborative development activities; however, so far these activities have not been adequately funded. The NOAA has entered into an agreement with the University Corporation for Atmospheric Research for a Cooperative Program for Operational Meteorology, Education and Training, whose stated purposes are (1) to provide mechanisms

to increase and improve the interactions between the academic and research communities and the operational services; (2) to enhance technology transfer to the operational services; and (3) to enhance the professional development of operational meteorologists, hydrologists, and hydrometeorologists.

The private sector provides much of the new technology now being implemented in the NWS modernization and also contributes to the technological advances on which operational improvements are based. The most important role of the private sector is probably the prompt and wide dissemination of NWS data, products, forecasts, and warnings, particularly to the general public. Although the private sector does provide these services today, it will become even more important in the era of the modernized NWS. Moreover, the new technology being introduced, particularly the Next Generation Weather Radar (NEXRAD) and the Advanced Weather Interactive Processing System, will require new dissemination capabilities. Therefore, the NWS is improving its communication and coordination with the private sector. It has selected three companies to collect and disseminate NEXRAD data. Increased attention to collaboration with the private sector will be required as modernization of the NWS continues.

THE COMMITTEE'S ENDORSEMENT AND INTENT

The Committee on National Weather Service Modernization has examined the plans for these components in some detail, and commends the federal government and the NWS for creating a modernization plan that offers tremendous potential for enhanced service to the nation. The recommendations presented in this report are intended to support that effort; to increase its likelihood of success; and to ensure a continuing evolution of the national capability to enhance understanding of the atmosphere and to combine that knowledge with technological advances so as to ameliorate the effects of weather on both public and private activities.

2

New Observation Systems

The key new observation systems in the NWS modernization are the Next Generation Weather Radar (NEXRAD), the Automated Surface Observing System, and the Next Generation Geostationary Environmental Satellites, which were described briefly in Chapter 1. The following sections contain a preliminary assessment of these systems; the Committee will provide additional assessments as the programs evolve.

Other observational systems may contribute significantly to the modernized NWS. Two particularly important ones for forecasting and warning of severe weather events, because of the high space or time resolution of their observations, are wind profilers and a sferics[1] network for lightning detection and analysis. A network of profilers will be tested during the Modernization and Associated Restructuring Demonstration (MARD) to be conducted in the midwestern United States around 1993. The results of the MARD will contribute to a future decision on operational implementation of profilers in the NWS. A private national lightning network now exists and is used by the NWS under a contract that expires in March 1991. The NWS has initiated a competitive procurement action for the collection of lightning data through the MARD period.

NEXT GENERATION WEATHER RADAR

The first network Next Generation Weather Radar (NEXRAD; technically, the WSR-88D) has been installed near Oklahoma City. Another is located at the NEXRAD Operational Support Facility (OSF) in Norman, Oklahoma and will remain an OSF resource for use in testing, evaluating, and

[1] Sferics refers to a radio direction-finding system used to detect and locate lightning by means of the "atmospherics" (electromagnetic radiation) produced by lightning discharges.

enhancing the NEXRAD system. The rate of installation had been planned to increase gradually to one per month by the end of 1991, then eventually to four per month in 1994. Originally, a period of one year had been planned between installation of the Limited Production Phase radars and initiation of the full production phase, to allow for a thorough and complete operational evaluation. No time is currently available because of slower-than-anticipated progress in the early phases of procurement and software development problems. Thus final testing and evaluation must take place in 1991, just prior to acceptance of the NEXRAD systems at the OSF and Oklahoma City. However, neither the installation of the radar nor the engineering acceptance of the system establishes that it is actually operational in the meteorological sense. That happens, as is the case for all new elements in the NWS modernization, when the radar is operationally ready and is certified to be fully commissioned after training of the local staff.

Status of Major Components of the Next Generation Weather Radar Program

Experience with NEXRAD units suggests that the hardware (transmitter, receiver, signal processor, and antenna) is robust and will prove to be reliable in the long term. There were reports of poor reliability during the NEXRAD Initial Operational Test and Evaluation, Phase II (IOT&E-2) (Air Force Operational Test and Evaluation Center, 1989). Some of this resulted from the fact that no changes, improvements, or fixes to the system were permitted during the approximately five-month IOT&E-2 process. Because of that constraint, repetitive failures of the same nature occurred throughout the process during which corrective actions were not allowed. This is not a criticism of the process, but merely a recognition of the fact that in a normal operational environment, appropriate corrective actions would have been taken and maintenance procedures revised.

The IOT&E-2 process involves independent test and evaluation of the entire NEXRAD system to determine its operational effectiveness and suitability, to identify its deficiencies and enhancements, and to determine which items should be addressed during subsequent tests and evaluation. Following are additional comments based on the IOT&E-2 report regarding functional performance and capability, human engineering, software documentation and maintenance, and training.

In the category of functional performance and capability, significant problems were encountered regarding the ability of the radar to generate automatically critical derived data reliably. These include, for example, effective range unfolding and error-free velocity dealiasing. A software error in the system prevented the range unfolding algorithm from working correctly, and

the algorithm for velocity dealiasing was inadequate. An improved velocity dealiasing algorithm, similar to that being used in the Terminal Doppler Weather Radar application for the FAA, is being installed and the range unfolding software error has been corrected.

It is now likely that a highly reliable algorithm for hail detection and quantitative hail measurement will not be available initially, but research at the National Severe Storms Laboratory of NOAA is expected to produce an improved technique. Also, the National Severe Storms Laboratory is working on an improved mesocyclone detection algorithm.

These problems are not surprising; the development of the NEXRAD system was deficient in not providing for adequate prototype demonstrations in an operational environment similar to the experiments and programs that were undertaken as part of the Terminal Doppler Weather Radar development for the FAA. Nevertheless, the Committee is confident that these deficiencies can be corrected.

Upgrades to the Next Generation Weather Radar Technical Requirements

Another group of comments in the Initial Operational Test and Evaluation, Phase II (IOT&E-2) report dealt with human engineering aspects of the system. Most result from inadequacies in the original NEXRAD Technical Requirements; they can be overcome, either through changes in the NEXRAD prime contract with UNISYS Corporation, or through enhancements developed by the Operational Support Facility (OSF). The IOT&E-2 report included a number of additional recommendations that also extend beyond the scope of the NEXRAD Technical Requirements. About one-half of the recommendations state that the System Requirement Review Board of the NEXRAD Joint System Program Office has referred certain matters to its Service Report Enhancement Committee for recommendations. It is presumably the responsibility of the Service Report Enhancement Committee to provide advice and recommendations regarding changes to system requirements. As mentioned earlier, such changes would have to be implemented either by modification of the contract with UNISYS or by the OSF itself. The Service Report Enhancement Committee is appointed by NOAA, FAA, and the United States Air Force (USAF) to consider these recommendations and advise the NEXRAD Program Council.[1] Presumably the NEXRAD Program

[1] The members of the NEXRAD Program Council are the Assistant Administrator of NOAA for Weather Services, the Commander of the USAF Air Weather Service, and the Deputy Associate Administrator of the FAA for National Airspace System Development.

Council would then direct that specific enhancements, where appropriate, be implemented.

Adequate direction and resources will be required throughout the lifetime of the NEXRAD system to ensure the continuing development and operational implementation of new processing algorithms based on scientific developments and operational experience.

Software documentation and maintenance is another important area. A number of the IOT&E-2 recommendations related to the system's software, its documentation, and its maintenance. Ultimate responsibility for system software maintenance rests with the OSF, and its leadership understands and accepts that responsibility.

Training

Another class of Initial Operational Test and Evaluation, Phase II (IOT&E-2) recommendations concerns training. In response, the NEXRAD Joint System Program Office and the NWS have adopted a revised approach to training NWS personnel. Training for system maintenance will take place in Kansas City, Missouri; training for system operations will take place at the Operational Support Facility (OSF) in Norman, Oklahoma. UNISYS will be responsible only for the initial training of NWS instructors (and perhaps for the first one or two operator courses). The NWS instructors will, in turn, be responsible for training weather service operational and maintenance personnel. It is the Committee's understanding that the NWS instructors were selected carefully. A 14-week software course will be conducted at the OSF; UNISYS is also responsible for this course. UNISYS is currently placing considerable emphasis on its responsibilities for training and documentation, and has appointed new people for these tasks. Thus the training deficiencies identified in the IOT&E-2 report are being addressed. Whether the training will actually be effective is the subject of an evaluation process that will begin soon.

Another issue related to training is continuing education. It appears that the OSF understands and is planning for its responsibilities related to initially training operators of the system and then to providing adequate training on system upgrades and changes as they occur. What is not explicitly included to date relates to procedural revisions. As the system matures, procedures are likely to change from time to time at many of the NEXRAD sites. It is essential that the OSF standardize such changes and apprise operational staff of the most effective procedures for fulfilling its responsibilities. The NWS must develop comprehensive training and education programs such that its mainte-

nance, operational, meteorological and hydrological staffs remain current. This must become part of its ongoing long-range plans.

