Review of the Draft Plan for the Modernization and Associated Restructuring Demonstration

National Weather Service Modernization Committee, National Research Council

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Toward a New National Weather Service

Review of the Draft Plan for the Modernization and Associated Restructuring Demonstration

NATIONAL WEATHER SERVICE MODERNIZATION COMMITTEE
COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS
NATIONAL RESEARCH COUNCIL

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Preface

This is the final report on the National Weather Service (NWS) modernization by the National Research Council's National Weather Service Modernization Committee. The committee's oversight of the NWS modernization program began in January 1990 when the committee was established by the National Research Council in response to a request from the National Oceanic and Atmospheric Administration (NOAA). During the course of the NWS's $4.5 billion investment in new technology and restructuring, the committee issued 15 reports (including the present report) that provided findings and recommendations to guide the NWS and NOAA in using new technologies to improve weather services to the nation. The committee's reports are listed chronologically below:

- Toward a New National Weather Service: A First Report (1991)
- Revised Standards for Entry-Level Meteorologists in the Federal Government. A letter report (May 1991)
- Toward a New National Weather Service: Second Report (1992)
- Review of Modernization Criteria (1993)
- National Weather Service Employee Feedback (1994)
- Weather for Those Who Fly (1994)
- Assessment of NEXRAD Coverage and Associated Weather Services (1995)
- The Importance of the United States Weather Research Program for NWS Modernization (1996)
- Preliminary Assessment of the Operational Test and Evaluation Process for the Advanced Weather Interactive Processing System (1996)
- Assessment of Hydrologic and Hydrometeorological Operations and Services (1996)
- Continuity of NOAA Satellites (1997)
- An Assessment of the Advanced Weather Interactive Processing System (1997)
- Future of the National Weather Service Cooperative Observer Network (1998)
- A Vision for the National Weather Service: Road Map for the Future (1999)
- Review of the Draft Plan for the Modernization and Associated Restructuring Demonstration (1999)

This report reviews the Modernization and Associated Restructuring Demonstration (MARD) Plan provided to the committee in September 1998. The report provides an analysis of the plan and recommendations to improve its implementation and follow-on evaluation processes.

I wish to acknowledge the chair of the MARD panel, Veronica F. Nieva, and the panel members, David Atlas, Dara Entekhabi, and Albert Kaehn, as well as advisors William D. Bonner and George J. Gleghorn, who gathered and analyzed information and drafted and coordinated this report for the committee. I also thank the NWS headquarters staff for their presentations on MARD to the committee, as well as the staff of the NWS central region, the meteorologists-in-charge, and the staff of other weather forecast offices and river forecast centers, who met with the panel during the course of this study. Finally, I wish to acknowledge the continuing support of staff members of the National Research Council, Floyd F. Hauth, Mercedes Ilagan, Carter Ford, and consultant Robert Katt.

Richard A. Anthes
Chair, National Weather Service
Modernization Committee

Acknowledgments

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

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While the individuals listed above have provided constructive comments and suggestions, it must be emphasized that responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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Executive Summary

The public law that authorized the National Weather Service (NWS) to modernize its technical systems and restructure its field office organization set the requirements for what has become known as the modernization and associated restructuring demonstration (MARD). The law requires testing of the integrated performance, over a sustained period, of the modernized components and an operational demonstration that no degradation in service will result from the modernization and associated restructuring. In this report, the National Research Council's National Weather Service Modernization Committee reviews the September 1998 draft plan for MARD. The committee drew three conclusions from its review of the plan and offers five recommendations to the NWS.

Conclusion 1. If MARD achieves the goals and objectives stated in the MARD Plan, it will meet the requirement in the public law for a multistation operational demonstration that tests the performance of the modernization in an integrated manner for a sustained period.

Conclusion 2. The MARD evaluation plan is intended to assess a wide range of local office capabilities, operations, and services. Before this plan is implemented, it will require refinement to link proposed evaluation variables to the evaluation and analysis objectives, provide directions for documenting actual site conditions during MARD, and minimize the burden on staff and operations.

Conclusion 3. Controlled tests of multistation capabilities, such as interoffice backup, that progressively stress the system up to and including total failure of a field office are needed to ensure system robustness. Tests of this kind for routine coordination and for interoffice backup during failure, covering both system capabilities and operational procedures, can be incorporated into the ongoing process of operational program evaluation, beginning with the Build 4.2 operational test and evaluation (OT&E) for the Advanced Weather Interactive Processing System (AWIPS).

