# TOWARD A NEW NATIONAL WEATHER SERVICE

*– – Second Report*

NATIONAL RESEARCH COUNCIL

*Cover:* The Automated Surface Observing System was recently installed at Colorado Springs, Colorado. Over 1000 of these units are being installed throughout the United States in a cooperative program of the Departments of Commerce (NOAA/NWS), Transportation (FAA), and Defense. (Photograph by Allan H. Layman, Jr., courtesy of Systems Management Incorporated, AAI Corporation.)

# TOWARD A NEW NATIONAL WEATHER SERVICE

## — — *Second 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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# Preface

During 1991, the National Weather Service Modernization Committee (NWSMC) continued its second year of studying various aspects of the modernization and associated restructuring of the National Weather Service (NWS). The Committee held five meetings during the year, supported by individual efforts of Committee members between meetings. The NWSMC has closely monitored the progress in procurement, development, and deployment of the hardware and software for the modernization to ensure that the public is the early beneficiary of the increased productivity and saving of lives that full implementation of the system will afford. Chairman Hosler had the opportunity to testify before the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate.

The Committee's First Report (NRC, 1991), the summary of which is reproduced in Appendix A, was a broad overview of the modernization plans and development. It covered the new observation systems; new information systems; new structure of the NWS; new and stronger collaboration with universities, the private sector (including the mass media and private weather services), and public institutions; and the implementation process. This report, the second in a continuing series, raises concerns about the funding and implementation of the modernization as well as the deterioration in the present NWS system, analyzes the response of the National Oceanic and Atmospheric Administration (NOAA) to the recommendations in the First Report, discusses the certification process and requirements, and provides additional recommendations dealing with climatological considerations of the modernization. The Committee is now studying the impact of the modernization on aviation weather services, the design of the Modernization and Associated Restructuring Demonstration

(MARD), system security and resiliency, communications in the modernization, and assessment of employee understanding of and reaction to modernization; it is also continuing its study of certification. The Committee will report on these and other topics, as appropriate, in future reports.

In the report that follows, Chapter 1 covers a number of concerns about the pace of deployment of the modernization and some early indications of the performance of system components. The Next Generation Weather Radar (NEXRAD) program, officially designated the WSR-88D (Weather Service Radar-1988 design Doppler), experienced some difficult contract negotiations last year. However, a revised contract has been signed and the limited-production units are being installed with good early results. The Next Generation Geostationary Operational Environmental Satellite (GOES-Next) development has had technical difficulties resulting in extensive delay; there is some promise now that the program is moving toward a solution. The Committee is increasingly concerned that budgetary problems and misunderstanding of the crucial role of the Advanced Weather Interactive Processing System (AWIPS) may lead to additional delays in the modernization and something less than maximum benefits if AWIPS does not proceed apace.

Chapter 2 contains a further analysis of issues raised in the Committee's First Report in light of the responses of NOAA to the recommendations in that report. The Committee highlights areas in which it still has significant concerns regarding NOAA's responses. The full Committee recommendations, NOAA responses, and Committee analyses are included in Appendix B.

As discussed in Chapter 3, the Committee spent considerable time in 1991 working with the NWS on the evolving plan for certifying, in compliance with Title IV of Public Law 100-685 (U.S. Congress, 1988), that there will be no degradation of services during and after modernization. The Committee feels that, beyond the basic certification requirements, the NWS should document the improvement in services and the new and useful products made possible by the modernization.

Appendix A is the Summary from the First Report for the benefit of those readers who are not familiar with its contents or with the background and structure of the modernization and associated restructuring.

Appendix C contains a preliminary report from the National Research Council's (NRC) Climate Research Committee (CRC) of the Board on Atmospheric Sciences and Climate. The CRC is continuing its study of the

climatological considerations of the NWS modernization program and expects to complete its final report during 1992.

Appendix D contains a letter to the Undersecretary of Commerce for Oceans and Atmosphere regarding the educational requirements for meteorologists. The reply from the Assistant Administrator of NOAA for Weather Services also is included.

*Acknowledgments*

The Committee appreciates the contribution of the CRC to this report and looks forward to receiving its final report. The Committee also would like to acknowledge the professional help of David S. Johnson, Study Director, and Mercedes Ilagan, Senior Study Assistant, of the NRC in carrying out its work. Their services are highly valued in logistical arrangements, liaison with federal agencies, and preparation of this report.

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

# Contents

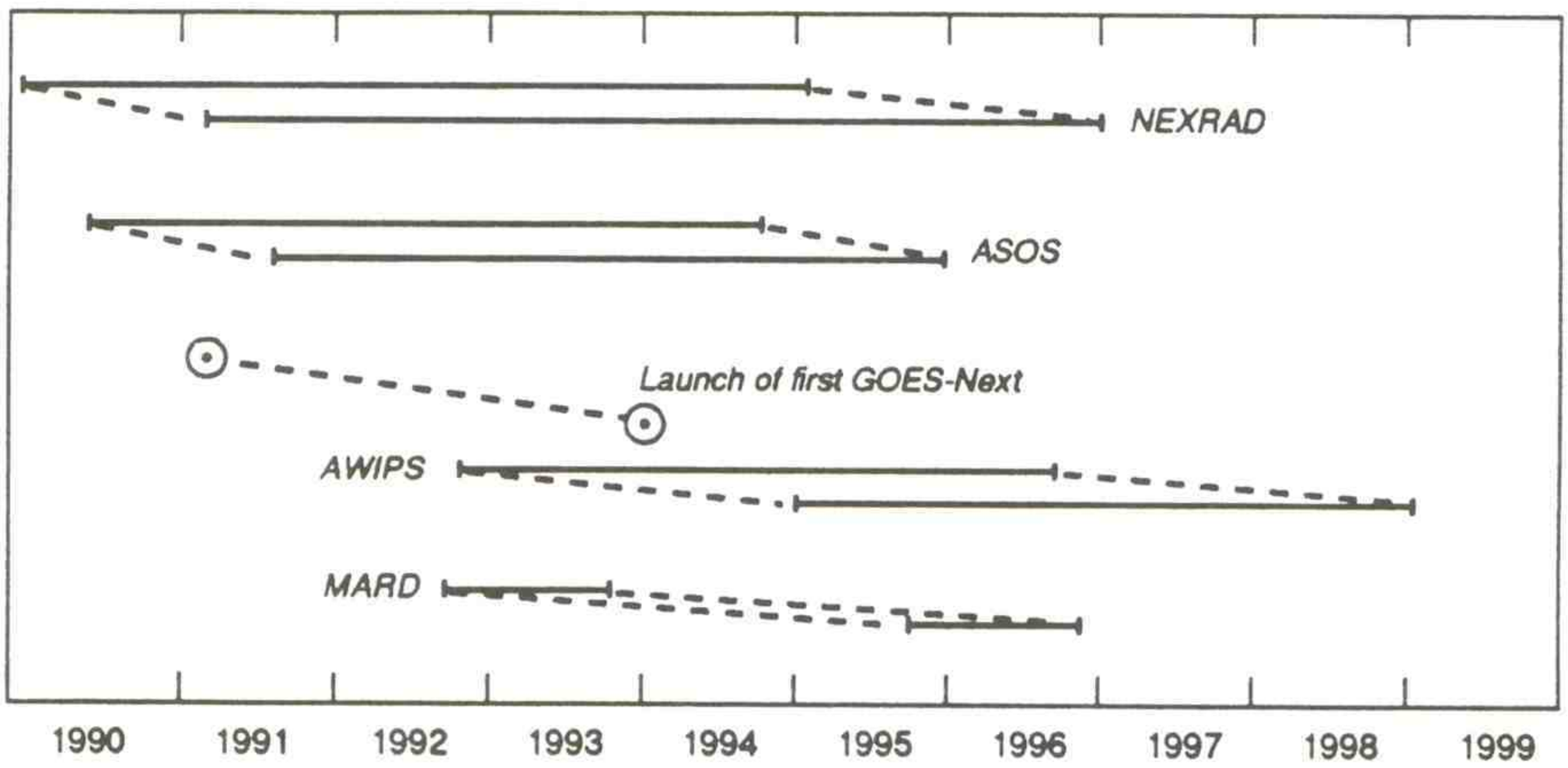
# 1

# Overview and Concerns

Information gathered at meetings, accompanying briefings, and site visits over the past year has continued to confirm to the Committee the soundness of the National Weather Service (NWS) plan for modernization. The Committee continues to be enthusiastic about progress being made in installing the Next Generation Weather Radar (NEXRAD), the Automated Surface Observing System (ASOS), and the software development for NEXRAD and for the Advanced Weather Interactive Processing System (AWIPS) test-beds.

## SUMMARY

Although the Committee is encouraged by the progress made during the past year in some elements of the modernization, it is concerned about a number of difficulties that may impact the schedule (Figure 1) as well as the quality of the implementation. The delay in development of the Next Generation Geostationary Operational Environmental Satellites (GOES-Next) is of concern as the current GOES 7 faces degradation, even though some relief may be obtained by borrowing a European satellite. The Committee also is very concerned that budget considerations may lead to further slowing of AWIPS development at a time when it should be accelerated in order to realize a full return on the present investment in modernization of the NWS. Any delay in AWIPS will delay the Modernization and Associated Restructuring Demonstration (MARD) or degrade the results.




Deployment Schedule (1989 versus 1992)

FIGURE 1 Changes in the schedules for deployment of key elements in the NWS modernization are shown by the pair of horizontal lines for NEXRAD, ASOS, AWIPS, and MARD. The upper line in each pair was the schedule as projected in 1989 (NWS, 1990); the lower line, in January 1992 (NWS, 1992). The left end of each line represents the beginning, and the right end the completion, of the deployment. For MARD, the line represents the one-year duration of the demonstration. Only the projected launch dates are shown for the first GOES-Next spacecraft.

The Committee is seriously concerned that currently projected budgets will not be adequate to cover the transition expenses necessary for implementation of the principal components of the modernization plan. Funding for replacement equipment must also be identified.

These are all areas that could endanger the modernization unless the entirety of the modernization is fully supported. This is becoming increasingly critical with the passage of time because the current weather system is obsolete and the frequency of outages of critical equipment is growing. Modernization is not a program that can be stretched out. Even if the present schedules can be maintained, there may be serious degradation of current services due to failures of old equipment.

**Recommendation:** *The Executive Branch should take the steps necessary to minimize further delays in implementation of the modernization in accordance with the Strategic Plan and the National Implementation Plan for the Modernization and Associated Restructuring of the National Weather Service.*[1]

The Committee notes the establishment of the new National Oceanic and Atmospheric Administration (NOAA) Systems Program Office (SPO) reporting to the Deputy Undersecretary of Commerce for Oceans and Atmosphere. Use of a SPO can be an effective mechanism, but only if it is staffed with the appropriate number of qualified technical and management people and, importantly, if it keeps the needs of the operator of the system (i.e., the NWS) closely in mind and ensures good communication with the operator. Further, the cómponents being developed and procured by the SPO must be installed and integrated into a complex, ongoing operation whose services cannot be interrupted. Thus, close collaboration between the SPO and the NWS is essential to the success of the modernization.

**Recommendation:** *Top management of the National Oceanic and Atmospheric Administration should carefully monitor the relationship and level of cooperation and collaboration between the Systems Program Office and the National Weather Service to ensure the success of the modernization.*

The Committee also reiterates and emphasizes the following recommendation from its First Report (NRC, 1991).

**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.*

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1 DOC, 1989, 1991.

## AUTOMATED SURFACE OBSERVING SYSTEM PROGRESS

Automated Surface Observing System installations are proceeding on schedule and promise more consistent and frequent surface data, without human-induced errors, and at a much lower cost per observation than the present manual observations. There are concerns about the continuity of the climate record due to the changeover to a new method of observation with different characteristics. These are being addressed by the National Research Council's (NRC) Climate Research Board as noted in Appendix C; this appendix contains a number of recommendations. The need for a comparison of new observations with those produced by the old units was addressed in the First Report.