Outlook and Recommendations

The current state of the development of the NEXRAD hardware is excellent. Its performance, even at this stage, gives great promise of providing a major improvement in forecasts and warnings. However, problems with completion of the operational software continue. As of December 1990, the initial operating capability software is not expected to be available until July 1991. Clearly, results of the definitive engineering tests, system functional evaluations, and system reliability evaluations that remain to be completed will be very important. An essential focus of the test and evaluation phase will be the performance of the software. The Committee cannot judge how well NEXRAD will meet its technical and functional requirements until this phase has been completed.

Recommendation: *Steps should be taken to ensure the continued development and improvement of Next Generation Weather Radar processing algorithms as new developments and operational experience accumulate.*

Recommendation: *The National Weather Service should develop a continuing comprehensive training and education program so that the skills of the Next Generation Weather Radar maintenance and operational staffs, as well as the meteorologists and hydrologists, reflect the ever-changing state of the art.*

AUTOMATED SURFACE OBSERVING SYSTEM

The Committee does not have any specific comments at this time regarding the status of the development and installation of Automated Surface Observing System (ASOS) units in the NWS modernization. Although the ASOS offers some clear advantages over the present surface observation method in operational weather forecasting and warning, serious concerns exist about its accuracy, representativeness, and system performance. The Committee is also concerned about the quality and appropriateness of the ASOS data in terms of continuing the climate record and monitoring climate change. This aspect is discussed in the last section of this chapter. Finally, NOAA has not addressed the need to augment ASOS data to maintain the climate data record.

Need for Use of Adjunct Sources of Surface Observations

The ASOS network of surface reporting stations will substantially increase the spatial resolution of the current surface reporting network, but even greater resolution will be needed for additional improvement in small-scale numerical forecast models (30 km horizontal resolution) being introduced by the National Meteorological Center. Although the observational resolution of Next Generation Weather Radar, the Next Generation Geostationary Operational Environmental Satellites, and NOAA (polar orbiting) satellites is compatible with these models, quantitative surface observations are also required. Therefore, an era is beginning in which local and state observations (e.g., the Illinois State Water Survey network or the Oklahoma Climate Survey network) will become increasingly important as a cost-efficient means of improving forecasts and warnings of small-scale weather events. Also, the use of these data to verify high-resolution forecasts undoubtedly will contribute to even further improvements as systematic model errors and errors from highly localized effects are uncovered and corrected.

Recommendation: *The National Weather Service should identify other local and state surface observation resources; assess their quality and utility for operational use as adjunct data; prepare a national summary of the nation's high-resolution observing capabilities; assess the cost of acquiring and upgrading the nation's high-resolution surface observing capabilities; initiate efforts to acquire existing data and, as feasible, to improve the quality and quantity of the data; and promote the development and installation of additional local and state networks in data-sparse regions.*

ENVIRONMENTAL SATELLITES

The Next Generation Geostationary Operational Environmental Satellites (GOES-Next) will play a particularly important role in continuously monitoring clouds and weather systems from above and increasing the number of measurements of free atmosphere winds, temperature, and humidity, thus contributing to the improved small-scale, short-period forecasting and warning that is the primary focus of the NWS modernization and associated restructuring. Improvements now being developed in the free atmosphere temperature and humidity soundings acquired by NOAA polar orbiting satellites will also contribute to improved longer-range numerical forecasts.

However, these developments are in the future. Today the nation has inadequate weather-observing satellites in orbit or available for launch to guard against the loss of satellite information owing to launch failure or delays

in the construction of additional spacecraft. The GOES system now has only one satellite in orbit rather than the two required to fully cover the United States and adjacent ocean areas. This results from a launch failure at a critical time (GOES G in May 1986), as well as continued delays in the development of the GOES-Next spacecraft (GOES I through M).[1] Although GOES 7 (launched in February 1987) is operating well, it will be five years old before the earliest first launch of the new series, GOES I, in 1992. The NOAA polar satellite system is in better condition with satellites in orbit, but continued funding constraints have forced delays in the availability of replacement satellites that certainly will be needed in the future.

The GOES-Next delays resulted from serious problems in the development of two new instruments, a cloud imager and an atmospheric sounder, by ITT Corporation-Fort Wayne under a subcontract from the prime contractor, Ford Aerospace Corporation. Fortunately, development by Ford of the remaining parts of the spacecraft has gone well, but integration and testing can only proceed so far before the instruments being built by ITT are required. The delays have caused a major overrun in the Ford Aerospace prime contract to produce and test the satellites. The contract is being managed by Goddard Space Flight Center of the National Aeronautics and Space Administration (NASA) for NOAA, and all funds come from NOAA. Although NASA believes that the worst of the development problems have been solved and the principal task now is to keep instrument assembly and test efforts on schedule, the same confidence has been expressed in the past and unexpected difficulties have suddenly appeared, forcing additional schedule slippage.

The overrun situation plus the limitations in funds available to NOAA in the past have resulted in stop work and slow orders on GOES K, L, and M. As a result, the Committee is concerned that reestablishment of the full two-GOES constellation may not take place until mid-1994 or later, should there be a launch or spacecraft failure with GOES I or J. Because the NWS modernization program depends on the GOES-Next satellites, along with the Next Generation Weather Radar, the Automated Surface Observing System, and the Advanced Weather Interactive Processing System, the fragility of the GOES program has the potential to delay the schedule for completion of the full modernization and restructuring.

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[1] The spacecraft are designated serially by letter before launch; after successful launch into orbit, the letter is changed to a number representing the new satellite's position in the sequence of successful launches of that particular series of satellites (e.g., GOES H became GOES 7 after its successful launch).

The NOAA polar orbiting satellite system is in better technical condition than the GOES system. However, funding constraints in the polar program also threaten continuity problems in the event of launch or premature satellite failure. It also should be noted that NASA now procures commercial launch services on behalf of NOAA, not just launch vehicles as in the past. This means that launch schedules will be far more difficult to change due to the requirements of other users of the launch services, which will make quick replacement of failed satellites even more difficult than before.

Recommendation: *The National Oceanic and Atmospheric Administration, the Department of Commerce, the Office of Management and Budget, and the Congress should provide more realistic budgeting and funding for the National Oceanic and Atmospheric Administration's operational satellite systems in order to realize the full potential benefits of the National Weather Service modernization and associated restructuring.*

VIABILITY AND INTEGRITY OF THE CLIMATE DATA RECORD

The nation's climate record is a valuable resource whose viability must be maintained. Climate information is used in a variety of analyses and applications of economic value and importance to safety. These include the design of structures, drought assessments, agricultural planning and assessment, and water management. The possibility of climate change as a result of human activity over the coming decades is another application; observational strategies and capabilities must be developed that will provide a data record from which regional and global climate trends can be determined unambiguously. The requirements for these data have been considered by several national and international organizations (for example, see NRC, 1990b), and data programs are being planned or enhanced by a number of U.S. agencies (Committee on Earth Sciences, 1990).

Climate data come from many governmental and nongovernmental sources; however, the NWS is the primary organization engaged in observing and recording in situ weather information in the United States. It must ensure the accuracy and integrity of the weather information it gathers to fulfill its operational requirements; however, the Committee is concerned about the adequacy of NWS data to meet NOAA's climate requirements. The NOAA (which includes the National Environmental Satellite, Data, and Information Service as well as the NWS) is responsible for the acquisition, integrity, storage, and timely availability of the weather and climate data it

acquires, as well as a substantial amount of such data from other federal agencies and other nations.

Modernization and restructuring of the NWS will affect the viability and integrity of the U.S. climate data record, but it will also provide the opportunity to enhance this record significantly through new kinds of data not formerly available. For example, Next Generation Weather Radar data can be used to derive improved estimates of time-integrated precipitation over most of the United States, an important climatological parameter. Also, the wind profiler data, because of the high frequency of observation, could provide new information on wind spectra. These and other opportunities to enhance the climate record should be examined by NOAA.

The most direct impacts of the NWS modernization and restructuring will arise from changes in observing locations and instrumentation. Changes of observing locations generally induce changes in climate statistics that are larger than those arising from climate variability. Changes in instrumentation pose problems of consistency and accurate calibration between old and new sensors. In the case of automated remote measurements, these problems include the lack of manual supervision of equipment, as well as the lack of direct viewing of weather events that are an integral part of the climate record such as statistics regarding summertime convection, distant thunderstorms, lightning, virga, and variable sky conditions.

Because the NWS has traditionally viewed its role as collecting observed data primarily to prepare forecasts and warnings, data quality has been determined largely by these needs. However, the accuracy, continuity, and consistency required of observed data may depend on whether the data are to be used in forecasting or climate research. For example, a slight shift in the location of a thermometer will have little effect on weather forecasts but often produces a noticeable discontinuity in average temperatures at a station, which clearly makes determining climate trends difficult.

Given the evident need for high-quality data for climate studies and applications, the Committee argues that the NWS must be concerned that its data satisfy the needs for consistent climate records as well as for forecasting. The record should be as free as possible from avoidable bias. The slight additional costs are more than justified by the importance of the climate-related policy issues that the nation will face. Because NWS modernization plans give little attention to the issues of data management and the quality of the climate record, the Committee recommends the following:

Recommendation: *The National Oceanic and Atmospheric Administration should set the requirements for the climate data to be derived*

from the modernized National Weather Service observations, establish the role of the National Weather Service in generating these data, and ensure the availability of the resources necessary for this purpose. The National Weather Service at all levels should recognize its responsibility to acquire a major portion of the national climate record; the preservation of data quality for climatic purposes should have equal priority with its mission of providing forecasts.