Recommendation 1. The National Weather Service should test failure modes at progressive levels of failure, including the complete failure of a field office (for both weather forecast offices and river forecast centers). These tests should be conducted during the Build 4.2 operational test and evaluation and demonstrated during MARD. The tests should focus on the effectiveness of capabilities and procedures for interoffice backup and intra-office recovery and document site configurations.

Recommendation 2. The National Weather Service should continue to make periodic assessments of technical, operational, and service capabilities as part of the ongoing operational program evaluation by expanding the operational test and evaluation process being used for AWIPS builds to include the integrated suite of technical systems. The assessments should include service programs such as coastal marine, fire, and mountain weather forecasts and warnings, which are not likely to be fully tested in the MARD area.

Recommendation 3. To ensure adequate evaluation of a stable system configuration, MARD should be continued for a reasonable period of time (several months at least) after AWIPS is commissioned at the MARD sites. During this period, the MARD sites should use the modernized systems without significant reliance on legacy systems.

Recommendation 4. The National Weather Service should use outside experts in program evaluation and survey design:

- to review the MARD evaluation plan, survey questionnaires, and other data forms
- to assist in developing a plan for analyzing the evaluation

- to assist in the collection of evaluation data in local offices

Surveys used in the service assessments of future operational program evaluations should also be reviewed by outside experts.

Recommendation 5. The National Weather Service should use an independent evaluator or evaluation board to assist in assessing MARD results.

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Introduction

BACKGROUND OF MARD

Public Law 100-685, which was passed in 1988, authorized the modernization and associated restructuring of the National Weather Service (NWS). This law also set forth the initial requirements for what has become known as the Modernization and Restructuring Demonstration (MARD). Initially, MARD was to be performed after major changes to all of the technical systems had been implemented and selected field offices had been restructured according to the approved plan. Legislation passed in 1992 redefined the MARD requirement to make it a part of the National Implementation Plan for the modernization. The specifics of the plan were spelled out in the legislation:

> . . . special measures to test, evaluate, and demonstrate key elements of the modernized National Weather Service operations prior to national implementation, including a multistation operational demonstration which tests the performance of the modernization in an integrated manner for a sustained period . . .
>
> Public Law 102-567, Section 703(a)(4)

This redefinition uncoupled the multistation operational demonstration (i.e., MARD) from the certification of NWS field offices.

Role of the National Weather Service Modernization Committee

In July 1989, the National Oceanic and Atmospheric Administration (NOAA) requested that the National Research Council establish a committee to review the modernization and restructuring of the NWS (NOAA, 1989). The council responded by establishing the National Weather Service Modernization Committee (NWSMC) in that same year.

In 1992 the NWSMC designated a number of its members as a MARD panel, whose task was to assess the evolving plan for MARD and report to the full committee. During the intervening years, the MARD panel and the full committee have discussed several draft versions of an NWS plan for MARD. The committee has commented on the MARD planning process in several previous reports to the NWS (NRC, 1992, 1993, 1994, 1995).

In its most recent Statement of Task (1995), the NWSMC was charged with reviewing the MARD plan. On September 10, 1998 the National Research Council approved a review of the current MARD plan including the following areas:

- MARD objectives and goals
- measures planned to test, evaluate, and demonstrate key elements of the modernized NWS, with emphasis on the effectiveness of weather forecast office (WFO) operations, including workload and staff utilization
- measures planned to evaluate the quality of modernized service, including the satisfaction of user groups
- measures planned to test and evaluate the operational effectiveness of a network of WFOs, river forecast centers (RFCs), and the national centers for environmental prediction (NCEPs), with emphasis on the adequacy of coordination and backup strategies
- identification of any major deficiency that could impact the full implementation of modernized and restructured operations

OVERVIEW OF THE MARD PLAN

Draft 3 of the *Modernization and Associated Restructuring Demonstration Plan* (referred to hereafter as the MARD Plan), dated September 1998, is the basis for the committee's review in Chapter 2. This overview highlights only those aspects of the plan that are significant for the committee's review and is not meant to cover the entire plan.