## PROGRESS OF THE NEXT GENERATION WEATHER RADAR

The Committee is encouraged by the progress being made in the deployment of the limited production models of the Next Generation Weather Radar (officially designated WSR-88D for Weather Service Radar-1988 design, Doppler). Operational results with the first three units installed at Norman, Oklahoma; Melbourne, Florida; and Sterling, Virginia, have already provided dramatic examples of new capabilities (see inset). Earlier contract difficulties appear to have been resolved, and the Committee trusts that the projected schedule for full implementation of the NEXRAD network can now be maintained. However, without the AWIPS, discussed below, only limited advantage can be taken of the NEXRAD output.

## DELAY IN NEXT GENERATION GOES

The delay in development of GOES-Next (see Figure 1) is of concern since the current GOES 7 faces degradation because it is running out of fuel for stabilization. With luck, GOES 7, the last of the current production of GOES satellites, will survive until 1994, which seems the most probable time for the first GOES-Next to become available. In the meantime, cooperative use of the satellites of other nations may help fill any gap that occurs if GOES 7 fails before the first GOES-Next is operational.[1]

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1 A geostationary satellite provides continuous coverage of the atmosphere within its field of view. This continuous coverage is important in the improvement of mesoscale (high resolution in space and time) warnings and forecasts that are being emphasized in the modernization.

## EARLY RESULTS WITH NEXT GENERATION WEATHER RADARS

In the initial weeks of operation, the Norman, Oklahoma, NEXRAD provided new information on the development of mesocyclones and tornado vortices that permitted early warning to those in the path of a tornado. The tornado vortex that developed on June 5, 1991, was detected 14 minutes before touchdown in a situation in which old radars would not have detected it. Undoubtedly lives were saved. From March through June 1991, 96 percent of all severe thunderstorms were detected by the new radar at Norman, compared with the national average of 65 percent during March through July 1991, using the old operational radars in most cases. The average lead time for verified tornado warnings was 18 minutes. When the public is educated to understand the precision and timeliness of these warnings and the need to react, more lives will be saved than in the past.

In the first days of operation, the Sterling, Virginia, NEXRAD was able to warn airports of a low level jet with large vertical wind shear and boating interests of a strong wind shift accompanying a dry cold front, both of which were not detected by the old operational radar.

Melbourne, Florida, was able to use the storm tracking and integrated precipitation algorithm of the NEXRAD to anticipate precisely where heavy rains would fall. This was of great help to the public and to emergency management personnel. Previously undetected phenomena, such as dry fronts and local circulations, are being observed that will greatly improve short-range forecasts.

This entire episode again emphasizes the need to manage the satellite component of the modernized system by including sufficient redundancy to minimize the consequences of failure of one satellite (see also page 13). Achieving this goal will require more than one GOES in orbit and sufficient satellites in production or reserve to launch replacements when needed. Not only will early failure of GOES 7 seriously degrade the national weather system—it will be a major national embarrassment.

**Recommendation:** *Once the technical problems associated with the current development of the Next Generation Geostationary Operational Environmental Satellites have been resolved, the Federal government should provide adequate funding for follow-on spacecraft and launchings to ensure the continuity of geostationary satellite observations, a vital part of the National Weather Service modernization.*

# DELAY IN THE ADVANCED WEATHER INTERACTIVE PROCESSING SYSTEM

Modernization of the NWS depends on the integration of several technological advances: the NEXRAD advanced Doppler radar, the ASOS for nearly continuous surface weather observations, GOES-Next satellites, and the improved computer-generated mesoscale products from the National Meteorological Center. Each of the components of the new system provides a significant advance in the detail and timeliness of data on a meteorological or geographical scale. Taken together they will comprise a comprehensive system whose impact on aviation, agriculture, public safety, and the general public is significantly greater than the contributions of the individual parts. To achieve this potential for the public, meteorologists of the NWS must have the capability to acquire, integrate, and process these data interactively in order to generate detailed and accurate products and to disseminate them in a timely fashion (see inset). This vital step requires a comprehensive interactive communication and processing component with specialized algorithms to make it work. This is the function of AWIPS. It also should be remembered that the personnel savings proposed as a result of modernization cannot be achieved without full implementation of AWIPS.

## DENVER PRE-ADVANCED WEATHER INTERACTIVE PROCESSING SYSTEM PERFORMANCE

The Weather Service Forecast Office in Denver, Colorado, has been using the Denver AWIPS Risk Reduction and Requirements Evaluation (DAR$^3$E) unit, which might be called a pre-AWIPS unit, in an operational environment for almost two years. The pre-AWIPS, computer-assisted warning messages it generates have permitted timely warnings not otherwise possible. Combined use of the Doppler weather radar and pre-AWIPS units has produced extremely accurate forecasts and warnings, such as during severe thunderstorms. For example, during a record-breaking hailstorm in the Denver area on July 11, 1990, the pre-AWIPS unit was used in conjunction with Doppler radar to track the storm that produced hail up to baseball size during its life cycle. The initial warning issued for Boulder County provided from 30 minutes to nearly one hour leadtime for the residents. The computer-assisted warning messages generated by the pre-AWIPS unit allowed the forecasters to stay ahead of the storm while quickly listing the specific towns in its path. The unit also was extremely important in separating the threat of tornadoes from the threat of hail by its ability to switch quickly between the radar velocity and reflectivity fields.

Thus, the Committee is very concerned that budgetary considerations may lead to additional slowing of AWIPS development. The Committee feels that AWIPS should be accelerated in order to realize a full return on the present investment in modernization of the NWS. The MARD will be a true demonstration only if all of the complementary parts of the system are in place. Any delay in AWIPS will delay MARD or degrade the results (see Figure 1).

**Recommendation:** *The full implementation of the Advanced Weather Interactive Processing System must be pursued with high priority and resources must be provided to accelerate its development and implementation.*

## BUDGET FOR IMPLEMENTATION

In addition to its concerns about having AWIPS on line in time to convert the plethora of data from the new observing components into usable information, the Committee is seriously concerned that the currently projected budgets, even in fiscal years 1992 and 1993, will not be adequate to cover the transition expenses necessary for implementation of the principal components of the modernization plan. Increased numbers of people for the initial operation of the new system before the old system is phased out, furniture, training, and funds to develop new products are all essential ingredients. Clearly, increased attention should be paid to improved dissemination techniques to ensure the timely delivery of new, more detailed products. Funding for replacement of the 40-year-old upper air units and for wind profilers must also be identified in the near future. These are all areas that could endanger the modernization unless the leadership in NOAA, the Department of Commerce, and the Office of Management and Budget fully supports the entirety of the modernization. Without each and every important component of the modernized weather system, the public will not be well served.

**Recommendation:** *The National Oceanic and Atmospheric Administration, the Department of Commerce, and the Office of Management and Budget should recognize and fully support funding and staffing requirements during the implementation of the modernization and associated restructuring, as well as the need for*

*replacing aging equipment that is not a part of the current modernization program.*

## COMMUNITY LIAISON AND EDUCATION

User education to provide the public with an understanding of the products the NWS will produce is important. Establishing strong liaison with and ensuring rapid dissemination of warnings to the public and action agencies are necessary. Thus, the Committee again urges that most of the Weather Service Offices (WSOs) slated for closure be strongly considered for continuance as one-person liaison and warning coordination stations even beyond the changeover and certification period. New people and new user groups will need a close link with the NWS and guidance on the use of the new and improved products it will provide. The Committee reiterates the following recommendation from its First Report.

**Recommendation:** *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.*

## COLLAPSING INFRASTRUCTURE

Everyone involved in supporting the NWS modernization must be reminded constantly that it is not merely the exchange of one set of instruments for another to provide the same old products. An obsolete and failing system is being replaced by a new integrated system that will move weather warning and prediction into a new era. It will provide more precise, more timely, and more useful information than ever before available. Lives and property will be saved in severe weather situations, and productivity will be improved in all weather conditions.

As mentioned earlier, GOES 7 could fail at any time. The United States did have three geostationary satellites available in orbit; now there is only one. The current WSR-57 radar equipment is being kept on line by scavenging parts from other radars and by the heroic efforts of engineers and technicians. In spite of this, the frequency of outages is growing. In 1986 the WSR-57 radars experienced 28 outages causing 107 days of lost observations. In 1991 these radars experienced 64 outages with 280 days of lost observations. These represent only outages that lasted 48 hours or

more. The radars are experiencing major gear, bearing, and drive failures that take as long as 10 to 20 days to repair. Outages are more frequent and last for longer times because parts are unavailable. Radars are being operated at reduced power to minimize outages, which in turn reduces their effectiveness.

The Automation of Field Operations and Services (AFOS) units at 256 field sites are deteriorating and approaching the end of their useful life. Parts are no longer in production, and test equipment is no longer available for these 1970s vintage computers and displays. Outages can be expected to increase, affecting the quality of weather warnings and forecasts.

The 1950s upper air sounding receivers can be maintained only by scavenging, and downtimes are increasing. The costs of expendables for soundings have escalated.

None of these individual failures of the infrastructure is likely to bring about the total collapse of the nation's weather service. However, the growing number of failures will cause a further degradation of the service through an increase in faulty storm warnings—or the absence of warnings—and a reduction in the accuracy of weather forecasts.

## THE BOTTOM LINE

Modernization is not a program that can be stretched out. Even if the schedules now projected are maintained in the future, there may be serious degradation of current services due to failures of old equipment. Figure 2 is a conceptual graph that illustrates the probable relative trends in quality of service to the nation by the NWS over the next decade or so under four scenarios. The area between the curve for the original modernization plan and the other alternative curves represents lost capability and could be expressed in terms of loss of life, property, and productivity.

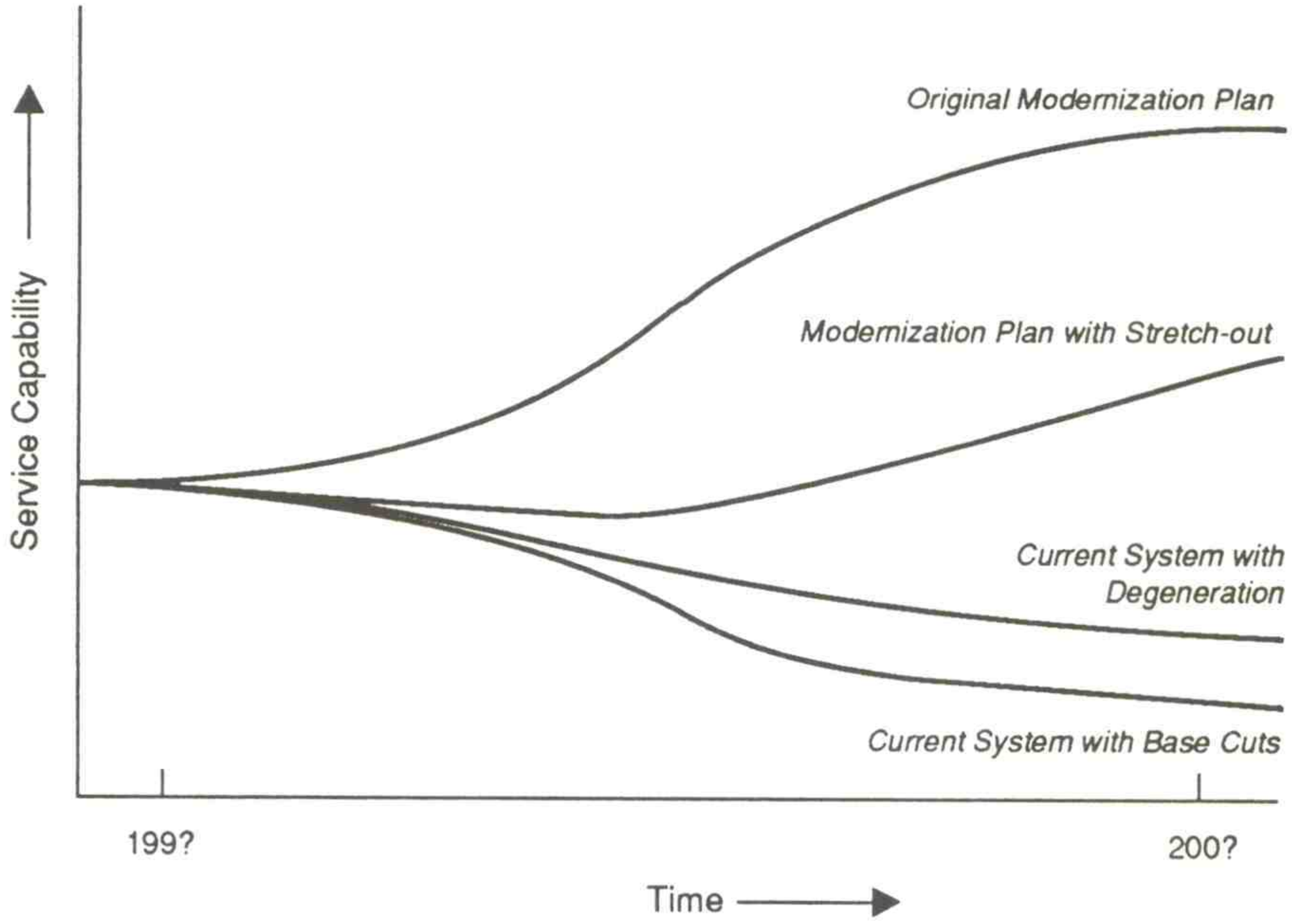


FIGURE 2 Conceptual graph of probable relative trends in the quality of service of the NWS over the next decade or so, under four program scenarios.