Recommendation: *Criteria for the accuracy of the various data collection systems should be selected carefully with attention both to the needs of the National Weather Service and to the quality of the climate record. Limits on both random and bias errors for data systems should be determined by the requirements of science rather than by the technology of the measurement.*

Recommendation: *When new instruments are brought into operation, there should be proof that their observations are within well-defined limits of the observations over the range of the record provided by the instruments they replace. This will require that new and old systems be operated simultaneously in an operational environment, for at least one year, at many locations around the country. Ideally, this simultaneous operation should occur at every site where new equipment is installed. If the new equipment does not meet the requirements that ensure the integrity and viability of the climate record, then the National Weather Service must be prepared to modify it or find an alternative.*

Recommendation: *When instrument sites are changed, simultaneous operation at the old and new sites should occur until adequate statistics on the difference of observations between sites can be developed. These statistics should be recorded carefully and made readily available.*

Recommendation: *Authority should be given to an individual or individuals at each site to question the accuracy of any observation system, and allowance should be made for that individual or those individuals to study the problem and recommend changes. The National Weather Service and its reward system should encourage individuals to ensure continuously the accuracy of data collection systems and of the climate record.*

Recommendation: *The National Weather Service should establish a network of observation stations in natural and undeveloped areas with the sole aim of acquiring baseline data for a long-term climate record. Consistency of the record over long periods should be the first priority. Areas in which these stations are located must remain*

natural and undeveloped; national parks would be candidate sites. This network will fit within the current Automated Surface Observing System program with only modest additional cost.

The Committee plans to continue its examination of the NWS modernization as it relates to the climate record to help ensure a positive impact on that record.

3

New Information Systems

Improved information systems are critical to the NWS modernization and associated restructuring. The key component of each modernized Weather Forecast Office (WFO) will be the Advanced Weather Interactive Processing System (AWIPS) supported by a new communications system that includes the NOAAPORT data access concept. Improved numerical forecast and guidance products, with higher space and time resolution, are required by the WFOs to improve their forecasts and warnings of small-scale weather features. In turn, these improvements necessitate enhanced computer capability and refined atmospheric models at the National Meteorological Center.

ADVANCED WEATHER INTERACTIVE PROCESSING SYSTEM

Extended developmental work by the Program for Regional Observing and Forecasting Services of the NOAA Environmental Research Laboratories in collaboration with the NWS has created the foundation for the AWIPS system. The Program for Regional Observing and Forecasting Services developed the Denver AWIPS Risk Reduction and Requirements Evaluation (DAR^3E) system as an experimental prototype of AWIPS. DAR^3E units are now operating at the Weather Service Forecast Offices in Denver, Colorado and Norman, Oklahoma. The Committee was very impressed with the capabilities, versatility, and "user-friendliness" of the DAR^3E system and has a favorable impression about the equipment, the system, and the personnel developing it. The Environmental Research Laboratories and NWS personnel devoted 10 years to planning, developing, and testing prototypes and appear to have thought through all of the necessary procedures and potential problems. If unforseen problems are encountered, the personnel involved can be expected to resolve them.

The experience of the Program for Regional Observing and Forecasting Services and DAR^{3}E has provided an excellent basis for proceeding with AWIPS. The definition phase of the AWIPS development, involving two competing contractors, is drawing to a close. The Committee is pleased that AWIPS will use "off-the-shelf" hardware components and, wherever possible, a standard operating system and programming languages. This will facilitate the maintenance and future evolution of AWIPS. The two-year developmental phase with a single contractor is scheduled to begin early in fiscal year 1992.

Attention must now turn to providing adequate access by private meteorologists and weather services, and by universities to raw data and information from AWIPS. In the case of private weather services, raw data are often needed to generate unconventional but highly useful information and products. Universities provide a large pool of creative talent to derive new products and techniques, but they also require raw data to do so. Costs may be incurred in providing these data to the university community, but the returns will eclipse these costs as new information is produced.

Recommendation: *The National Weather Service, in consort with the university community and private sector users of National Weather Service data and information, should develop viable plans for broad access to the raw data and information that will become available via the Advanced Weather Interactive Processing System, keeping in mind the benefits such collaboration can provide to the government, the public, and the private sector.*

The Committee is favorably impressed with the prototypes of AWIPS and the capabilities that are afforded to meteorologists and hydrologists in producing warnings and forecasts. However, it is concerned with the steady slippage of the schedule for full implementation. This has resulted in a two-phased approach. The AWIPS is essential to the conduct of the Modernization and Associated Restructuring Demonstration. Also, without this system, Weather Forecast Offices will be unable to use the new observational technology in an effective manner or to reduce staff through restructuring while increasing service effectiveness.

Recommendation: *The Administration and Congress should take the necessary steps to maintain the implementation schedule for the Advanced Weather Interactive Processing System and its associated communications.*

SUPER COMPUTERS AT THE NATIONAL METEOROLOGICAL CENTER

To achieve the primary objective of modernization, Weather Forecast Offices will need numerical weather forecasts and guidance products from the National Meteorological Center (NMC) that have a higher space and time resolution than those now available. The first new Class VII super computer has been installed at the NMC, and an improved small-scale atmospheric computer model with a horizontal resolution of 30 km and improved physics is being developed. Funds are being requested beginning in fiscal year 1992 for a second super computer to facilitate production of more accurate numerical forecasts of smaller-scale weather elements and to provide increased reliability through backup of the most important processing. Greater sophistication in understanding the atmosphere, which will lead to improved, more complex models, and the rapidly growing volume of observations mandate the acquisition of the most advanced computational capability to realize additional forecasting improvements. Thus, computational facilities must be continuously improved.

4

New Structure of the National Weather Service

A major purpose of the NWS modernization is to improve dramatically the short-term forecasts of significant weather events and warnings of severe weather. The new observation and information systems will not merely replace antiquated equipment but, rather, will provide new insights into the evolution of small-scale atmospheric systems, as well as provide longer lead times and precision in forecasting small-scale, short-duration weather events. Details about the weather that have been lost between stations on the conventional weather map will now be as visible as the large-scale weather systems observed since the days of Benjamin Franklin. Moreover a 12- to 24-hour forecast of convective weather somewhere in a region, can be updated with observations and forecasts of precise locations, intensities, and life cycles of specific weather phenomena with lead times of 30 minutes to six hours. To achieve this aim, meteorologists and hydrologists must be able to observe their service domains continuously and must have a workload commensurate with the area covered, the short response time necessary for effective warning, and the effective range of available observations (e.g., Next Generation Weather Radar). These human factors must be paramount in evaluating field service structures proposed for the modernized NWS.

WEATHER FORECAST OFFICES

The Committee has examined the various configurations of the Weather Forecast Office (WFO) network that have been considered and endorses the network of 115 WFOs proposed in the strategic plan (DOC, 1989). The area of forecasting and warning responsibility for each WFO within a 115-station network appears to be a reasonable compromise. This network configuration will be validated by the Modernization and Associated Restructuring Demonstration (MARD) to be conducted for one year in the midwestern United

States around 1993, a schedule that is in jeopardy because of continued delays in implementation of the Advanced Weather Interactive Processing System as discussed in Chapter 3. However, the Committee is very concerned about a report that the Department of Commerce has decided to modify the MARD to test the efficacy of a "two-tiered" network having about one-half as many WFOs as now planned while maintaining the current proposed network of 115 Next Generation Weather Radar (NEXRAD) units.

Attempting to double the area covered by each WFO without a proportional increase in staff on shift could seriously jeopardize the ability of each WFO to deal effectively with small-scale weather events in the issuance of forecasts and warnings over such a large area. The Committee believes that a significant reduction in the total number of shift meteorologists will not be feasible until there are major advances in the quality and accuracy of small-scale numerical prediction models. Moreover, coordination of warnings with state and local government would also be degraded by doubling the area of responsibility for each WFO.[1] Furthermore, the 115-station WFO network configuration coincides with the expected effective coverage of the new NEXRADs, which has a radius of around 200 km from each unit. Thus, each WFO can be located at or very near its associated NEXRAD system to take maximum advantage of high-resolution Doppler radar data for severe storm forecasts and warnings without the cost and complexity of relaying and remotely processing all of the data produced by each NEXRAD. The planned NEXRAD network (Figure 1) will provide nearly total coverage of the coterminous United States, except for some gaps in the western United States where mountains block the radar signal. (Additional units will be installed in Alaska, Hawaii, and Puerto Rico.)

In the two-tiered network alternative (about 50 WFOs and 115 NEXRADs) proposed by the Department of Commerce for testing in the MARD, the Committee understands that those NEXRAD locations that are not also WFOs would perform radar observation functions and issue warnings. If the staff at the NEXRAD-only offices does not include meteorologists on each shift to utilize fully the new technology being introduced in modernization, there is a danger that these offices will not be able to produce warnings and local forecasts of the requisite quality. The certification process (see Chapter 6) requires that the quality of the forecasts and warnings for all areas of the United States, regardless of distance from a weather office, be at least as high as today even though the number of offices will be cut in half. To achieve this level of performance, the quality of the output of each office after the restructuring must be substantially increased to compensate for the reduc-

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[1] See also discussion and recommendation in the section on public institutions in Chapter 5.