MARD Goals and Objectives

The Introduction (Section 1) of the MARD Plan lists the following goals:

- Validate the WFO concept (one-tier operating structure).
- Refine new operational procedures and resolve implementation issues.
- Demonstrate that the quality of warnings and forecasts has not been degraded by modernized and restructured operations.

The one-tier operating structure is the replacement for the previous two-tier structure of NWS forecast offices and smaller NWS offices with a single tier of WFOs. Section 3 of the plan includes a list of objectives that the MARD evaluation methodology is meant to implement (see Box 1-1). According to the plan, meeting these objectives will accomplish the MARD goals (MARD Plan, p.1.).

Activities Prior to the MARD

Section 2 divides the modernization and restructuring into two stages. The division appears to be based on whether an activity will have been completed prior to MARD or will continue during MARD. This section also describes the risk reduction activities that were used to test and evaluate various aspects of the modernization prior to MARD.

MARD Assumptions and Constraints

Most of the assumptions (Section 4) pertain to the

BOX 1-1
MARD Evaluation Objectives

1. Measure the operational effectiveness of WFOs: the ability of the forecast team (meteorologist(s) and hydrometeorological technician) to complete the assigned workload (e.g., operations, CPM [county preparedness meteorologist], required training, etc.) using only acceptable overtime and nonoperational personnel involvement. This evaluation is based on using current AWIPS [Advanced Weather Interactive Processing System] capabilities and meeting Objectives 3 and 4.

2. Measure the operational effectiveness of a network of WFOs and other elements of the modernized forecast process. Specifically:
   - Evaluate coordination between WFOs, RFCs, and NCEPs on forecasts and warnings to ensure no marked discontinuity across WFO boundaries and to ensure a reasonable coordination workload at each office.
   - Evaluate service backup to determine if it is sustainable and if it produces timely, quality products and services at the office being backed up and at the offices(s) providing the support; determine if the workload for the office(s) providing the backup is acceptable.

3. Determine customer satisfaction with the quality and timeliness of WFO products and services. This may be based on:
   - Comparison of customer satisfaction before restructuring based on user survey responses,
   - An indication of overall satisfaction with the quality of products and services,
   - Survey results that fall within the range of "acceptable norms" of customer satisfaction based on generalized survey results from many locations.

4. Validate that WFO warnings and forecasts are overall as good or better than premodernization and restructuring products. Validate that warnings and forecasts from spin-up offices (former NWSOs [National Weather Service offices]) are equivalent in quality, accuracy, and timeliness to those from WFOs that were former NWSFOs [National Weather Service forecast offices].

5. Determine the adequacy of MAR [modernization and restructuring] technology in supporting modernized operations.

Source: MARD Plan, p. 4.

workload of field offices and the relation of staffing levels during MARD to staffing levels targeted for the end of restructuring into a single tier of forecast offices ("end-state staffing"). These assumptions provide important ground rules for evaluating the first MARD objective (see Box 1-1). Other assumptions state that the Advanced Weather Interactive Processing System (AWIPS) does not have to be commissioned for MARD to begin but that AWIPS will be commissioned before MARD ends. Another assumption is that the MARD will last for one year.

Constraints on MARD are listed in Section 4.2. The first two are crucial for understanding why MARD evolved into its present form: "(1) MARD is designed to fulfill a requirement outlined in Public Law 102-567," and "(2) the operations and evaluation of the MARD must be consistent with the MARD budget." The third and fourth constraints reflect the original intent of the MARD: "(3) AWIPS capabilities must be sufficiently mature to demonstrate 'modernized operations'" and "(4) All MARD offices must be conducting restructured operations." ("Restructured operations" are defined in Section 4.1 to mean that the public forecast program and the convective watch and warning program are responsibilities of the field offices participating in MARD.)

Participating Office Functions

Eight WFOs and two RFCs will participate in MARD (Section 5). The areas of responsibility for these adjacent offices form a roughly rectangular area, which includes nearly all of Kansas and Oklahoma and parts of Arkansas, Missouri, Nebraska, Colorado, and Texas (Figure 1-1). This area was selected for MARD in part for the frequency and diversity of significant weather that typically occurs there.