# 2

# Further Analysis of Issues Raised in the First Report

With his letter of September 9, 1991 to Dr. Charles L. Hosler, Jr., Chairman of the National Weather Service Modernization Committee, Dr. John A. Knauss, Undersecretary of Commerce for Oceans and Atmosphere, forwarded the detailed response of the National Oceanic and Atmospheric Administration (NOAA) to the Committee's First Report. In his letter, Dr. Knauss stated: "I am pleased to see that the Committee members clearly understand the promise that the National Weather Service (NWS) modernization and associated restructuring program holds for a dramatic improvement in weather services to the Nation, endorse the organizational approach and implementation philosophy of the NWS, and recognize the challenges that lie ahead. The number and specificity of the recommendations in the report are clear indications of the depth and thoroughness of the Committee's work. ... While this response does not attempt to respond to every recommendation in the report, NOAA will give each recommendation serious consideration."

The following material reviews the responses of NOAA to the Committee's broad recommendations in the summary of its First Report (NRC, 1991) and addresses certain of the more detailed recommendations found in the main body of that report. Appendix B contains all of the recommendations in the First Report followed by NOAA's responses and the Committee's analyses. The section titles in this chapter and in Appendix B are the same as those in the First Report for ease of cross-reference. The detailed response of NOAA was dated August 1991; where later developments are known to the Committee, they have been taken into account in the Committee's analysis.

The Committee views NOAA's response as forthright and detailed; it covers many of the Committee's concerns. In this chapter, the Committee highlights areas in which it still has concerns regarding NOAA's responses. The Committee feels that it will have to monitor some of these areas of concern closely, particularly where NOAA's ability to make progress depends on decisions by the Department of Commerce, the Office of Management and Budget, and the Congress.

## BROAD RECOMMENDATIONS

The First Report set forth four broad recommendations dealing with (1) the need for adequate financial and personnel support for the modernization, (2) strengthening of management, (3) use of advisory panels, and (4) the need to continue modernization after the modernized weather system now being developed has been deployed, including the Next Generation Weather Radar (NEXRAD), the Automated Surface Observing System (ASOS), the Next Generation Geostationary Operational Environmental Satellite (GOES-Next), and the Advanced Weather Interactive Processing System (AWIPS).

Despite the assertion of high priority in the NOAA response, the Committee remains concerned that funding will be inadequate to meet the schedule in the National Implementation Plan (DOC, 1991). If the schedule continues to be stretched out, there is an increasing likelihood that the quality of the present weather service will degrade, as discussed in Chapter 1. A prime example is the apparent delay in the funding and contract award for a full start-up of AWIPS, the critical component for integrating all of the new data and for preparing warnings and forecasts.

With regard to the strengthening of management, the Committee has noted the establishment of the new NOAA Systems Program Office (SPO) as discussed in Chapter 1. The portion of the Committee's recommendation dealing with additional resources and personnel is discussed below in the section "Implementation Process."

The response of NOAA to the recommendation in the First Report with respect to the use of technical advisory panels is inadequate. The Committee recognizes that panels have been used on an ad hoc basis in the past but reiterates its recommendation for standing panels composed of outside experts for each of the major components of the new system.

Regarding the Committee's earlier recommendation on the introduction of additional observational components beyond those now approved for

procurement, NOAA will require a strong commitment, top-level support, and carefully phased spending plans to continue modernization, for example, through the addition of profilers, a permanent lightning detection network, and a replacement for the present upper air observation system.

## OBSERVATION COMPONENTS

The Committee is encouraged that the NEXRAD program now appears to be back on track. Committee members were impressed, during site visits, with the operation of the Norman, Oklahoma, and Sterling, Virginia (near Washington, D.C.), radars even though they were still undergoing engineering tests. The response of NOAA concerning algorithm development, improved precipitation processing, training, and education is commendable.

The response of NOAA on observations to supplement those from ASOS is positive; the Committee looks forward to learning of the progress made in obtaining these observations.

The Committee supports the decision of the Secretary of Commerce to proceed with the current GOES-Next program by completing and launching a thoroughly tested, specification-compliant GOES-I, and to provide a backup to the present GOES 7 by using the European Meteosat 3 geostationary weather satellite, moved from viewing Europe to covering the western Atlantic and the United States. The communications link between the NOAA satellite station for GOES at Wallops, Virginia, and the Meteosat station in Darmstadt, Germany, established to facilitate this move, should benefit both the United States and Europe in future cooperative operations. The Committee is still concerned about the possible loss of satellite service in the future because the funding of the GOES-Next geostationary satellite program is too limited. A minimum of two fully operational satellites in orbit, plus one available to be launched and a fourth nearing completion (in case of a launch failure), is required to ensure continuity of operational coverage.

With respect to the climate data record, NWS proposes to compare one year of observations from a subset of 16 ASOS units to be deployed in the "central United States." The Committee believes that this approach is inadequate to test for bias in the record in other meteorological regimes, such as desert, coastal, and mountainous. Concerning climate in general, it is not clear that there is a NOAA-wide plan for the acquisition and archiving of climate data from all sources, including requirements for

parameters, accuracies, locations, what is to be saved, etc. More attention should be given to the synergistic use of all of NOAA's modernized observing units for climate monitoring. Additional preliminary findings on data for climate studies from the National Research Council's (NRC) Climate Research Committee of the Board on Atmospheric Sciences and Climate appear in Appendix C.

## NEW INFORMATION COMPONENTS

The Committee is increasingly concerned that funding for AWIPS may be inadequate for NOAA to pursue this essential program vigorously and without further delays. Committee members were impressed with AWIPS research at NOAA Environmental Research Laboratories as manifested in the pre-AWIPS units operating in Boulder, Colorado, as well as at the NWS forecast offices in Denver, Colorado, and Norman, Oklahoma.[1] The need for AWIPS is compelling, and program implementation should not involve high-risk developments. The NWS meteorologists must have the capability to acquire, integrate, and process all the data to be available in the modernized system in order to generate and disseminate in a timely manner detailed and accurate warnings and other products. Full AWIPS capability will not be available in the MARD, which will compromise the results because of delayed development of software for full data integration and interpretation. The Committee is very concerned about recent delays in the implementation of AWIPS. Award of the developmental-phase contract has slipped as much as one year from the date projected by NOAA in August 1991. This will further delay the MARD and the implementation of the modernization.[2] Personnel savings proposed as a result of modernization cannot be achieved without full implementation of AWIPS. The Committee also remains concerned about the adequacy of plans for the dissemination of data and information to the private sector.

## NEW STRUCTURE OF THE NATIONAL WEATHER SERVICE

The Committee recommended in its First Report that the Department of Commerce should carefully reconsider its decision to conduct a two-tiered demonstration of the network of Weather Forecast Offices (WFOs) during MARD. The objective of the Department of Commerce was to

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1 See insets, Chapter 1.

2 See Figure 1, page 2.

demonstrate that a national network of about 50 WFOs, compared to the planned 115, would be adequate, thus saving money. The Committee is gratified to learn that the general structure of MARD has not been changed. It remains convinced that 115 WFOs are near the minimum number required for an effective weather service in the United States.

The response of NOAA regarding hydrology risk reduction activities at Norman and Tulsa, Oklahoma, is quite positive. The Committee looks forward to examining the new plan for hydrometeorological service operations (NWS Office of Hydrology, 1991), particularly with regard to other recommendations in the First Report, including the use of improved quantitative precipitation forecasts and associated uncertainties in hydrologic models, cross-training of meteorologists and hydrologists, development of software for AWIPS work stations in the River Forecast Centers (RFCs), and the serious issue of the validity of using the same NEXRAD precipitation algorithm in all conditions and locations.

## NEW AND STRONGER COLLABORATION

In its First Report the Committee urged new and stronger collaboration[1] (1) with the university community, through the location of WFOs on university campuses and through collaboration in education and research; (2) with the private sector, by strengthening the use of Constituent Affairs Officers, planning for the dissemination of data and products to the private sector, and noting the impact of the proposed increase in user fees; and (3) with public institutions, by ensuring adequate community preparedness in anticipation of dangerous weather. Although NOAA's response is generally positive, questions remain concerning the scope of collaboration and the strength of its resolve.

Although NOAA plans to collocate nine WFOs with universities, the Committee understands that there are procurement issues to be faced in other places. In some instances, a difficult choice must be made among competitive proposals; in others, a perceived lack of competition may be a concern. The Committee believes that much more can be accomplished if top-level attention is devoted to the issue; the benefits to be derived warrant this attention.

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1 See Appendix A, page 38 for a summary in the section "New and Stronger Collaboration."

The early and dramatic success of the Cooperative Program for Operational Meteorology, Education, and Training (COMET) provides convincing evidence for this view. The COMET outreach program has already led to 19 cooperative research projects located at 17 universities throughout the nation. These projects are addressing a wide range of forecasting problems of immediate and significant concern to the NWS. They provide excellent opportunities for students and faculties to contribute to improved forecasting techniques. These opportunities should lead to more motivated faculties and better-trained students, many of whom will serve as NWS employees in the future. The projects should also improve relationships and collaboration between the universities and the NWS. Moreover, these accomplishments are being achieved with a very modest budget, which demonstrates the leverage that can be obtained from such a cooperative program.

Both the COMET program and the location of WFOs on university campuses are very significant efforts for the NWS, and the Committee reemphasizes their importance. Moreover, the Committee believes that the NWS would derive significant long-term benefits from a broader and more intense effort to collaborate with the academic and industrial communities by sponsoring research and the development of new techniques. It would be able to tap a wider reservoir of new ideas, and the broader community would become aware of both the challenges and the opportunities involved in operating at the level of sophistication expected of the modernized NWS.

With respect to the private sector, NOAA's intent to improve communication and coordination seems appropriate. The response is not clear, however, concerning new resources. Nevertheless, the Committee is pleased to learn that a Constituent Affairs Officer is being assigned to each of the four NWS Regional Offices in the contiguous states. This officer should act as an ombudsman for the private sector within each region.

The Committee also recommended in the First Report that the community preparedness function at Weather Service Offices (WSOs) slated for closure be retained during the changeover. NOAA responded that maintaining a local presence in most communities with an NWS office planned for closure is under consideration. The Committee is encouraged by this and hopes that it may still be possible, with minimal staffing, to keep these offices open for some time in the future.[1]

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1 See also Chapter 1, page 8, "Community Liaison and Education."