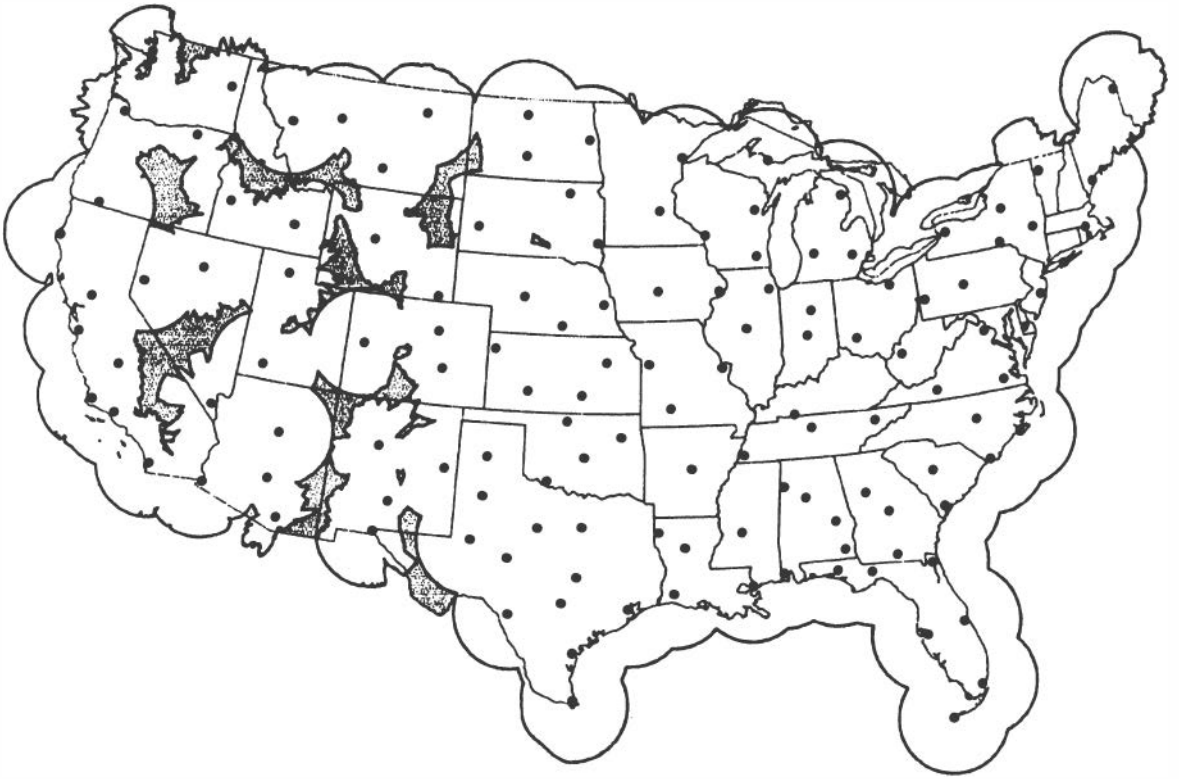

FIGURE 1 Locations and total coverage (at 3,000 m elevation) of the national NEXRAD network. Shaded areas represent gaps, mostly in mountainous areas, in NEXRAD coverage. (Reprinted with permission of the National Weather Service.)

tion in the number of offices. Limited staffing places this requirement in jeopardy.

Conduct of the proposed test of the two-tier concept clearly would delay the MARD and add major complexities to an already difficult demonstration. For example, proper design of the demonstration would require isolating the personnel operating one kind of network being tested from those operating the other network so that the output of one would not influence the output of the other. Also, erroneous conclusions may be drawn from extrapolation of the MARD results to other geographic regions and time periods. Moreover, a two-tier test would surely increase significantly the difficulties involved in using the MARD results in the certification process required by Congress. Finally, the need to transmit the full-resolution data from two or three remote NEXRADs to a WFO and to merge these data in "real time" for use by meteorologists, although technically feasible, would add significantly to the complexity, cost, and the time required to implement both the MARD and, subsequently, the entire modernization.

Recommendation: *The Department of Commerce should carefully reconsider its decision to have the National Oceanic and Atmospheric Administration/National Weather Service conduct a two-tiered Modernization and Associated Restructuring Demonstration because a configuration of significantly fewer than 115 Weather Forecast Offices will lead to serious degradation of weather services. Moreover, such an experiment would be much more complex and expensive, and would probably lead to a serious delay in the National Weather Service modernization.*

HYDROLOGY IN THE NATIONAL WEATHER SERVICE MODERNIZATION

The nation's need for improved management of water resources and more accurate flood forecasting will increase during the 1990s. Growth in population in the arid western United States and increasing sensitivity in all parts of the country to precipitation anomalies will result in demands on the NWS for more detailed and more timely hydrological forecasts.

Modernization of the NWS presents two opportunities for improving hydrological services: (1) The detailed quantitative precipitation measurements and forecasts that will become available through new observational technology and forecasting capabilities will significantly improve both flash flood prediction and regional runoff estimates that will also impact forecasts for larger basins. (2) The development of new forecast techniques and more

powerful communications systems will promote better cooperation between the meteorologists producing forecasts and hydrologists than now exists, a deficiency highlighted by the executive summary of *Hydrometeorological Service Operations for the 1990's* (NWS Office of Hydrology, 1989).

Each of the 13 River Forecast Centers (RFCs) will be collocated with a WFO after the NWS modernization is completed. Thus the Committee anticipates that proper integration of the new developments in hydrological science and practice (NRC, 1991) and the capabilities being created by the modernization of NWS operations could provide greatly improved hydrological services on all time scales.

Interaction of Weather Forecast Offices and River Forecast Centers

Forecasting the effects of extensive and persistent rainfall associated with large-scale weather systems requires strong collaboration between Weather Forecast Office (WFO) meteorologists and RFC hydrologists. Currently, RFC hydrologists use the temperature and Quantitative Precipitation Forecasts produced by meteorologists in the Weather Service Forecast Offices to prepare hydrological forecasts. The improved numerical weather prediction guidance expected in the 1990s should result in better utilization of Quantitative Precipitation Forecasts and temperature forecasts by hydrologists, thereby improving the quality of hydrological forecast services.

Recommendation: *Incorporation of improved Quantitative Precipitation Forecasts and associated uncertainties into the hydrologic models for short-range and long-term stream-flow forecasts is essential and requires collaborative scientific investigation by the National Weather Service and the academic community.*

Cross-training of both meteorologists and hydrologists will help to ensure optimum collaboration between RFC and WFO personnel during the preparation of hydrological forecasts. The present lack of training in hydrology for meteorologists and the equivalent lack of meteorological training for hydrologists have impeded collaboration. The planned assignment of cross-trained Hydrometeorological Analysis and Support personnel to RFCs and of hydrometeorologists to many WFOs should promote this much needed interaction.

Recommendation: *Training programs in meteorological practices for Hydrometeorological Analysis and Support hydrologists and in*

hydrology for meteorologists should be established to promote maximum interaction between Weather Forecast Office and River Forecast Center operational personnel.

Under the existing infrastructure of academic meteorology and hydrology programs, the development of a hydrometeorology track seems difficult. Perhaps the NWS can request that a group of universities investigate this issue further and recommend ways to implement the academic training of hydrometeorologists.

The interaction in the 1990s of WFO meteorologists and RFC personnel during rapidly developing situations, such as flash flood events, is less clear. Meteorologists are responsible for issuing flash flood warnings; this is usually done without hydrological input. Yet the hydrologist has important knowledge of river basins and the effect that given rainfall intensities have on basin runoff. Modernization of the NWS should facilitate interactions between RFC and WFO personnel during these rapidly developing situations. The result will be improved weather and hydrological flash flood forecasts.

Recommendation: *Hydrometeorological Analysis and Support functions at River Forecast Centers and the interaction of Hydrometeorological Analysis and Support personnel with Weather Forecast Office meteorologists require clarification and better definition, especially as they relate to flash flood situations.*

New techniques are emerging that can improve flood forecasting in small basins. However, NWS professionals must have the knowledge and tools to take advantage of this capability. For example, in addition to developing expert systems to select proper algorithms for converting Next Generation Weather Radar information to rainfall amounts, the opportunity now exists to use first principles and actually calculate the rainfall intensity based on divergence measurements. Such calculations, using radar and other data, can validate the use of a particular algorithm.

Current efforts to develop a hydrological computer work station are commendable and should be continued. This work station will be helpful to the WFO meteorologists as well as hydrologists. The software being developed by hydrologists will permit more efficient integration of hydrological observations (e.g., river and stream gauge data) and the meteorological data needed to produce better and more timely flash flood forecasts. However, development of the hydrological work station does not now seem to take into account the planned relationship of Hydrometeorological Analysis and Support person-

nel and WFO meteorologists. Meteorologists as well as hydrologists should be involved in this development work.