Roles of National Weather Service Personnel and Special Evaluation Teams

Sections 6 and 7 specify the people who will direct and conduct MARD and the staffing of the 10 field offices participating in MARD. Outside support services are mentioned as assisting in collecting, processing, and analyzing evaluation data and surveys. The role of the NWSMC in reviewing

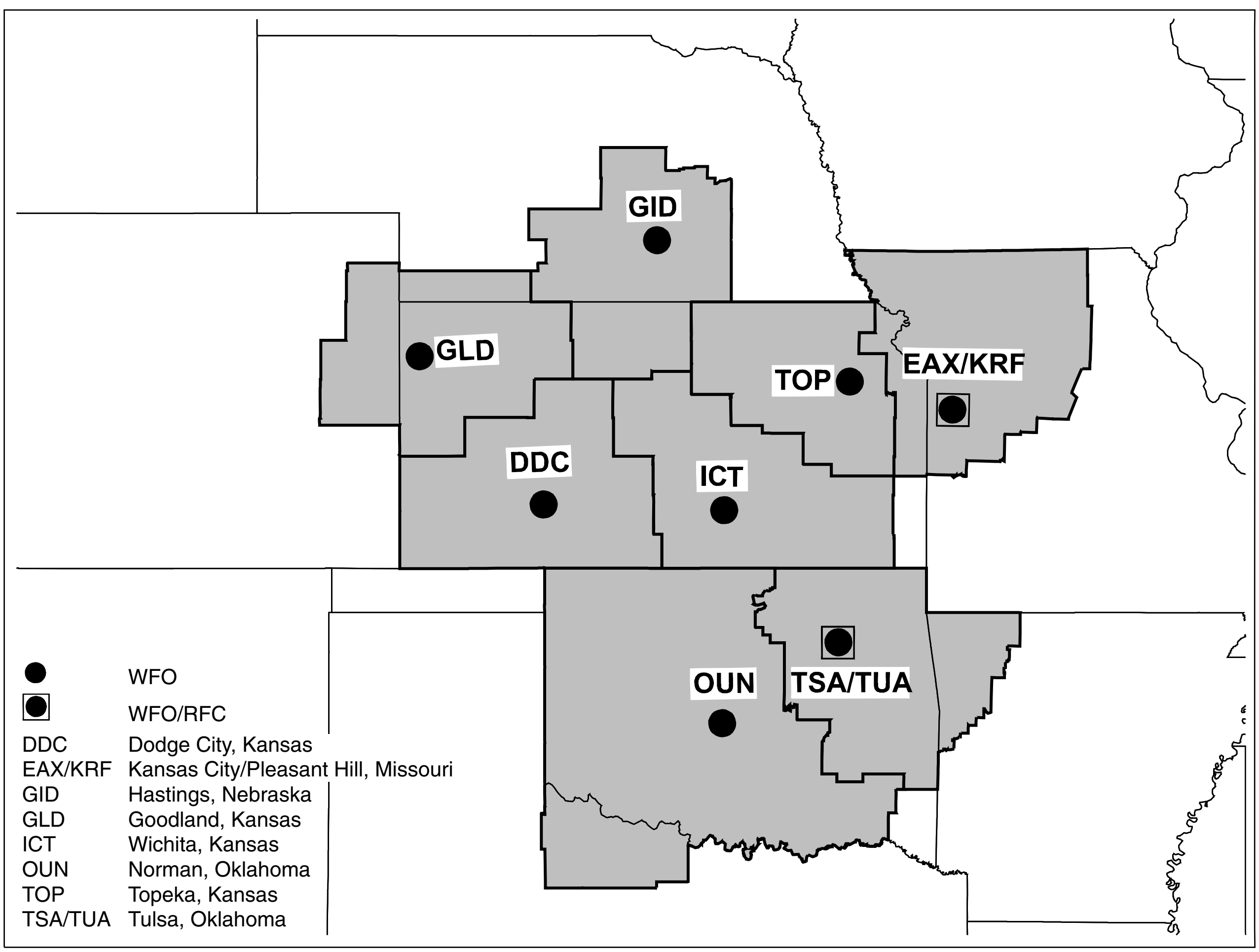

FIGURE 1-1 MARD area.

the MARD Plan (but not the MARD event) is noted. Otherwise, all the MARD participants are NWS employees.

Technical Systems

Section 8 describes how the county-by-county approach for interoffice service backup relates to the overlapping coverage provided by adjacent next-generation weather radars (NEXRADs).[1]

The operational version of AWIPS is scheduled to be installed in June 1999 but is not expected to be commissioned until early 2000, more than halfway through MARD. Official products will be disseminated by legacy systems until AWIPS is commissioned at a given field office, after which that office will use the AWIPS Communication Network. Section 8 does not specify which technical systems will be used for interoffice service backup before or after AWIPS is commissioned.