## IMPLEMENTATION PROCESS

The Committee strongly reaffirms its recommendations in the First Report dealing with (1) the need for overall policies and procedures for the development of major components of the system and (2) the need to ensure data security. With the recent establishment of the new NOAA Systems Program Office, the Committee will monitor how well these two recommendations are being addressed. Software documentation is of critical importance, given the long time during which these new components will be in use. The Committee expects to study system security and resiliency in the near future. Both are critical in all components, but AWIPS is particularly vulnerable to improper intervention.

In its First Report, the Committee recommended the temporary augmentation of staff during implementation of the modernization. Although it may be too early, no significant augmentation is apparent. However, the Committee is encouraged by NOAA's response that expansion of transition staff is being implemented and that additional resources will continue to be sought to supplement existing staff during the modernization transition.

Regarding its concern about plans to staff WFOs at night with only one meteorologist, the Committee is pleased with NOAA's assurance that the reduced staffing level will not be implemented unless and until the technology and skills necessary to support operation with a single forecaster have been demonstrated satisfactorily.

The Committee continued to work with the NWS on the certification plan throughout 1991. Indeed, certification is the main topic of this report (see Chapter 3). The Committee looks forward to NOAA's response to the recommendations presented there.

# 3

# The Certification Process and Requirements

The certification process specified by law is a critical part of the sequence of events involved in modernizing and restructuring the National Weather Service (NWS). Certification requires demonstration that there will be no degradation in services as a result of closing, consolidating, automating, or relocating any existing NWS office. The Committee has examined the preliminary plans of the NWS for certification, to the extent they are currently formulated, and offers its advice and recommendations here.

In summary, the Committee believes that the NWS has made considerable progress in the development of a certification process that meets the requirements of the law.[1] Moreover, the certification process offers considerable additional opportunities and benefits to the NWS if that process is carefully and adequately structured. Such structuring will require a precise specification of goals, process, and expected results. Indeed, the results of the certification process may be expected to lead to improved service and greater appreciation of the benefits and value of NWS efforts. In this respect, the Committee is impressed by the plans of the NWS to consult with the users of its products and services throughout the nation regarding the modernization.

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1 The Committee views its role regarding certification as reviewing and commenting on the government's plans and proposed process in accordance with the law, not drafting the plans or process. Further, it is the position of the National Research Council that it is able to review only the generic process, not each individual certification.

## LEGAL REQUIREMENT FOR CERTIFICATION

Congressional concern about the impacts of replacing existing NWS offices with the new array of Weather Forecast Offices (WFOs), as proposed in the NWS restructuring associated with modernization, led to the certification requirements in Title IV of Public Law 100-685 (U.S. Congress, 1988). Two sections of this law are of particular relevance:

- Section 408 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 ... special measures to test, evaluate and demonstrate key elements of the Modernized National Weather Service operations prior to national implementation, including a multi-station operational demonstration which tests the performance of all components of the modernization in an integrated manner for a sustained period ... ."

The Modernization and Associated Restructuring Demonstration (MARD), planned for a period of one year in the Midwest, is the NWS primary response to the requirement of Section 407(b). The NWS considers the MARD to be the foundation of the certification process.

## CERTIFICATION ISSUES

In the Committee's view, four significant issues are associated with the certification process as specified by the law. The first issue is whether the requirement for certification should be viewed as an impediment to effecting the modernization and restructuring of the NWS or whether it should be viewed as an opportunity to demonstrate benefits and improved services. The second is the level of effort that should be invested in formal planning

and structuring of the certification process. The third issue is the extent to which the process should be unique for each site and thus the extent to which it should demonstrate improvements in service by using verification statistics from individual locations or from additional regional experiments modeled on the MARD. The fourth concerns the specification of verification statistics and the effort to be devoted to gathering and analyzing them.

## CERTIFICATION AS AN OPPORTUNITY FOR THE NWS

The requirement for certification should be embraced by the NWS as an opportunity to demonstrate improvements in service, to identify and effect additional improvements, and to secure greater public confidence, even though the legislation specifies only that NWS actions "will not result in any degradation of weather services... ."

Taking a positive approach to the certification will, in the Committee's view, provide a number of opportunities for the NWS. First, such an approach will provide convincing evidence to the executive and legislative branches of the federal government that the investments in modernization and restructuring have produced dramatically improved services and benefits. Some examples of improved services are given in Chapter 1. Second, it will increase public confidence in the NWS and its products. Third, it will enhance the morale of employees by demonstrating their effectiveness. Fourth, it will point the way to further improvements in service and products, and will provide justification for the expenditures required to effect them.

Although intended to demonstrate at least no degradation in present services, planning for an effective certification process should identify the useful functions that it also can serve, both for the NWS and for its constituency.

**Recommendation:** *The National Weather Service should focus its planning for the certification process on identifying the many potential benefits of the process for both the National Weather Service and its constituency and by setting specific goals that will realize those benefits. The certification process should be designed (1) to acquire information on specific cost savings and economic and other benefits to users of weather information and forecasts, (2) to identify user needs that are now inadequately served, (3) to anticipate the need for continuing attention to technology life*

*cycles and further modernization, and (4) to ensure the credibility of the certification.*

## CERTIFICATION PROCESS

The NWS has made considerable progress in the development of a certification process that meets the requirements of Public Law 100-685. However, the Committee believes that additional effort is appropriate now to structure the certification process itself to be a positive force by demonstrating improvements in service and thus secure greater public confidence in the NWS. The key to success lies in identification of the specific information that will be collected and analyzed. Most significantly, the control of the collection and analysis process should be specified. Careful planning and control are essential to ensure high-quality results.

In short, the Committee is arguing that the certification process must be thought through in detail. Further, it believes that the process, along with the method of information control, must adhere to a carefully specified standard (see outline in inset).

The Committee recognizes that developing plans for certification is a challenging task, but one that is essential to the success of the process. Moreover, developing detailed plans for certification according to this outline will be an iterative procedure, with goals and strategies evolving as the implications of implementing procedural steps become clear and are assimilated in the higher-order descriptions of the process (inset outline items 1, 2, and 11).

This approach will have the advantage of producing a generic specification of the certification process, as well as templates for implementing it and describing the results. This is especially important because responsibility for effecting the process will fall principally upon the Meteorologist-in-Charge (MIC) at each new WFO being commissioned. The interaction of the MICs and their staffs with users and user groups is especially critical and must be addressed in developing the standard for the certification process.

**Recommendation:** *The certification process should be thought through in detail and structured to be a positive force. It is essential to identify the specific information that will be collected and analyzed, and the process and information control scheme should adhere to a carefully specified standard.*

## DEVELOPING A PLAN FOR CERTIFICATION

The following outline is a useful checklist for preparing the detailed plan and standard for certification:

1. Specify the goals and benefits of the certification process.

2. Develop an abstract or overview of the process, indicating the strategy for attaining each goal.

3. Specify the conditions that must be satisfied before the process can begin (the entry criteria).

4. Specify the input data and information to the process and the measures that will quantify performance of the process itself; specify the interactions with user groups to be used in collecting data and information.

5. Describe the procedures that will be applied to analyze and interpret the data and information.

6. Specify the roles and responsibilities of various organizations and individuals in obtaining and analyzing the information.

7. Specify the outputs, products, and results to be obtained from the certification process and the analysis of the information.

8. Specify the evidence needed to ensure that the outputs conform to their specifications and that the process has performed as expected.

9. Describe the sequence of procedures for feeding back measures of process performance, progress reports, and output evidence to the person or entity responsible for the success of the certification process.

10. Specify the conditions that must be satisfied before the process is considered complete (the exit criteria).

11. As a summary of these steps, describe the minimum essential information that is needed to plan, schedule, stage, initiate, operate, conclude, and evaluate the effectiveness of the certification process.

Note: adapted from IEEE Computer Society, 1989.

## LOCAL EMPHASIS IN CERTIFICATION

The requirement for certification might be satisfied by the NWS verifying no degradation in service at a location being certified by drawing an analogy to the results obtained in other locations or by using local results to compare the old and new systems. Current preliminary plans of the NWS are to base the certification of individual weather offices on the

results of the MARD, a major demonstration to be conducted for one year in the Midwest; some more limited regional demonstrations in different climate regimes; and on verification statistics collected at stations that have already been certified, rather than using verification statistics on the performance of the new office to be certified. This approach will allow certification of service in a specific area shortly after the Advanced Weather Interactive Processing System (AWIPS), the last scheduled component of the current modernization, has been installed in the last WFO with responsibility for part of the area of concern. However, this approach precludes the use of local verification statistics, except some warning statistics.[1] The major justification for this approach is the NWS argument, with which the Committee agrees, that verification statistics must be collected for at least one year to be meaningful.

An alternative to the demonstration-by-analogy approach is the use of local verification statistics. Collecting local verification statistics for at least one year would require parallel operations of existing stations and new WFOs for extended periods. According to NWS estimates, extending the time between commissioning of the AWIPS at a new WFO and certification, to allow the use of local verification statistics, would increase the cost of the transition by some $56 million.

The advantage of local verification is that certification can be made more convincing by providing local emphasis through the monitoring of local experience with the new system: (1) local verification statistics would be more convincing to local users and legislators, (2) they would stimulate improved service locally; and (3) their collection and interpretation should promote stronger interaction with local user groups. These benefits might outweigh the additional costs incurred in providing parallel services. However, parallel operations present the difficult issue of determining whether the services provided to the public would be furnished by the present offices or by the new offices equipped with the latest technology. In either case, one set of products would be prepared for the record rather than for public consumption. Those who prepared them would be deprived of this principal stimulation and motivation enjoyed by NWS employees.

Other alternatives are possible as well. The NWS now plans to supplement the MARD with some additional demonstrations at sites typifying

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1 As stated in Chapter 1, the AWIPS is critical to the modernization and satisfactory conduct of the MARD; MARD is to be the demonstration called for in Public Law 100-685 as one component of the certification process.

other regions of the country, such as desert, coastal, and mountainous areas. The Committee agrees that these additional demonstrations are essential. Another alternative would be for Congress to permit the NWS to proceed with its plans to restructure the national configuration of offices based on the MARD results, with improvements in the region served by each WFO to be demonstrated a year or more after it is in full operation. This approach would provide a stimulus to both local forecasters and NWS managers to ensure that the new WFO's services are an improvement over those previously available.

**Recommendation:** *The Committee believes that significantly greater consideration should be given to the verification alternatives by the National Weather Service. The Committee prefers the alternative of restructuring the national configuration of offices based on the Modernization and Associated Restructuring Demonstration results, with improvements in each affected area served by a Weather Forecast Office to be demonstrated a year or more after it has been in full operation. Nevertheless, the Committee is aware that this would necessitate a change in the law. Except for its cost, the Committee would prefer the local verification approach. Clearly, the advantages and disadvantages of the various approaches must be explicated and evaluated by the National Weather Service.*

## VERIFICATION AND INTERACTION WITH USER GROUPS

Clearly, the objective of the modernization and restructuring of the National Weather Service is to provide improved weather services to a wide range of users. The certification process can be viewed as both an opportunity and a requirement to demonstrate that this improvement is being realized. The Committee believes that the new technology, new office structure, and renewed emphasis on training and professional skills will indeed produce greatly improved weather services and severe weather warnings. Nevertheless, it will be essential to demonstrate those improvements quantitatively and convincingly. Thus, a key aspect of planning for certification is to specify appropriate verification statistics and processes and to design useful interactions with users and user groups.

The Committee offers the following observations to assist the NWS in developing its plan for verification as part of certification.