Recommendation: *Consultation with meteorologists should be included in the current and future development of software to be used at hydrological computer work stations. This software should be installed in all of the Advanced Weather Interactive Processing System work stations at the River Forecast Centers and Weather Forecast Offices so that it is accessible to all of the meteorologists, hydrometeorologists, and hydrologists.*

The improvements in both small-scale weather forecasts and hydrological basin models expected in the 1990s should result in improved anticipation of when and where flash floods will occur. This, in turn, should result in more time being available for interaction between shift meteorologist and hydrologist and longer warning lead times for the public.

Problem Areas

The anticipated needs for hydrological services in the 1990s mandate a major increase in hydrological observations. At present there are about 3000 stream gauge sites in the United States. According to members of the NWS Office of Hydrology, this is an order of magnitude lower than necessary. Meteorologists and hydrologists can only speculate what is occurring in areas devoid of gauges. The NWS modernization may mitigate inadequacies in gauge data to some extent by use of Next Generation Weather Radar (NEXRAD) and satellite observations. Current plans call for River Forecast Center (RFC) personnel to combine radar observations from multiple NEXRADs, using Advanced Weather Interactive Processing System facilities, to infer precipitation rates and accumulations. However, there is concern that the same general algorithms for estimating rainfall may not be applicable at all NEXRAD locations. These plans also raise the question of whether RFC staffing patterns will accommodate this increase in workload.

Recommendation: *The validity of using the same general Next Generation Weather Radar algorithms for determination of rainfall estimates in all seasons, in all weather conditions, and at all Next Generation Weather Radar locations should be tested.*

Because of the large number of Weather Forecast Offices (WFOs) in each RFC area of responsibility, coordination will be required to ensure consistency in the forecasts of precipitation and temperature that the RFC uses. Careful plans must be developed to ensure that improved numerical weather prediction guidance, observations, and interaction of WFO meteorologists and RFC personnel will address this problem as reorganization of the NWS proceeds.

The anticipated workloads of Hydrometeorological Analysis and Support personnel at the RFCs may be more than they can accommodate. The interaction and shared responsibilities with WFO meteorologists require clearer definition. Cross-training and full mutual appreciation of the functions and responsibilities of Hydrometeorological Analysis and Support and WFO meteorological personnel are needed to ensure optimum collaboration. Adequate training of meteorologists in hydrology and RFC personnel in meteorology is thus a major prerequisite to improved hydrological-related watches, warnings, and services in the 1990s.

Recommendation: *In light of the National Weather Service modernization and restructuring, the workloads, responsibilities, interactions, and cross-training of meteorological, hydrometeorological, and hydrological personnel planned for Weather Forecast Offices and River Forecast Centers should be examined carefully and redefined.*

5

New And Stronger Collaboration

Collaboration of the NWS with the academic community, the private sector, and public institutions is essential if the NWS is going to accomplish its mission successfully. Universities supply trained personnel for the NWS and develop much of the new scientific and technological foundation for improving forecasts and warnings. The private sector, through television, radio, and newspapers, is the primary means for the NWS to disseminate its warnings and forecasts. The private sector also provides much of the new technology used by the NWS and a wide variety of additional specialized meteorological and hydrological services that are outside the mission of the NWS. In the public sector, state and local government agencies are the critical link for the community action necessary when the NWS issues warnings of severe storms or floods and forecasts of snow storms or other hazardous weather phenomena.

Strong and effective collaboration between the NWS and these three communities is necessary for the NWS to accomplish its mission, "to provide weather and flood warnings [and] public forecasts...primarily for the protection of life and property" (DOC, 1989, page 2), as well as to improve its services. Thus planning and fostering these collaborations must be an important part of the NWS modernization. The importance that NWS places on this collaboration is reflected in one of its goals for the modernization (DOC, 1990, page 7): "Strengthening cooperation with the mass media, universities, the research community, and the private hydrometeorological sector to collectively fulfill the nation's weather information needs from provision of severe weather warnings and general forecasts for the public as a whole, which is a Government responsibility; to provision of detailed and customer specific weather information, which is a private sector responsibility."

UNIVERSITIES

The success of the NWS in accomplishing its mission depends on the effective integration of the skills and knowledge of its meteorologists, on employing advancing technology for observing the atmosphere, on continued improvement in its systems for transmitting information and creating numerical simulations and forecasts of atmospheric behavior, and on effective utilization of new and basic scientific understanding of the atmosphere.

Clearly then, the effectiveness of the NWS is dependent on education, on technological development, and on scientific advances. For example, the cloud imaging and atmospheric sounding sensor used on the present Geostationary Operational Environmental Satellite was conceived by a professor at the University of Wisconsin. Thus the Committee believes that the federal government must take a new view of the relationship among NOAA, the NWS, and the atmospheric sciences community, especially in the universities.

It is evident that universities are the sources of the professional employees of the NWS and of much of the research on which current operations are based. Yet the NWS does not have strong ties with the academic community. Most significantly, the vast majority of research and development funded by NOAA and the NWS is performed by in-house organizations and laboratories. In this arrangement, students and university researchers are not stimulated by the most pressing or most interesting NWS scientific issues and opportunities. The NOAA and the NWS are remote from the academic community and are not adequately perceived as presenting scientifically exciting opportunities for young meteorologists. Neither organization receives the stimulation and advice that would flow if it were in more intimate contact with university researchers.

The Committee believes, therefore, that an important new component of the modernization of the NWS should be a strong commitment by NWS and NOAA to strengthen their research partnership with the academic community. Some components of NOAA have very effective cooperative institutes on university campuses, staffed by NOAA and academic personnel; however, the NWS has none. Even though the NWS is a mission agency, its success depends on scientific advances and it should participate more broadly in development of the national scientific base in atmospheric and hydrologic sciences. Increased collaborative research is necessary to realize the full benefits of the modernization, for example, by developing the scientific basis for improved numerical prediction models of small-scale atmospheric phenomena. Plans for the proposed national Stormscale Operational and Research Meteorology (STORM) program are directed toward improving the understanding and prediction of these phenomena. Recent recommendations

regarding this program are contained in the report *Advancing the Understanding and Forecasting of Mesoscale Weather in the United States* (NRC, 1990a).

The relocation of Weather Forecast Offices (WFOs) provides another important opportunity for enhanced collaboration. The Committee agrees with the NWS intent to collocate, to the extent possible, WFOs with universities offering undergraduate and graduate education in meteorology. Such collocation, preferably in intimate proximity to atmospheric science departments, would enable students and faculty to be aware of NWS issues and opportunities, and would provide both motivation and opportunity for NWS meteorologists to continue their studies and to seek advanced degrees. Study of the new data made available by the modernization undoubtedly will result in scientific advances which, in turn, will lead to better forecasts and warnings. Unfortunately, NWS efforts to implement this ideal situation are being impeded by lack of a high-level federal policy on collocation and by ponderous procurement procedures that delay and mitigate against the necessary commitments.

Recommendation: *The Administration and Congress should adopt a policy that fosters the collocation of as many Weather Forecast Offices as possible on university campuses with atmospheric science departments.*

The Committee believes that more intimate and effective collaboration between the NWS and the universities in education and research would greatly benefit both parties and the nation. It would help to maintain the momentum of the present modernization initiative and lead to a greater involvement of the academic community in the success of the NWS.

Recommendation: *The National Oceanic and Atmospheric Administration and the National Weather Service should implement enhanced collaboration with universities in the atmospheric and hydrologic sciences, in both education and research.*

PRIVATE SECTOR

Mass Media

The only federally operated facility that broadcasts forecasts and warnings directly to the public is the NOAA Weather Radio network. Thus, the

primary sources of weather information for the general public, including forecasts and warnings, are the mass media: television, radio, and newspapers. Clearly, maintaining effective collaboration with the mass media is crucial. The *National Implementation Plan for the Modernization and Associated Restructuring of the National Weather Service* (DOC, 1990, page 1) states: "The NWS will continue to rely on the mass media as its major method of dissemination of weather and flood warnings and forecasts to the public."

Any inadvertent actions that were to impair the linkages between the NWS and the media would have serious impacts on the safety and well-being of the populace and on the commercial sector as well.

Private Weather Services

Private weather services provide a major interface between the NWS and the general public or other elements of the private sector. There are a few hundred such services in the United States, most of which are very small and provide specialized services, usually in a local area. The several large organizations that exist generally provide a larger variety of services nationally or even worldwide (e.g., weather or ocean forecasts in support of optimum ship routing, weather forecasts for aviation, or crop-weather information in support of agricultural operations).

The value-added services that the private meteorological community should continue to provide include

- generating data and information (forecasts and analyses) based on output from the NWS, usually collated and reformatted for clarity and convenience of use, and redistributing the resulting products to a variety of users ranging from large media organizations to individual subscribers;
- compiling and reorganizing NWS data into tailored regional or local information products for the media;
- utilizing NWS data to make specialized, highly detailed, or locally oriented forecasts for operational use by such entities as municipalities, utilities, industrial plants, agribusiness, marine and air transportation, and general aviation;
- generating and maintaining a database of observations and analyses acquired in real time from the NWS, often correcting errors in content and format, to provide the data to consumers in a more utilitarian mode than may be available directly from NOAA; and
- advising individuals or organizations, either to clarify weather information received from any source or to provide more depth, detail, or alternative

opinions regarding the information itself or its implications for a particular customer's activities.

The NWS modernization plan appropriately recognizes the contributions and responsibilities of the private sector. It mandates that meteorological data and information products be available to the private sector. The general information content now available on the "Family of Services," the principal real-time data and information transmission link today from the NWS to the private sector, will be incorporated into the NOAAPORT broadcast; however, a much larger volume of data will be involved. A detailed and definitive description of how the NWS communication system will function and evolve until the completion of modernization should be developed in collaboration with representatives of the user community.

Recommendation: *The National Weather Service should develop detailed plans for evolution of the communication of data and products to the private sector (including the academic community) during modernization; such planning should be undertaken in collaboration with the user communities.*

Outlook

The Omnibus Budget Reconciliation Act passed in October 1990, authorizes NOAA to sell its data, information, and products at fair market prices, rather than for only the added cost of provision as in the past. The Act calls for the collection of fees NOAA-wide not exceeding $2 million in each of fiscal years 1991 to 1993 and $3 million in 1994 and 1995. Certain products can be excluded from added fees, such as warnings and watches, exchanges under international agreements, and those for noncommercial use of government and nonprofit institutions. The NOAA is conducting a market analysis for a wide variety of its outputs that appear to have commercial value, to provide a basis for setting their cost. The proposed fee structure will be published in the *Federal Register*; 30 days will be allowed for comments prior to implementation.

The Committee is concerned that a significant increase in fees could put vital NWS weather information beyond the financial reach of the majority of private weather organizations, potentially resulting in a significant loss of quality, service, and economic utility to the ultimate user and the public at large. This may vitiate the policy that the private sector should be the primary means for disseminating official forecasts to the public and for providing all specialized weather services (many formerly provided by the government).

Recommendation: *The Department of Commerce, in implementing the law to increase payments of user fees, should consult with the affected user community to minimize the impact such increases will have on the vital weather services of this nation.*

The NWS Constituent Affairs Officer in the NOAA Office of Legislative Affairs has been serving as the primary point of contact for consultation and coordination with the private sector on matters of mutual interest or concern, such as the issue of user fees discussed above. In recent years, this function has been handled commendably by the Constituent Affairs Officer. However, with the growing complexity of the NWS systems and the increasing amount of legislation impinging on collaboration with the private sector, a strengthening of the office appears necessary.

Recommendation: *To ensure that the association between the National Weather Service and the private sector functions smoothly and efficiently to the best advantage of all parties, including the general public, the constituent affairs activities of the National Weather Service should be strengthened; the Constituent Affairs Officer should act as an ombudsman for the private sector to the Assistant Administrator of the National Oceanic and Atmospheric Administration for Weather Services, coordinate program changes with the private sector, obtain its inputs to National Weather Service planning and evaluation, and arbitrate or resolve conflicts as they arise.*

The National Implementation Plan (DOC, 1990, page 43) states that "the Transition Program Office has drafted a national plan to design, execute, monitor and evaluate a systematic NWS program to provide for communications exchange and technical coordination with both the internal and external communities either affected by, or interested in, modernization activities." The Committee assumes that the plan embraces all sectors of the external community and looks forward to examining the adequacy of the plan during the coming months.

PUBLIC INSTITUTIONS

Community preparedness is essential to save lives and minimize property damage during severe weather situations. The critical role of the NWS is to participate actively in preparedness planning and then communicate both to state and local governments, and to the public, the seriousness of specific

weather situations. A leadership role is necessary, and the Committee believes that a limited, part-time approach to this key function is entirely inadequate. Many of the expected improvements in the forecasting of storms and severe weather will go to waste if there is inadequate planning for response to the improved watches and warnings.

The flash floods on June 14, 1990, in the vicinity of Shadyside, Ohio caused 26 fatalities and extensive property damage. Anticipating the flood event, the Weather Service Forecast Office in Cleveland issued a Flood Watch about two hours prior to the flood (NOAA, 1991a). Although the Flood Watch was promptly broadcast by local television and radio stations and the Flood Watch message was successfully received by the Belmont County Sheriff's office, it was not relayed from that office to the Shadyside police or the county emergency management coordinator. This example points out the need for close and frequent coordination between the NWS and public institutions. This will become even more important with the advent of new technology in the NWS modernization whereby a major improvement will occur in the continuous monitoring of weather phenomena that pose a threat to life and property. Effective warning and preparedness require adequate planning, coordination, and education at the national, regional, and local levels.

Recommendation: *To ensure adequate community preparedness, professional staff time equivalent to a full-time person should be provided at each Weather Forecast Office to work with state and local governments and other involved agencies in preparing plans for the community's response to severe weather. To maintain liaison with public institutions and to assist in community preparedness, the federal government should consider retaining, with limited staff, most Weather Service Offices now planned for closure.*

6

Implementation Process

MANAGEMENT AND SYSTEM ENGINEERING APPROACH

The Committee has reviewed the NWS plans, management strategies, and system engineering approach for implementing its modernization, including the three systems essential for improved weather services and planned restructuring in the field: Next Generation Weather Radar (NEXRAD), Automated Surface Observing System (ASOS), and Advanced Weather Interactive Processing System (AWIPS).

Management

The NWS has done a commendable job in planning its modernization. A new matrix organization is in place and top management staffing is complete. Under the NOAA Assistant Administrator for Weather Services (the head of NWS), deputies have been appointed for operations and for modernization. The Deputy Assistant Administrator for Modernization oversees the NEXRAD Joint System Program Office, Office of Systems Development (which includes the ASOS and AWIPS projects), Office of Systems Operation, Office of Hydrology, and the Transition Program Office. All of the other NWS headquarters and field offices are also involved in the modernization effort to varying degrees. Using a matrix approach to management, the Deputy Assistant Administrator for Modernization also oversees and coordinates the modernization roles and activities of these other NWS offices as well. The Transition Program Office supports the coordination function. Support functions, such as contracting, personnel management, external relations, and facilities construction, are provided by NOAA headquarters and the Department of Commerce.

The NWS has developed a number of innovative procedures intended to facilitate effective implementation of the modernization concept. Techniques

such as risk reduction through prototyping and strong user involvement help ensure that the products of modernization will be useful and will accurately embody the original requirements. A new system was created recently to ensure adequate internal communications, reporting, and coordination; all offices of the NWS are now aware of the plans and status of the modernization. However, NOAA and the Department of Commerce appear to have a shortage of staff to provide administrative support, such as procurement and personnel, and to handle the external contacts with Congress, user groups, and the public that are essential to implementation of the modernization and associated restructuring. Moreover, the Committee is concerned that the project management, engineering, and support staff may not be as strong as required for an effort of this magnitude.

System Engineering and Integration

It appears to the Committee that the NWS lacks an overall policy for configuration control of large systems and for the development and maintenance of complex software. Even though government policy wisely expects contractors to provide their own well-understood and tested standards and methods, it is in the government's interest to monitor carefully and to manage development and maintenance contracts. An overall NWS guiding policy is needed to set forth minimum requirements to be met by contractors in the process of developing and maintaining software and in reporting progress through specific process-sensitive metrics. Such a policy would mitigate against problems in multicontractor development and maintenance, and would protect the government against undue cost and hardship should a contractor be unable to complete a contractual commitment or should a subsequent change in contractors occur.

System engineering in the NWS environment is vital because of the phased development and because the NWS systems must remain operational during upgrading and modernization. It appears that some elements of the systems now being procured may be abandoned during subsequent phases of modernization. For example, the functions of the Principal User Processor, a part of the Next Generation Weather Radar system, eventually will be performed by the Advanced Weather Interactive Processing System. Although this change may be appropriate and necessary, it might have been avoided if an overall system design or configuration control process had been in place several years ago. Communications and interfacing standards or planned evolution toward such standards is currently lacking.

In a related issue, the NWS may be reticent to apply resources to the development of formal standards and methods because of the lack of adequate funding. Whereas this may reduce near-term costs, it probably will increase

life-cycle costs by making long-term maintenance and enhancement more difficult. Despite these near-term funding pressures, preserving the viability of the NWS systems suggests that a stronger commitment to formal methods is in the national interest.

Recommendation: *The National Weather Service should establish overall policies and procedures for the development of major systems, including consideration of the interaction between systems, and establish software development and maintenance standards.*

Hardware Status

The NWS plans for its contractors to install as well as construct hardware. Both Next Generation Weather Radar (NEXRAD) site preparation and Weather Forecast Office (WFO) building construction are being handled by a special Department of Commerce activity and appear to be under control. The Advanced Weather Interactive Processing System (AWIPS) and Automated Surface Observing System (ASOS) contractors are also expected to handle site preparation for their systems. Overall, the Committee is impressed with the progress that has been made in developing hardware and preparing for field installation. Delays in procurement and funding for the AWIPS are the most serious concerns involving hardware.

The NEXRAD, a joint program with the USAF and the FAA, is well along, with initial production units already being installed, although some troublesome delays have occurred in software and hardware delivery. Cooperation among agencies seems excellent. There is no question that the system will constitute a major step forward in severe weather warning.