- The NWS serves a broad range of users and user groups with a remarkable range of general and specific forecasts and warnings. To provide comprehensible results, it is essential that data and information gathered for certification be organized by both product groups and user groups. One might begin with a two-dimensional matrix, listing user groups (e.g., general public, agriculture, construction, municipalities, emergency managers, aviation) as the columns and products (e.g., freeze warnings, strong-wind warnings, terminal forecasts, maximum and minimum temperature forecasts) as the rows. The importance of each product to each user group could be assessed on a tripartite scale (say, of slight, moderate, or critical interest). A selection of products of critical interest to key user groups in each affected area[1] would provide a subset to be emphasized in certification. Moreover, this matrix approach could serve as the basis for interaction with various user groups, to refine the NWS's understanding of their needs and expectations, and to refine the users' understanding of what they can realistically expect to receive. Part of this process could be an analysis of the changes to be expected on completion of the modernization and associated restructuring, compared to the premodernization era. Any weak points identified could be examined to determine how they could be ameliorated.
- Verification statistics collected for the certification should concentrate on warnings plus short-range and midrange forecasts; that is, the first 12 to 24 hours should receive the greatest emphasis,[2] with less emphasis on 48-hour forecasts.
- The severe weather watch and warning verification program, as now operated by the National Severe Storms Forecast Center, includes the variables necessary to validate the expected improvement in severe weather watches and warnings. Comparisons of watches and warnings before and after implementation of modernization should provide the data necessary to support certification.
- Verification statistics for routine forecasts should emphasize events and extremes, rather than averages. Accuracy and timing of severe weather warnings are of first importance. Rather than comparing mean

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1 The area affected by the closing, consolidation, automation, or relocation of an NWS office.

2 This is the time range of warnings and forecasts that will benefit most from the new technology being introduced in the NWS modernization.

errors of temperature forecasts, it would be more useful to analyze and verify predictions of maximum and minimum temperatures or of the magnitude and time of large temperature changes. Similarly, verification of precipitation forecasts should concentrate on rewarding accuracy in predicting the timing and intensity of events and penalizing generalities such as "showers today and tonight."

- A comparison of forecast language before and after modernization actions should also demonstrate that forecast products have become more useful by becoming more specific and more timely. Verification of such forecasts will require schemes based on timing and intensity, as suggested in the preceding paragraph.
- The NWS should give renewed attention to the very difficult problem of evaluating aviation forecasts. The modernization should produce better terminal, route, and area aviation forecasts and more timely amendments as changing conditions become more accurately and promptly detected and evaluated. Meaningful ways to demonstrate these expected improvements should be developed.
- Some measures of the timeliness with which observations, forecasts, and warnings are delivered to users should be included in the statistics to support certification. Modernized WFOs should demonstrate quite clearly that the speed of delivery of key products is greatly improved.

The Committee is mindful of the fact that a verification program such as it suggests above is more extensive and sophisticated than that now contemplated by the NWS. Designing and implementing such a program will require thought and considerable effort. In the Committee's view, the benefits will justify this additional investment in the certification process.

**Recommendation:** *The Committee suggests a more extensive and sophisticated verification program than that now contemplated by the National Weather Service because it will be essential to demonstrate the improvements resulting from the modernization quantitatively and convincingly. Appropriate verification statistics and processes, such as those suggested by the Committee, need to be specified, including their application and importance to various categories of users.*

## DISSEMINATING THE RESULTS

A final and critical part of the planning for certification should address issues related to relations between the public and the NWS. The NWS has already initiated contacts with user groups and government officials at the state and local level. Since the Committee believes that the modernization will produce dramatically improved service and enhanced public benefits, it also believes that the NWS must convincingly demonstrate these improvements to the public.

Verification statistics have been gathered routinely by the NWS for decades, but the results are rarely seen by the public. A primary reason is that most current procedures are technical and not easily explained to the public. The consequence is that the public relies on intuition to form a subjective opinion, one that discounts many successes because of an occasional error.

**Recommendation:** *It is critical that the certification process involve interaction with users and user groups, first to determine what they consider their needs to be and then to demonstrate that those needs are actually being met. A public relations program aimed at providing the media with factual summaries of forecast accuracies in easily comprehensible terms should be developed and made a part of the responsibilities of each Weather Forecast Office.*

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# Appendix A

# Summary[1]

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

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1 This is a reproduction from the First Report of the Committee on National Weather Service Modernization (NRC, 1991).

Modernization Committee[1] of the National Research Council (NRC) 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 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.**

■ **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**

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[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.

**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 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. 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 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, 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.**

## 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 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.**

## 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.

■ **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.

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 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:

■ **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 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.

# Appendix B

# Review of Recommendations in the First Report

In the following, the recommendations of the National Research Council's (NRC) National Weather Service (NWS) Modernization Committee, taken from its First Report (NRC, 1991), are given, followed by the response of the National Oceanic and Atmospheric Administration (NOAA). This detailed response was dated August, 1991. Where later developments are known to the Committee, NOAA's response has been updated. Finally, the Committee's analysis of the response is presented. The section titles in this appendix are the same as those in the First Report and in Chapter 2 of this report for ease of cross-reference.

## BROAD RECOMMENDATIONS

The First Report set forth four broad recommendations dealing with (1) the need for adequate financial and personnel support for the modernization, (2) strengthening of management, (3) use of advisory panels, and (4) the need to continue modernization after the modernized weather system now being developed has been deployed, including the Next Generation Weather Radar (NEXRAD), also known as the Weather Service Radar-1988 design, Doppler (WSR-88D), the Automated Surface Observing System (ASOS), the Next Generation Geostationary Operational Environmental Satellite (GOES-Next), and the Advanced Weather Interactive Processing System (AWIPS).

## Financial and Personnel Support

**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.*

**NOAA Response:** NOAA, the Department of Commerce (DOC), and the Administration strongly support NWS modernization and associated restructuring as evidenced by a continuing commitment to fund the modernization program during difficult budget times. One of the first things Secretary Mosbacher did upon taking office was to direct NOAA to assure that there would be no degradation of weather support for this country as a result of modernization of the NWS. Every action the Secretary has taken since supports this resolve, and he has maintained an active interest in the program. The NWS modernization has been, and remains, the highest priority program within NOAA. NOAA will continue to pursue completion of NWS modernization and associated restructuring as aggressively as possible.

**Committee Response:** Despite the assertion of high priority in the NOAA response, the Committee remains concerned that funding will be inadequate to meet the schedule in the National Implementation Plan (DOC, 1991). If the schedule continues to be stretched out, there is an increasing likelihood that the quality of the present weather service will degrade, as discussed in Chapter 1. A prime example is the apparent delay in the funding and contract award for a full start-up of AWIPS, the critical component for integrating all of the new data and for preparing warnings and forecasts.

## System Management

**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.*

**NOAA Response:** DOC has established a new Systems Program Office (SPO) reporting to the Deputy Under Secretary for Oceans and Atmosphere. The SPO will bring improved systems development and acquisition talent to bear on all four of the systems in the NWS modernization and

associated restructuring program. The SPO will consolidate relevant system acquisition components in the NWS; the National Environmental Satellite, Data, and Information Service (NESDIS); and DOC Major Systems Procurement Division. This office will streamline and strengthen program management by assigning full responsibility for the design, procurement, and acceptance of new systems in a single office. NOAA believes this action will greatly improve its ability to meet critical time schedules and cost estimates. The NWS will retain responsibility for establishing the requirements for systems' capabilities required to support modernization. In addition, this change will allow NWS management to concentrate on the facility planning and construction, training, staff restructuring, and service aspects associated with the program--each of which is vital to an improved NWS. NOAA does not see any significant change in the role of the NRC Committee in light of the SPO. The NWS and the SPO will jointly participate in future NRC Committee activities.

**Committee Response:** The Committee has noted the establishment of the new NOAA Systems Program Office (SPO) as discussed in Chapter 1. Use of a SPO can be an effective mechanism, but only if staffed with the appropriate number of qualified technical and management people and, importantly, if it keeps the needs of the operator of the system (i.e., the NWS) closely in mind and ensures good communication with the operator. The portion of the Committee's recommendation dealing with additional resources and personnel is discussed below in the section "Implementation Process."

## Technical Advisory Panels

**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.*

**NOAA Response:** NOAA recognizes the importance and value of technical advisory panels and has utilized this vehicle a number of times already on NWS modernization. Some examples which the NRC Committee is already familiar with are: The Advisory Committee for NEXRAD Systems Requirements Evaluation, chaired by Mr. Raymond G. Kammer (September 1985); National Bureau of Standards Review of the AWIPS Procure-

ment, led by Dr. Merrill M. Hessel (August 1988); National Institute of Standards and Technology Panel Review of the AWIPS Program at the Definition Phase, chaired by Dr. Merrill M. Hessel (September 1989); and The ASOS Interagency Test Review Board (September 1990). NOAA will continue to utilize technical advisory panels in the future.

**Committee Response:** The response of NOAA with respect to the use of technical advisory panels is inadequate. The Committee recognizes that panels have been used on an ad hoc basis in the past but reiterates its recommendation for standing panels composed of outside experts for each of the major components of the new system.

## Additional New Technology

**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.*

**NOAA Response:** A wide range of research programs are in place, within NOAA and in cooperation with academic communities and other agencies of the Federal Government, that provide for the transfer of scientific and technological knowledge to the NWS modernization program and go beyond ASOS, NEXRAD, AWIPS, and GOES. Some examples of these are: A demonstration network of vertical wind profilers is being installed across the central part of the Nation. A total of 25 profiler systems are being installed this year, and the wind data from these systems will be made available to NWS offices. NWS will be conducting an assessment of the utility of the wind profiler data this coming year. Research on thermodynamic profilers continues. A request for proposals to acquire lightning data for use by NWS field offices is being prepared. The AWIPS program has been structured to take advantage of improved computational capabilities as they become available. NOAA's Forecast Systems Laboratory is one of the major contributors to the NWS modernization program through its Program for Regional Observing and Forecasting Services (PROFS) project. The PROFS mission is to improve operational weather services by testing and transferring advances in science and technology to the NWS.

**Committee Response:** NOAA will require a strong commitment, top-level support, and carefully phased spending plans to continue modernization, for example, through the addition of profilers, a permanent lightning detection network, and a replacement for the present upper air observation system.

## OBSERVATION COMPONENTS

### Next Generation Weather Radar

**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. 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.*

**NOAA Response:** The National Severe Storms Laboratory's (NSSL) successful results in the field of Doppler radar were important precursors to the NEXRAD program and NSSL continues to support that program in critical ways. NSSL has developed, refined, and improved a number of algorithms planned for use in NEXRAD. NSSL also prepares studies on mesocyclones in attempts to discriminate between tornadic and non-tornadic mesocyclones. Output from these efforts will feed into the development of enhanced algorithms for the NEXRAD system to improve severe weather forecasting performance at NWS offices. The WSR-88D Operational Support Facility will play a key role in furthering the development and improvement of NEXRAD algorithms and ensuring their introduction into NWS field offices. The modernization depends upon the new technology working well to deliver the kinds of information needed by forecasters. But the modernization will fail if NOAA does not have well-trained staff in the offices of the future. NOAA is concentrating on the training requirements for all categories of employees to provide them with the intellectual tools they need to make good use of the technological capabilities represented by these systems. Every one of the operational employees will be offered a significant amount of training and professional development.

**NOAA Update:** The Office of Hydrology has developed, refined, and improved a three-stage precipitation processing system for deriving quantitative precipitation estimates from the NEXRAD. Four-week NEXRAD (WSR-88D) operations training courses began in September 1991. All NWS operational meteorologists and hydrologists will take this course after

using on-site training materials (workbooks and video tapes). The classes combine Doppler radar theory and hands-on case studies played back on student work-stations. All electronic technicians and electronic system analysts will learn about the WSR-88D system through a combination of resident classes at the NWS Training Center and on-site training materials.

**Committee Response:** The Committee is encouraged that the NEXRAD program now appears to be back on track. Committee members were impressed, during site visits, with the operation of the Norman, Oklahoma, and Sterling, Virginia (near Washington, D.C.), radars even though they were still undergoing engineering tests. The response of NOAA concerning algorithm development, improved precipitation processing, training, and education is commendable.

## Automated Surface Observing System

**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.*

**NOAA Response:** NOAA recognizes the value of local and state observational resources and will aggressively seek these out to supplement ASOS. In addition, NOAA is exploring technologies and data sources to complement the ASOS observation.