The ASOS is now in the production phase. Because at least 1000 ASOS units are to be built, installing the system will be a major effort involving the NWS, the FAA, and airport authorities. Indeed, at full production, one or two ASOS units will be installed every day for four years.

The AWIPS and its associated communications, essential for the integration and operation of the modernization systems, are not as far along in development because of external delays in the approval of contracting steps and continuing funding constraints. This situation poses a major problem in the Modernization and Associated Restructuring Demonstration (MARD) and certification process that must precede restructuring of the NWS. Present plans call for a two-step implementation of AWIPS, an initial configuration followed by a software upgrade after certification. Even with this approach, there is very little time to commission the initial operational configuration of AWIPS before performance confirmation, MARD, and certification. It is

essential that AWIPS move forward expeditiously in fiscal years 1991 and 1992 if the NWS schedule for restructuring is to be met.[1]

The systems discussed above must be integrated, which in itself is a major project. The NWS management is aware of this and has several support service contractors assisting in both planning and in the integration of NEXRAD, AWIPS, and ASOS.

System Security

In the broadest sense, system security embraces all elements that can influence overall system resiliency. These include such diverse factors as satellite continuity, availability of backup power, and access security of communications, computer, and software systems. The Committee's study to date has not reviewed the security issues involved in modernization. It is already apparent, however, that the NWS has concentrated on physical security and has not paid sufficient attention to the security of electronic access. Meeting the needs of public and private users of NWS data requires "connectivity." This must be balanced by the provision of adequate security to ensure the continuity, integrity, and accuracy of the data and information being distributed.

> **Recommendation:** *The National Weather Service should satisfy itself that the security of its data systems will be adequate to preclude a breakdown of critical services in the event of improper intervention, either intentional or inadvertent, in its data and communications systems.*

The Committee plans to examine in greater detail those aspects of modernization related to system security and resiliency.

HUMAN AND FINANCIAL RESOURCES

Temporary Management and Project Staff

Over the past several years the NWS has assumed an increasingly large workload associated with modernization and restructuring. Additional management workload has been undertaken both at NWS headquarters and in

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[1] See also Chapter 3, page 33.

NWS regions with essentially no increase in total staff. Several people have been shifted entirely to planning and implementing the modernization, whereas others have modernization duties in addition to their former workloads. The NOAA and the Department of Commerce also provide administrative support and assist with constituent and congressional affairs.

Management of some operations has been curtailed or eliminated to prepare for the modernization and restructuring. The following are two examples:

- The branch at NWS headquarters concerned with the management of warning and coordination was eliminated and the work distributed to other offices; the individuals thus made available are now working on the modernization. However, the ability of NWS headquarters to manage properly an important ongoing warning operation and to formulate plans for carrying out this function under modernization has been impaired. For example, there now is no leadership in planning the way in which the warning and coordination functions will be conducted by the 115 Weather Forecast Offices whose responsibilities will cross state boundaries versus today's 50 offices that operate within state boundaries.

- Management workload at NWS headquarters and in the field is increasing as maintenance problems increase with the aging of current equipment and facilities. At the same time, the installation and maintenance of new systems must be planned and managed.

Other areas are understaffed, particularly at NWS headquarters, as indicated by the following examples:

- The Committee, as of January 1991, had not received from the NWS a draft of its detailed plans for the certification process, even though NWS management had placed a high priority on early review of the plan by the Committee. This is indicative of the work overload in the Transition Program Office.

- As mentioned in the previous section, the size of the project management, engineering, and support staff appears to be insufficient. This is of particular concern with regard to the length of time required to initiate procurements, the provision of appropriate oversight of contractors, and the ability to respond properly to the inevitable difficulties that arise during development and implementation of complex hardware and software systems.

- There is rapid growth at NWS headquarters and in the field in the need to communicate with the external world—government officials at all levels, user groups, and the general public. This external community is very concerned about the restructuring associated with modernization; lack of adequate communication could jeopardize the plan to restructure the NWS. The

constituent affairs staff assisting the NWS headquarters should be increased[1] and a Constituent Affairs Officer added to each of the four regional offices in the contiguous 48 states.

- Development by NWS headquarters of plans for transition of service activities (e.g., agriculture, aviation, fire weather, and marine programs) to the era of the modernized NWS is behind schedule.

> **Recommendation:** *A Constituent Affairs Officer should be assigned to each of the four National Weather Service Regional Offices in the contiguous 48 states until the completion of modernization and restructuring.*
>
> **Recommendation:** *The management and project staffs at National Weather Service headquarters, National Oceanic and Atmospheric Administration, and Department of Commerce administrative support should be increased temporarily during the implementation of modernization by at least 20 to 40 well-qualified people.*

At the regional level, staffing is marginal to cover ongoing operations and the new work associated with modernization. The latter, for example, includes the logistics of acquiring property for new offices, placement and surveys for the installation of new equipment, analyzing the meteorological aspects of the workload, and planning staffing and training. The intensity of this activity is increasing rapidly to the point that serious problems may arise unless the staff is increased.

> **Recommendation:** *The staff at each National Weather Service regional office should be increased temporarily during the implementation of modernization by one to four people as required.*

Operational Staff

The Committee's review has identified a number of areas in which staffing could be insufficient. Some of these are discussed elsewhere in this report:

- Workloads at the River Forecast Centers (Chapter 4, page 42).

[1] See also discussion of Constituent Affairs Officer in Chapter 5, page 48.

- Weather Forecast Office (WFO) staffing to handle community preparedness activities (Chapter 5, page 48).

In addition, the Committee is concerned about the plan to have only one meteorologist on duty during the night shift at each WFO. The weather is no less life-threatening and damaging at night than during the day and evening. It is doubtful that a single meteorologist can adequately monitor and forecast changes and issue timely warnings under bad weather conditions.

The Committee understands that the concept of one meteorologist covering the night shift is based on the premises that

- a single meteorologist can properly review, modify, and keep up to date a four-dimensional database in the Advanced Weather Interactive Processing System (AWIPS) which covers at least 48 hours and from which all operational forecasts will be produced automatically and disseminated with no manual activity involved; and

- the meteorologist's main role during bad weather situations will be to concentrate on only the first 12 hours of the forecast period using the AWIPS database, and relying on computer-generated forecasts beyond 12 hours.

A major problem with this concept is that it is based on the untested and questionable idea of producing all operational weather forecasts by computer, a deferred capability of the AWIPS system. The concept of machine-produced operational public weather forecasts based on a meteorologist modifying or accepting computer-generated Model Output Statistics is to be tested at Norman, Oklahoma in the near future. However, this will involve the shift meteorologist merely accepting or changing numerical values in the Model Output Statistics guidance.

The NWS needs to determine whether restrictions inherent in the new concept will prevent shift meteorologists from incorporating their expertise and evaluation of the synoptic situation and its expected evolution into the final forecast. For example, the ability to add manually significant detail to automated analyses, by using additional data not employed in the automated analyses, appears to be eliminated. Antecedent weather conditions, current radar and satellite data, and locally acquired observations can be important in producing correct analyses. The Committee questions whether all of this can be done by one meteorologist who merely changes the geometry of some lines in guidance graphics or the numbers in a Model Output Statistics matrix.

It is certainly advisable to have a minimum number of people working at night, especially when the weather is expected to be benign. The problem of minimum night staffing arises when bad weather is expected or develops unexpectedly. Perhaps flexibility can be incorporated into the one-person staffing when significant weather and associated forecast problems are antici-

pated during a night shift. For example, the Science and Operations Officer or the Warning Coordination meteorologist, who normally works in the daytime at Weather Forecast Offices, could be responsible for assisting the night shift meteorologist. Such persons may be needed to provide special interpretation and advice to emergency management centers regarding specific local warning and community response problems.

Recommendation: *As a part of the Modernization and Associated Restructuring Demonstration, the National Weather Service must thoroughly test the concept of forecasts being automatically produced at night by using a final four-dimensional database.*

Recommendation: *The proposal to produce operational forecasts by computer that are equal to or better than current manually produced forecasts and warnings should be demonstrated for a variety of weather conditions and locations. The new procedures should be operational and their efficacy established before the meteorological staff at a Weather Forecast Office is reduced to the proposed one person on the night shift.*

Recommendation: *An alternate operational plan for staffing the night shift should be formulated for use until the proposed concept has been fully developed and proven.*

Financial Resources

The Committee recognizes that many of the suggestions made in this report have a potential impact on the budget for the NWS modernization and associated restructuring. For example, the Committee is aware that the limiting factor in the employment of additional personnel is money, not authorized positions. However, in most cases, the additional personnel required temporarily to assist in modernization activities could save money in the long term by reducing future development, implementation, and maintenance problems and their attendant costs. Although the solution proposed for the problem of limited meteorological staff on the night shift at the Weather Forecast Offices may reduce the overall savings visualized from restructuring the NWS until the effectiveness of automation can be demonstrated satisfactorily, the Committee believes that this would be compensated by savings to the public and governments from reduced loss of life and destruction of property.

The Committee recommendation with the largest cost impact is undoubtedly that concerning the phasing of funds for NOAA satellites to ensure their continuity (see discussion of environmental satellites in Chapter 2). This requires early funding rather than an increase in total cost over the life of the

program. Satellite data have become such an important part of the nation's weather forecasting and warning services that the continuity of observations must be ensured to avoid a major degradation or interruption of these services. Rectifying the current low incremental funding of the Advanced Weather Interactive Processing System program (discussed on pages 33, and 52) would also require an increase in near-term budgets, but would probably reduce the overall cost of implementation.

The network of observation stations required in natural and undeveloped areas to preserve the viability and integrity of the climate record (see Chapter 2), will also lead to additional costs; these might properly be borne by the U.S. Global Change Research Program.

CERTIFICATION REQUIREMENTS AND APPROACH

Congressional concern about the impact of the changes in existing weather stations, as proposed in the restructuring of the NWS associated with modernization, resulted in the certification requirements in Title IV of Public Law 100-685 (U.S. Congress, 1988). The relevant parts are

- Section 408 which requires the Secretary of Commerce "not to close, consolidate, automate, or relocate any...office" unless the Secretary certifies to the Congress "that such action will not result in any degradation of weather services provided to the affected area." It further states, "Such certification shall include—

  "(1) a detailed comparison of the services provided to the affected area and the services to be provided after such action;

  "(2) any recent or expected modernization of National Weather Service operations which will enhance services in the affected area; and

  "(3) evidence, based upon operational demonstration of modernized National Weather Service operations, which supports the conclusion that no degradation in services will result from such action."

- Section 407 (b) states that "...the National Implementation Plan shall include... (2) special measures to test, evaluate, and demonstrate key elements of the Modernized National Weather Service operations prior to national implementation, including a multistation operational demonstration which tests the performance of all components of the modernization in an integrated manner for a sustained period;..".

The latter is the Modernization and Associated Restructuring Demonstration (MARD) that is being planned for a period of one year in the Midwest. The NWS considers MARD to be the cornerstone upon which the certification process will be based.

Clearly, the need to certify expected performance before each step in the modernization and associated restructuring is implemented places a major burden and responsibility on the NWS, the NOAA, and the Secretary of Commerce. Because of the large temporal (daily, seasonal, and annual) and geographical variations in the weather, it will be difficult to establish certification procedures to demonstrate conclusively "that no degradation in services will result from [any] action." Clearly, the certification procedure must assess objectively the quality and timeliness of the forecasts and warnings.

Although the Committee has not received the proposed detailed certification plans for review, its following initial views are offered for consideration. First, specific comparisons of the quantity and quality of weather information, forecasts, and warnings, and their prompt dissemination must be obtained, both during the MARD and during the process of certifying the capabilities of any Weather Forecast Office (WFO) to serve its area of responsibility. The comparison process must be designed to be an end-to-end verification of the capabilities of the NWS and the WFO to acquire information; convert it into useful analyses, forecasts, special weather statements, and warnings; and transmit these products in a timely manner to users in the public and private sectors. The Committee believes that carefully constructed and unbiased comparisons will demonstrate a noteworthy improvement in the quality and accuracy of service. Second, to increase the credibility of the certification process in the eyes of user groups and Congress, it may be appropriate, at some stage, to involve an independent evaluation of the statistical and analytical measures developed during the initial operations of the WFOs as applied to each specific certification.

The Committee intends to give careful and thorough attention to the proposed NWS certification plans as soon as they are received.

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1 National Research Council

Acronyms

ASOS	Automated Surface Observing System
AWIPS	Advanced Weather Interactive Processing System
DAR^{3}E	Denver AWIPS Risk Reduction and Requirements Evaluation
DOC	Department of Commerce
DOD	Department of Defense
FAA	Federal Aviation Administration
GOES-Next	Next Generation Geostationary Operational Environmental Satellite
IOT&E-2	Initial Operational Test and Evaluation, Phase II
MARD	Modernization and Associated Restructuring Demonstration
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite, Data, and Information Service
NEXRAD	Next Generation Weather Radar
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NWS	National Weather Service
OSF	Operational Support Facility
RFC	River Forecast Center
STORM	Stormscale Operational and Research Meteorology (program)
USAF	United States Air Force
WFO	Weather Forecast Office
WSFO	Weather Service Forecast Office
WSO	Weather Service Office

Appendix A

Letter from the National Oceanic and Atmospheric Administration to Dr. Frank Press requesting establishment of a National Research Council committee to review the National Weather Service modernization and associated restructuring

UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary
National Oceanic and Atmospheric Administration
Washington, D.C. 20230

JUL 7 1988

Dr. Frank Press
President, National Academy
of Sciences
2101 Constitution Avenue
Washington, D.C. 20418

Dear Dr. Press:

I am writing to request the support of the National Research Council (NRC) as the National Oceanic and Atmospheric Administration (NOAA) moves toward implementation of plans to modernize and restructure the National Weather Service. The formulation of these plans was both encouraged and assisted by the seminal study of NRC's Select Committee on the National Weather Service, whose report, Technological and Scientific Opportunities for Improved Weather and Hydrological Service in the Coming Decade, was published in 1980. Subsequently, the NRC formed a study panel that reviewed plans of Federal agencies to upgrade the Nation's weather observing and processing systems. Its report, sent to the Administrator of NOAA by the Panel Chairman, John W. Townsend, Jr., in August 1987, also was helpful in assessing priorities and coordinating Federal efforts.

After several years of internal planning within the Executive Branch, the Department of Commerce recently issued a Strategic Plan for the Modernization and Associated Restructuring of the National Weather Service. The Strategic Plan represents a first step in the planning process prescribed by Public Law 100-685, which was signed by the President in November 1988. This law establishes guidelines for planning, reporting, and certifying the modernization and restructuring.

To support our efforts, I propose the establishment of an NRC review committee on the modernization and associated restructuring of the National Weather Service. As I envision it, the committee would have two broad areas of responsibility: (1) to help ensure the most cost-effective levels of systems and services by assessing the availability, applicability, and timing of appropriate underlying technological and scientific capabilities and (2) to help ensure the successful demonstration and acceptance of modernized and restructured Weather Service operations by reviewing test, demonstration, and certification plans and by independently reviewing the data collection and interpretation processes.

Some specific areas for analysis and study include:

1. projections of the extent and timing of emerging scientific foundations of improved services and the

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techniques and technologies needed to apply them operationally;

2. trade-offs of functional capabilities of the Advanced Weather Interactive Processing System for the 1990's in terms of feasibility, risk, service impact, and cost;

3. review and assessment of performance, operational readiness, and value of radar wind profilers;

4. assessment of the availability and timing of automated, remote sensing, thermodynamic profilers;

5. review of the validity and effectiveness of methodologies for demonstrating that services are improved and not degraded when the new technological and organizational configurations are introduced; and

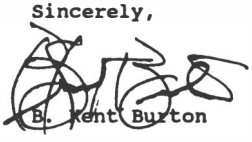
6. review the validity of the collection, analysis, and interpretation of data for demonstration and certification of service operations.

These areas involve a very broad range of scientific and engineering issues, so I am writing both to you and Dr. White with this request. Individuals selected for the review committee should possess skills and experience in disciplines represented in both communities.

I welcome your additional thoughts and suggestions on this proposal. I have asked Dr. Elbert W. Friday, Jr., Assistant Administrator for Weather Services, to assist me in working with appropriate persons representing the Academies in developing an action plan. I am anxious to establish an arrangement as soon as possible because significant decisions and actions are beginning to occur ever more frequently. The proposed review mechanism would serve a useful purpose throughout the national deployment of new technology and phaseover to the new structure, a time period extending into the mid-1990's.

I look forward to developing another productive collaboration with the Academies that serves the best interests not only of the Government but of the Nation. Thank you for your cooperation.

Sincerely,



B. Kent Burton

Appendix B

Members of the Committee on Meteorological Analysis, Prediction, and Research

Board on Atmospheric Sciences and Climate

COMMITTEE ON METEOROLOGICAL ANALYSIS, PREDICTION, AND RESEARCH

PETER V. HOBBS, Department of Atmospheric Sciences, University of Washington, *Chairman* (beginning 7/1/90)
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JAMES A. COAKLEY, Department of Atmospheric Sciences, Oregon State University
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**FRANCO EINAUDI, Goddard Space Flight Center, NASA
J. MICHAEL FRITSCH, Department of Meteorology, Pennsylvania State University
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**EARL E. GOSSARD, Cooperative Institute for Research and Environmental Sciences (CIRES), University of Colorado, Boulder
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*PETER S. RAY, Department of Meteorology, Florida State University, *Chairman* (thru 6/30/90)
THOMAS W. SCHLATTER, Forecast Systems Laboratory/Environmental Research Laboratories, NOAA
ROBERT J. SERAFIN, National Center for Atmospheric Research
LEONARD SNELLMAN, University of Utah
**WARREN H. WHITE, Washington University

Staff

John S. Perry, Staff Director, Board on Atmospheric Sciences and Climate
Kenneth H. Bergman, Staff Officer until 8/90
Richard Kelley, Staff Officer beginning 11/90

* Term expired 6/30/90.
** Term began 7/1/90.