**Committee Response:** The response of NOAA is positive; the Committee looks forward to learning of the progress made in obtaining supplemental observations.

## Funding for Satellites

**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.*

**NOAA Response:** The technical, cost, and schedule problems with GOES I development have been well documented. Secretary Mosbacher and Under Secretary Knauss are giving the GOES situation their personal attention. Currently, the present GOES 7 is working very well, and NOAA believes it is likely that it can continue to provide full service through 1993 and partially degraded service through 1995. NOAA is aware that continued contractor delays coupled with a premature failure of GOES 7 could leave the United States without any geostationary satellite capability which would severely impact the ability of the NWS to deliver accurate and timely warnings and forecasts of severe weather. NOAA has, therefore, developed a No-GOES Plan. The plan consists of using NOAA and Department of Defense polar orbiting satellites to generate composite snapshot images of the United States, increasing the availability of all polar-orbiter data throughout NWS offices, relying more on European geostationary satellite coverage over the Atlantic Ocean, and increasing the use of conventional radiosonde and buoy data. The Europeans have agreed to move an older Meteosat satellite over the mid-Atlantic, providing coverage over the eastern portions of North America. It may even be possible to move this satellite to a position even further west to provide greater U.S. coverage. The No-GOES Plan is the best "fix" available for a short-term interruption in GOES coverage. However, these measures fall far short of constituting an adequate substitute for GOES 7. NOAA is exploring other options to provide alternate sources of data for a longer "No-GOES" period, including borrowing a Japanese GMS satellite and evaluation of whether to proceed with a "gap-filler" GOES-7 clone satellite. The polar satellite program is in much better shape. NOAA, DOC, and the Administration strongly support and will continue to seek necessary funding for these vital programs.

**Committee Response:** The Committee supports the decision of the Secretary of Commerce to proceed with the current GOES-Next program by completing and launching a thoroughly tested, specification-compliant GOES-I, and to provide a backup to the present GOES 7 by using the European Meteosat 3 geostationary weather satellite, moved from viewing Europe to covering the western Atlantic and the United States. The communications link between the NOAA satellite station for GOES at Wallops, Virginia, and the Meteosat station in Darmstadt, Germany, established to facilitate this move, should benefit both the United States and Europe in future cooperative operations. The Committee is still concerned about the

possible loss of satellite service in the future because the funding of the GOES-Next geostationary satellite program is too limited. A minimum of two fully operational satellites in orbit, plus one available to be launched and a fourth nearing completion (in case of a launch failure), is required to ensure continuity of operational coverage.

## Climate Data Record

**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.*

**NOAA Response:** NOAA recognizes the importance of preserving the data quality for climatic purposes. Several steps are being taken. NOAA will continue the NWS Cooperative Weather Observer Program which provides climatological and hydrological data taken at 11,000 locations by volunteer observers. NOAA will also conduct a Climate Data Continuity Project, with the objective of determining any systematic differences (biases) that exist between the climate record as recorded by the ASOS and the historical climate record at NWS first order stations and to document those differences. The change in the observing system with ASOS will mean changes in instrumentation, procedure, data archival, and in some instance relocations. The determination and application of biases to ASOS observational data will ensure a continuous climate data record upon which time series analyses can be performed without fear of contamination of the record by changes in the way observations were taken. Initially, it is planned that NWS staffed locations will provide comparative observations at a subset of the 16 ASOSs to be deployed in the central United States during 1991. This study will consist of at least 1 year of comparative observational and ASOS data. The comparative observations will consist of daily liquid precipitation accumulation observations with standard weighing rain gages and maximum and minimum temperatures and 6-hour temperature and dew point observations with liquid-in-glass thermometers in standard instrument shelters located adjacent to the NWS office. In addition to these comparative observations, six-hourly observations of sky condition, visibility and obstructions to vision, and present weather will be taken to aid in the analysis. A comparative study will be conducted using 1 year of observations. Observations will be continued during the course of the study to maintain continuity.

**NOAA Update:** The NOAA Climate Data Continuity Project began in FY 91. The objective of the project is to determine and document any biases that exist between the climate record as recorded by the ASOS and the historical climate record at NWS first order stations for 24-hour accumulated precipitation and daily maximum and minimum temperature. Data collection will start with ASOS commissioning beginning in the spring of 1992.

**Committee Response:** The Committee believes that comparing one year of observations from a subset of 16 ASOS units deployed in the "central United States" is inadequate to test for bias in the climate record in other meteorological regimes, such as desert, coastal, and mountainous. Concerning climate in general, it is not clear that there is a NOAA-wide plan for the acquisition and archiving of climate data from all sources, including requirements for parameters, accuracies, locations, what is to be saved, etc. More attention should be given to the synergistic use of all of NOAA's modernized observing units for climate monitoring. Additional preliminary findings on data for climate studies from the NRC Climate Research Committee of the Board on Atmospheric Sciences and Climate appear in Appendix C.

## NEW INFORMATION COMPONENTS: AWIPS

**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. 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.*

**NOAA Response:** NOAA, DOC, and the Administration strongly support the AWIPS program. The fiscal year 1992 President's budget includes funding for award of the development phase contract. The development, deployment, and operation phase proposals for AWIPS were received from the two contractors in February 1991. The evaluation of those proposals is currently underway. NOAA expects to award the AWIPS contract to the successful offerer in March 1992. NOAAPORT will provide communications support for the operational distribution of the centrally collected data and centrally produced analysis and guidance products, as well as the

satellite imagery and sounding data processed by NESDIS. In addition to supporting the requirement for AWIPS point to multipoint communications, NOAAPORT will also deliver a wide range of NOAA products, such as oceanographic and environmental data, to external users, including other government agencies, universities, private research organizations, and business interests.

**NOAA Update:** Evaluation of Development, Deployment, and Operations Phase proposals continues and software risk reduction tasks are being completed under the current extension of the definition phase contract. Based largely on findings from these major activities, the program schedule for the follow-on phases is currently undergoing a comprehensive review. A formal rebaselining of the schedule is expected to be completed in February, 1992. Award of the development phase contract in early FY 1993 is anticipated. An additional follow-on extension to the definition phase contracts is being planned to keep the critical nucleus of each definition phase contractor team intact until development phase contract award.

**Committee Response:** The Committee is increasingly concerned that funding for AWIPS may be inadequate for NOAA to pursue this essential program vigorously and without further delays. Committee members were impressed with AWIPS research at NOAA Environmental Research Laboratories as manifested in the pre-AWIPS units operating in Boulder, Colorado, as well as at the NWS forecast offices in Denver, Colorado, and Norman, Oklahoma.[1] The need for AWIPS is compelling, and program implementation should not involve high-risk developments. The NWS meteorologists must have the capability to acquire, integrate, and process all the data to be available in the modernized system in order to generate and disseminate in a timely manner detailed and accurate warnings and other products. Full AWIPS capability will not be available in the Modernization and Associated Restructuring Demonstration (MARD), which will compromise the results because of delayed development of software for full data integration and interpretation. The Committee is very concerned about recent delays in the implementation of AWIPS. Award of the developmental-phase contract has slipped as much as one year from the date projected by NOAA in August 1991. This will further delay the MARD and the implementation of the modernization.[2] Personnel savings proposed as a result of modernization cannot be achieved without full

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1 See insets in Chapter 1.

2 See Figure 1, page 2 for implementation schedules.

implementation of AWIPS. The Committee also remains concerned about the adequacy of plans for the dissemination of data and information to the private sector.

## NEW STRUCTURE OF THE NATIONAL WEATHER SERVICE

### The Number of Weather Forecast Offices

**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.*

**NOAA Response:** As the NRC report points out, "a configuration of significantly fewer than 115 Weather Forecast Offices will lead to serious degradation of weather services." NOAA agrees with this statement and is unaware of any support in DOC for a two-tiered MARD test. In fact, the Secretary of Commerce recently signed the fiscal year 1991 annual update to the National Implementation Plan which describes the 115 WFO concept underpinning the modernization and associated restructuring. Similarly, testimony of Administration officials before the Congress continues to support the Strategic Plan. NOAA, therefore, believes that the Department's policy has not been changed from the full 115 WFO concept.

**Committee Response:** The Committee is gratified to learn that the general structure of MARD has not been changed. It remains convinced that 115 WFOs is near the minimum required for an effective weather service in the United States.

### Hydrology in the National Weather Service Modernization

**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.*

**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.*

**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.*

**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.*

**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.*

**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.*

**NOAA Response:** NOAA has recently installed prototype equipment at Norman, Oklahoma, with the goal of emulating a WFO. At Norman, NOAA will have a prototype of the modernized WFO that will be put in place across the country. NOAA has also started a risk-reduction activity at Tulsa to demonstrate AWIPS-era RFC operations and interactions with the Norman WFO. Evaluation of the Norman and Tulsa risk-reduction projects will include the central data feed, the interface between the NEXRAD and the pre-AWIPS workstation, WFO staffing configuration, WFO and RFC services, WFO and RFC operations, and the interface between the WFO and RFC. Each of these risk-reduction programs increases confidence in NOAA's ability to execute the Strategic Plan for the Modernization and Associated Restructuring of the National Weather Service. NOAA believes that the results also will increase the public's confidence in the modernized NWS.

**NOAA Update:** NOAA has developed a comprehensive plan (NWS Office of Hydrology, 1991) in support of the modernization of the Weather Service, to more closely couple and enhance hydrologic and meteorological operations and services through new hydrologic and hydrometeorological operations; new training programs to enhance interaction and transfer of information between hydrologists and meteorologists; improved technology; and a detailed concept for hydrometeorological system support.

**Committee Response:** The response of NOAA regarding hydrology risk reduction activities at Norman and Tulsa, Oklahoma, is quite positive. The Committee looks forward to examining the new plan for hydrometeorological service operations (NWS Office of Hydrology, 1991), particularly with regard to other recommendations in the First Report, including the use of improved quantitative precipitation forecasts and associated uncertainties in hydrologic models, cross-training of meteorologists and hydrologists, development of software for AWIPS work stations in the River Forecast Centers (RFCs), and the serious issue of the validity of using the same NEXRAD precipitation algorithm in all conditions and locations.

## NEW AND STRONGER COLLABORATION

### Universities

**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.*

**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.*

**NOAA Response:** The modernization of the NWS is truly a national program. NOAA is doing all it can to enlist the assistance of the national academic community. NOAA is striving to collocate as many new offices as is economically and operationally feasible with academic facilities in an effort to promote a closer interaction between the researchers and practitioners of the meteorological and hydrological sciences. The collocation of NWS's Norman, Oklahoma, facility with NOAA's NSSL and the University of Oklahoma's School of Meteorology has been invaluable in helping make significant progress in improving the understanding of severe storms and the ability to forecast them. NOAA is also working closely with the academic community through the Cooperative Program for Opera-

tional Meteorology, Education, and Training, a program conducted by the University Corporation for Atmospheric Research through a cooperative agreement with the NWS.

**NOAA Update:** It is now proposed to collocate nine WFOs with universities and nine with research institutes. A "Strategic Plan for Collaborative Research Activities Between National Weather Service Operational Offices and Universities," is in final draft form. The plan includes the framework for collaborative research activities at Weather Forecast Offices (WFOs), Experimental Forecast Facilities (EFFs), and RFCs. The EFFs will pursue an organized program of operational research conducted by a staff of research forecasters. EFFs have been established at the Weather Service Forecast Office (WSFO) at Denver, Colorado; the WSFO at Norman, Oklahoma; and the National Severe Storms Forecast Center at Kansas City, Missouri. A fourth EFF may be established at the National Meteorological Center in Camp Springs, Maryland.

**Committee Response:** Although NOAA's response is generally positive, questions remain concerning the scope of collaboration and the strength of its resolve.

Although NOAA plans to collocate nine WFOs with universities, the Committee understands that there are procurement issues to be faced in other places. In some instances, a difficult choice must be made among competitive proposals; in others, a perceived lack of competition may be a concern. The Committee believes that much more can be accomplished if top-level attention is devoted to the issue; the benefits to be derived warrant this attention.

The early and dramatic success of the Cooperative Program for Operational Meteorology, Education, and Training (COMET) provides convincing evidence for this view. The COMET outreach program has already led to 19 cooperative research projects located at 17 universities throughout the nation. These projects are addressing a wide range of forecasting problems of immediate and significant concern to the NWS. They provide excellent opportunities for students and faculties to contribute to improved forecasting techniques. These opportunities should lead to more motivated faculties and better-trained students, many of whom will serve as NWS employees in the future. The projects should also improve relationships and collaboration between the universities and the NWS. Moreover, these accomplishments are being achieved with a very modest budget, which demonstrates the leverage that can be obtained from such a cooperative program.

Both the COMET program and the location of WFOs on university campuses are very significant efforts for the NWS, and the Committee reemphasizes their importance. Moreover, the Committee believes that the NWS would derive significant long-term benefits from a broader and more intense effort to collaborate with the academic and industrial communities by sponsoring research and the development of new techniques. It would be able to tap a wider reservoir of new ideas, and the broader community would become aware of both the challenges and the opportunities involved in operating at the level of sophistication expected of the modernized NWS.

## Private Sector

**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.*

**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 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.*

**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.*

**NOAA Response:** A vital element of NWS modernization is the External and Internal Communication Program. This program involves the design, execution, monitoring, and evaluation of a systematic NWS effort to provide a forum for external and internal technical coordination and communication exchange which will help to achieve external and internal

awareness, cooperation, and support for the end goals of the modernization. NWS must fully inform all affected individuals and organizations regarding the goals and objectives of the modernization and associated restructuring, the changes that are planned, and a demonstration of the capability to attain these goals. This can only be accomplished through careful planning, good management, and close coordination between all levels of staff, users, and other interested constituencies. These constituencies consist of: Congress, governors, other Federal agencies, private industry users and equipment/software manufacturers, the scientific community, universities, cooperative institutes, the media, trade associations and professional societies, and the general public. Coordination with these groups will take place in parallel on national, regional, state, and local levels. In large measure, this coordination and interaction must and will be accomplished by NOAA and NWS managers at all levels utilizing the existing organizational structure. NOAA will, however, aggressively seek any additional resources necessary to successfully implement this important program.

**NOAA Update:** Constituent Affairs Officers already have been assigned to three of the four NWS Regional Offices in the contiguous 48 states.

**Committee Response:** With respect to the private sector, NOAA's intent to improve communication and coordination seems appropriate. The response is not clear, however, concerning new resources. Nevertheless, the Committee is pleased to learn that a Constituent Affairs Officer is being assigned to each of the four NWS Regional Offices in the contiguous states. This officer should act as an ombudsman for the private sector within each region.

## Public Institutions

**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.*

**NOAA Response:** Each WFO will be staffed with a full-time Warning

Coordination Meteorologist (WCM) who will interact with users in the WFO's area of responsibility. WCM preparedness responsibilities include: creating and maintaining spotter networks; educating local government officials about proper actions to protect life and property during severe weather; working with other Federal agencies and city, county, and state officials in anticipating and conducting weather-related disaster prevention operations for the public safety; and working with the media in developing public awareness of the threat of severe weather events and in devising the most effective means for rapid warning dissemination. During severe weather outbreaks, the WCM will make sure that spotter networks are activated and Emergency Operations Centers and other local agencies are notified. The advisability of maintaining a local NWS presence after certification, at least on a temporary basis, for most communities with an NWS office planned for closure is currently under consideration within DOC.

**NOAA Update:** The WCM also will assess the critical information needs of the entire hazards community and develop operational methodologies and capabilities to meet stated requirements within the constraints of the science and technology.

**Committee Response:** The response of NOAA is encouraging; the Committee hopes that it may still be possible, with minimal staffing, to keep open for some time in the future the Weather Service Offices (WSOs) now slated for closure.[1]

## IMPLEMENTATION PROCESS

### Policy and Procedures for Development of Systems, System Security

**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.*

**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.*

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1 See also Chapter 1, page 8, "Community Liaison and Education."

**NOAA Response:** As the NRC report points out, NOAA relies on its system contractors to provide their own well-understood and tested standards and methods. As a normal part of contract management, NOAA monitors contractor compliance and performance very closely but will take this recommendation to establish overall policies under advisement. NOAA looks forward to working with the NRC Committee in more detail on system security in the coming year.

**Committee Response:** The Committee strongly reaffirms these two recommendations. With the recent establishment of the new NOAA Systems Program Office, the Committee will monitor how well these two recommendations are being addressed. Software documentation is of critical importance, given the long time during which these new components will be in use. The Committee expects to study system security and resiliency in the near future. Both are critical in all components, but AWIPS is particularly vulnerable to improper intervention.

## Temporary Management and Project Staff

**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.*

**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.*

**NOAA Response:** As a matter of policy, the NWS has adopted a management philosophy for the transition that, to the maximum extent possible, utilizes the existing organizational structure to plan and implement all transition activities. As the transition proceeds, ongoing operational support activities become inexorably linked to modernization activities. This approach is particularly efficient since, as the new system programs mature, support for the corresponding existing systems that are being replaced can be phased down and resources can be reallocated. However, NOAA recognizes that not all the resources necessary to accomplish the transition can be reprogrammed internally. Program offices for each of the new systems were established and included plans for the phased build-up and draw-down of staff commensurate with program maturity. Transition staffs were established at NWS Headquarters and each of the NWS regional

headquarters. Plans for expansion of these transition staffs are being implemented. NOAA will continue to seek additional resources necessary to supplement existing staffs during the transition.

**Committee Response:** Although it may be too early, no significant temporary augmentation of staff is apparent to the Committee. However, it is encouraged by NOAA's response that expansion of transition staff is being implemented and that additional resources will continue to be sought to supplement existing staff during the modernization transition.

## Operational Staff at Weather Forecast Offices

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

**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.*

**NOAA Response:** All aspects of modernization and associated restructuring will be thoroughly tested through prototyping, risk-reduction activities, and operational demonstrations before being fully implemented into the field environment. The ability to operate a WFO with a single meteorologist a shift requires systems capabilities, particularly in AWIPS, that will not be present when the systems are initially deployed. The so called "AWIPS-deferred capabilities," as well as other system upgrades that will permit these productivity savings to be achieved, will be introduced into the field offices in a carefully phased manner. After the introduction of these system capabilities at several advanced development sites (e.g., Denver), an assessment will be made of both the maturity of operations (systems, staff, training, etc.) and the ability to reduce staffing levels without degrading services. Only after a successful operational demonstration will full field implementation take place and staff be drawn down to Strategic Plan target levels.

**Committee Response:** The Committee is pleased with NOAA's assurance that the reduced staffing level will not be implemented unless and until the technology and skills necessary to support operation with a single forecaster have been demonstrated satisfactorily.

## Certification

The NRC Committee had not received a detailed certification plan to review, and, therefore, the First Report provided no recommendations. The report did, however, offer two initial observations by the NRC Committee: "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."

**NOAA Response:** NOAA continues to work closely with the NRC Committee on this very important aspect of modernization and associated restructuring. Since the NRC report was issued, NOAA has prepared several drafts of a certification plan and held working sessions with NRC Committee members and staff to review the drafts in detail. Input and advice obtained through these interactions are being used to modify the certification plan. NOAA believes that the certification plan has evolved to the point where it is ready for full NRC Committee review and endorsement.

**Committee Response:** The Committee continued to work with the NWS on the certification plan throughout 1991. Indeed, certification is the main topic of this report (see Chapter 3). The Committee looks forward to NOAA's response to the recommendations presented there.

# Appendix C

# Climatological Considerations of the National Weather Service Modernization Program[1]

## PREFACE

In its first report, the Committee on the Modernization of the National Weather Service (NWS) raised concerns and made some recommendations regarding the impact of the NWS modernization on the viability and integrity of the climate data record. The Committee asked the Climate Research Committee (CRC) to examine the topic in detail. The following is a preliminary report on the CRC study.

## BACKGROUND

The CRC is in the midst of a one-year critical assessment of the atmospheric observations and data management required to support climate and climate change research. The CRC expects to complete its final report during the calendar year of 1992. At this time however, the CRC welcomes the opportunity to provide some early recommendations regarding the implementation of various new observing systems within the NWS.

There is no doubt that the advent of several new observation systems within the NWS will lead to profound advances in our understanding of meso-scale and synoptic-scale atmospheric processes. For example, observations from a national network of Next Generation Weather Radars (NEXRAD, or WSR-88D) and atmospheric wind profilers will afford a view of the atmosphere not previously available to atmospheric scientists. The introduction of the NWS's Automated Surface Observing System

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1 From the Climate Research Committee, Board on Atmospheric Sciences and Climate, National Research Council.

(ASOS), anticipated to begin becoming operational in 1992, with a several-fold increase in the spatial coverage of the station network by 1995, will provide a more comprehensive weather watch than is presently available. In addition to their operational utility, these observation systems will be the foundation of state-of-the-art research on atmospheric processes.

A comprehensive understanding of the Earth's climate system and its feedback to socioeconomic and biogeophysical systems, however, requires knowledge of atmospheric properties on various time and space scales. In earlier decades, climatologists used operational weather networks to define the climate based on limited sampling strategies, such as 30-year normals of various time averages (diurnal, daily, monthly, seasonal, annual, etc.) for various space scales (stations, climate divisions, hydrologic drainage basins, etc.). Up until the last few decades, climate was generally viewed as a stationary system, stationary at least within one human lifetime. Given this assumption, classical statistical sampling theory could be used to project the statistical ensemble of climate and weather over future time intervals. Over the past several decades however, and especially during the most recent decade, climatologists and atmospheric scientists have argued that a more dynamic climate system exists, one that accommodates various statistical representations, including stable climate statistics such as those derived from 30-year climate normals. For example, a consensus is emerging in the science community that climate is not only subject to the rapid variations that can arise from a nonlinear chaotic system but also to changes arising from human activities as well. For this reason, a new burden is placed on the National Oceanic and Atmospheric Administration's (NOAA) operational observing systems. Specifically, these systems must be able to provide the information necessary to document, detect, and help understand climate variation and change. In order to meet this challenge it would be prudent, cost-effective, and practical to rely on the infrastructure already developed for existing weather observing systems to carry out this very important national and international responsibility, with the recognition that part of this responsibility is demonstrating to an international community that both climate and operational weather requirements can largely be met by an observing network justified primarily by operational weather needs.

The CRC recognizes the considerable amount of information and knowledge that has already been learned about climate variation and change from NOAA's existing weather networks. However, the CRC is concerned about a number of issues that, in order to fulfill a climate-related mission, should be addressed by NOAA in the operation of observation systems and

the management of data. The CRC notes a significant deterioration over the past several decades of the infrastructure within NOAA to support basic measurements and management of data from existing weather networks. This arises just at a time when these observations are becoming more important to scientists in the climate community as well as to the well-being of society. Introduction of new observing systems compounds the problem. Special consideration of the long-term homogeneity of existing climate records is especially important when major changes are introduced into existing observation systems. Without such consideration, irreparable damage to the climate record is likely, which can affect both climate studies and climate change research.

## PRINCIPLES OF OBSERVING AND MANAGING DATA FOR CLIMATE AND CLIMATE CHANGE RESEARCH

Because observations of basic weather and climate variables will differ with instrument exposure to nearby structures and terrain, sensor response characteristics, the time of observation, or the method of recording, care must be taken to understand fully the ramifications of changing an instrument, its site, or the routine of observation. The objective is to maintain regional representation of decades of uninterrupted observations of a changing atmosphere. As a minimum requirement for new weather observing systems, the following general recommendations are offered:

**Recommendation:** *(1) Develop and apply standard procedures for collecting side-by-side overlapping measurements for all potentially significant changes made in observation and measurement techniques. This period of overlap should span at least one annual cycle.*

**Recommendation:** *(2) Make routine assessments of ongoing calibration, maintenance, and climate record homogeneity problems for which corrective action can be taken. Such assessments and subsequent actions must be documented and archived with the data.*

**Recommendation:** *(3) Along with routine transmissions of observations, regularly (as opposed to ad hoc) schedule transmissions of station observation and measurement practices, as well as local environmental conditions in the vicinity of the station, that are pertinent to the interpretation of the observations and measurements. Station histories should be a mandatory part of the permanent data archive along with the measurements and observations. They should be treated with importance equal to the data itself.*

**Recommendation:** *(4) Ensure that network designers and instrument engineers are provided climate requirements at the outset of network design and instrument design.*

**Recommendation:** *(5) Develop, wherever feasible, some level of "low-technology" backup to "high-technology" observing systems to safeguard against unexpected operational failures (power interruptions, lack of replacement parts, etc.).*

**Recommendation:** *(6) Archive raw data sensed from the instruments prior to transformation into standard atmospheric variables or products along with the processed data and processing algorithms.*

**Recommendation:** *(7) Restrict the number of station relocations to an absolute minimum.*

**Recommendation:** *(8) Discontinue observations of atmospheric variables with a long historical record (spanning many decades) only after a thorough evaluation of the impact on the climate record.*

**Recommendation:** *(9) Develop standard data packages that fully describe all algorithms, averaging procedures, quality control, homogeneity checks, and corrections that have been applied to the derived data. This now includes quantities such as temperature or precipitation, which can now be measured indirectly.*

In addition to these general principles there are a number of specific recommendations relevant to existing and planned observing networks within the NWS.

## AUTOMATED SURFACE OBSERVING SYSTEM

The CRC is concerned that present and planned surface observations of cloud types and cloud cover, present weather, snowfall and water equivalent, total sunshine, radiation fluxes and turbidity may be insufficient to support future climate studies. An assessment of these needs and the ability of station personnel and ASOS to meet them is underway by the CRC. It is clear, nonetheless, that ASOS operations should meet long-term continuity and comparability standards for climate research.

**Recommendation:** *(1) Side-by-side comparisons of all new instruments and observing procedures should be made at a diversity of climate types over the course of at least one annual cycle, depending on the time required to quantify inhomogeneities that may be introduced into the climate record.*

**Recommendation:** *(2) The reliability of the precipitation measurements by the Automated Surface Observing System should be tested in side-by-side comparisons with existing instruments. A comprehensive assessment of instrument bias for various rainfall rates and precipitation states should be published and widely distributed. Data should be archived prior, as well as subsequent, to the application of built-in adjustment factors, including those used for heavy precipitation rates.*

## UPPER AIR OBSERVATIONS

Upper air observations have been vital in climate research, and the rawinsonde network has been the mainstay. New remote sensing wind and temperature profiler systems are vastly different from the instruments and in situ observing methods of the rawinsonde. Further analysis by the CRC is in progress to determine how to overcome or compensate for these differences for the benefit of climate research. The CRC is concerned that long-term records may be in jeopardy.

**Recommendation:** *(1) Copies of upper air station histories stored at field locations, regional offices, and National Weather Service headquarters should be in a permanent archive. These metadata should be made easily accessible to the researcher.*

**Recommendation:** *(2) The type of instruments flown, as well as the manufacturer, should be reported along with the data.*

## COOPERATIVE WEATHER OBSERVER PROGRAM

**Recommendation:** *(1) Develop a policy to assess biases introduced by station relocation or changes in instrumentation, and develop and deploy a standard observing system to be operated by part-time volunteer observers that meets accuracy and reliability requirements for climate data.*

**Recommendation:** *(2) Quantify the biases introduced by the Maximum-Minimum Temperature System relative to the liquid-in-glass thermometric measurements obtained in Cotton Region shelters. This is likely to be heterogeneous over various weather regimes and should be quantified on this basis.*

**Recommendation:** *(3) Quantify the bias associated with unshielded precipitation measurements. This bias is likely to be heterogeneous over various weather regimes and should be quantified on this basis.*

**Recommendation:** *(4) Wherever and whenever possible, conduct overlapping simultaneous measurements when there is a necessity to change observation sites. The simultaneous measurements could be discontinued when the impact of the change can be quantified. The National Weather Service Operations Manual (Section B-11) recommends overlapping observations for a period of one to three years. A rededicated commitment to this procedure is required. In an operational environment, this may not always be possible. For this reason it is advisable to operate a dense network of stations designed so that occasional station losses will not badly degrade climatic analyses. The trend over the past two decades of moving toward fewer and fewer temperature monitoring sites should be stopped or reversed.*

**Recommendation:** *(5) Site stability needs to be a key criterion in the selection of new sites. National parks should be ideal candidates for sites not likely to undergo substantial changes.*

**Recommendation:** *(6) Every effort must be applied to protect the sites and data sets in the network that have provided the crucial, long-term, consistent measurements utilized to assess climate change within the United States. The cooperative observer program should develop a prioritized list of network sites for preservation and continuation based on their contribution to climate change assessment.*

**Recommendation:** *(7) Every effort should be made to implement the technology to retain maximum and minimum temperature measurements on a midnight-to-midnight basis.*

**Recommendation:** *(8) Routine reports of each station's operations should be included with the monthly data sent to the archives. Ad hoc reporting of changes leads to questions regarding the quality of the station histories.*

## CONTINUING WORK

The CRC is currently assessing other observation capabilities and data management systems, such as the NEXRAD (WSR-88D) Doppler radar, that relate to weather service operations. Further recommendations by the CRC will be forthcoming as a result of its continuing examination of climate observation requirements and current technological advancements.

Board on Atmospheric Sciences and Climate

## CLIMATE RESEARCH COMMITTEE

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**WILLIAM A. SPRIGG**, Staff Director, BASC

# Appendix D

# Exchange of Letters on New Meteorologist Standards

NATIONAL RESEARCH COUNCIL
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
2101 Constitution Avenue Washington, D.C. 20418

NATIONAL WEATHER SERVICE
MODERNIZATION COMMITTEE

(202) 334-2856
(202) 334-3279

May 31, 1991

The Honorable John A. Knauss
Undersecretary for Oceans and Atmosphere
U.S. Department of Commerce, Room 5128
14th Street and Constitution Avenue, N.W.
Washington, D.C. 20230

Dear John:

In its review of plans for the modernization and restructuring of the National Weather Service (NWS), the National Weather Service Modernization Committee (NWSMC) has been examining the future education and training of NWS personnel. The NWSMC was pleased to learn of the development of proposed revised standards for the GS-1340 Meteorologist series (grade GS-5 and above) in the federal government (copy enclosed). The Committee believes that the proposed standards represent a positive step in establishing a sounder educational foundation for operational meteorologists required in the era of the modernized and restructured NWS. As the report of the NWSMC, *Toward a New National Weather Service--A First Report* (pp 15-16) states: "Modernization requires...taking advantage of the collective skills of a highly trained cadre of professional meteorologists; and...the development of effective new applications of atmospheric knowledge to ensure the continuing evolution of weather service capabilities in the decades ahead."

It is our understanding that the proposed standards were coordinated with managers from other federal agencies that also hire meteorologists and submitted recently to the personnel specialists in the Department of Commerce prior to their transmission to the Office of Personnel Management. The NWSMC learned at its meeting May 13-14, 1991, that the Department of Commerce personnel specialists are concerned about including calculus as a prerequisite or corequisite for courses in atmospheric dynamics and thermodynamics, differential equations, and physics. The skills, knowledge, and professional growth of NWS forecasters in the modernization era will require that they have mastery of physics and atmospheric dynamics and thermodynamics; this mastery cannot be attained unless their education in these subjects is based on calculus. Therefore, the Committee wanted to call this matter to your attention; we hope you will be able to resolve any difficulty that may exist in the Department of Commerce regarding this requirement.

Sincerely,

Charlie

Charles L. Hosler, Jr.
Chairman

Enclosure

c: Elbert W. Friday, Jr., NOAA/NWS

GS-1340
METEOROLOGY
GS-5/above

Basic Requirements

Candidates must show successful completion of a full course of study leading to a bachelor's degree in an accredited college or university which has included or been supplemented by:

(1) At least 24 semester (36 quarter) hours of credit in meteorology including:

a. 6 semester hours of atmospheric dynamics and thermodynamics with calculus as a prerequisite or corequisite;
b. 6 semester hours of analysis and prediction of weather systems (synoptic/mesoscale);
c. 3 semester hours of physical meteorology;
d. 2 semester hours of remote sensing of the atmosphere and/or instrumentation.

(2) A course in differential equations which has a prerequisite of at least two semesters of calculus.

(3) 6 semester hours of physics with calculus as a prerequisite or corequisite. At least one course must include laboratory sessions.

(4) 3 semester hours of computer science appropriate for a physical science major.

(5) 6 semester hours of course work appropriate for a physical science major selected from a combination of at least two of the following topics: physical hydrology, statistics, chemistry, physical oceanography, and physical climatology.

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE
Silver Spring, Md. 20910

AUG 21 1991

Mr. Charles L. Hosler, Jr.
National Research Council
Commission on Engineering
and Technical Systems
2101 Constitution Ave.
Washington, D.C. 20418

Dear Charlie,

Thank you for your letter to Dr. John A. Knauss regarding the status of our efforts to modify the current Federal qualification requirements for meteorologists and related concerns you raised in your recent letter.

First, let me assure you that the National Oceanic and Atmospheric Administration (NOAA) and the National Weather Service (NWS) are fully pursuing the academic standards for hiring meteorologists as they were originally proposed last year. Our target implementation date remains as October of 1993. We firmly believe in the need for calculus as a prerequisite or corequisite for courses in physics, differential equations, and atmospheric dynamics or thermodynamics to increase the scientific skills and knowledge which will be required of employees in the modernized NWS.

One of the concerns raised by personnel specialists within the Department of Commerce was over the ability for personnelists to accurately identify those courses which are based in calculus when there is no clear indication as to whether calculus is a basis of the course. Another unrelated concern was over the lack of an alternate standard by which in-house meteorological technicians could be judged for conversion to professional status. We are working on solutions for both of these concern areas, and we do not envision that the end result of these efforts will affect the proposed academic standards in any way.

Our efforts on this new standard are on-track, and we appreciate the support we have received from the Committee in its implementation.

Sincerely,

Elbert W. Friday, Jr.
Assistant Administrator
for Weather Services

# Acronyms

| | |
|---|---|
| AFOS | Automation of Field Operations and Services |
| ASOS | Automated Surface Observing System |
| AWIPS | Advanced Weather Interactive Processing System |
| COMET | Cooperative Program for Operational Meteorology, Education and Training |
| CRC | Climate Research Committee of the Board on Atmospheric Sciences and Climate, NRC |
| DAR$^3$E | Denver AWIPS Risk Reduction and Requirements Evaluation |
| DOC | U.S. Department of Commerce |
| EFF | Experimental Forecast Facility |
| FAA | Federal Aviation Administration |
| GOES-Next | Next Generation Geostationary Operational Environmental Satellite |
| MARD | Modernization and Associated Restructuring Demonstration |
| MIC | Meteorologist-in-Charge |
| NESDIS | National Environmental Satellite, Data, and Information Service |
| NEXRAD | Next Generation Weather Radar |
| NOAA | National Oceanic and Atmospheric Administration |
| NRC | National Research Council |
| NSSL | National Severe Storms Laboratory |
| NWS | National Weather Service |
| NWSMC | National Weather Service Modernization Committee |
| PROFS | Program for Regional Observing and Forecasting Services |
| RFC | River Forecast Center |
| SPO | Systems Program Office of NOAA |

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| WCM | Warning Coordination Meteorologist |
| WFO | Weather Forecast Office |
| WSFO | Weather Service Forecast Office |
| WSO | Weather Service Office |
| WSR-88D | Weather Service Radar-1988 design Doppler |

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