Pre-MARD Exercise and Other Preparations for MARD

Section 10 states that all MARD sites must be operating with AWIPS Build 4.2 before MARD begins and that a MARD readiness checklist must be completed by each office to confirm that the office is prepared to begin MARD. Section 11 describes a six to eight week exercise, scheduled for early 1999, to validate operational procedures and provide baseline operational statistics.

Concept of MARD Operations

Section 11 notes that the one-year duration for MARD will begin when the assistant administrator for weather services (who is also the director of the NWS) considers the MARD field offices to be ready. The MARD is expected to begin in June 1999. This section also describes how an extra forecaster, beyond the end-state staffing for some MARD sites, may be used to ensure an operational "safety net" when significant weather cannot be handled by the scheduled staff.[2]

MARD Verification, Evaluation Methodology, and Measures of Success

Section 12 and Appendix A describe the plan for verifying that the weather services provided by the NWS have not been degraded as a result of the modernization. Section 13 describes the methodology by which the NWS will evaluate how well it has met the five MARD objectives (listed in Box 1-1).

[1] Traditionally, some interoffice backup arrangements have assigned different products for a given geographic area, defined by county boundaries, to different backup offices. In the "county-by-county" approach, all products for an area are assigned to one backup office. For most WFOs, all or most of the counties in a field office's warning area will be assigned to one backup office, as is currently done.

[2] The provision for an extra forecaster during some shifts at some MARD sites may be eliminated. In previous reports, the NWSMC has expressed concern that the end-state staffing levels may not be sufficient during the transition period (NRC, 1991, pp. 55–57; NRC, 1992, pp. 61–62).

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Review of the MARD Plan

GENERAL PERSPECTIVE ON MARD

The NWS modernization has occurred in increments, proceeding more gradually than anticipated. Efforts to develop and implement the technical systems for the modernization have been delayed well beyond the original assumptions of the NWS planners. The NWS is currently targeting the summer of 1999 for operational deployment of the final suite of modernized systems and the completion of organizational changes that will approach end-state staffing.

AWIPS, which is the last of the new systems, is expected to be deployed by the summer of 1999 in a version that can be commissioned as an operational system. MARD is scheduled to begin shortly after this version of AWIPS, called "Build 4.2," is deployed and will continue for one year. The MARD Plan states that installation of AWIPS Build 4.2 at the MARD field sites is an assumption for the initiation of MARD. However, the operational test and evaluation (OT&E) of Build 4.2 will continue for several months after Build 4.2 is installed. The MARD Plan projects that the commissioning of AWIPS as the official system for use in field office operations will not occur until the early months of 2000, or about two-thirds of the way through the MARD year.

The timing of commissioning with respect to Build 4.2 deployment and the subsequent OT&E seems reasonable. The OT&E process can be expected to lead to numerous small changes in AWIPS, and perhaps a few major changes, during and soon after the rigorous testing period, which will continue for several months after deployment. These changes should be installed and confirmed prior to AWIPS commissioning. This timing is also fortunate for evaluating AWIPS for any software problems related to the change of year to 2000 ("the Y2K problem").

MARD will be in progress throughout the OT&E period, so changes resulting from OT&E will be made during MARD. The committee assumes that the system after AWIPS commissioning will remain unchanged until the year-long MARD is completed. If the schedule holds, there should be several months of MARD with the stable (after OT&E changes) AWIPS system. These timing considerations are important factors in the committee's assessment of the extent to which the MARD Plan can meet its objectives.

Even after MARD and the commissioning of AWIPS, improvements to AWIPS are planned to enhance its capabilities for supporting interoffice coordination and backup, improving system reliability, and delivering products and services. The committee recently reviewed the OT&E process that the NWS has implemented as part of the incremental deployment of AWIPS (NRC, 1997). If the NWS preserves and enhances the strengths of this process and addresses the weaknesses previously noted, OT&E will play a valuable role in continuing to improve the entire suite of technical systems and the operational procedures for employing them. The committee assumes that the AWIPS OT&E process will become an integral part of a continuing operational program evaluation.

MARD and the Public Law

The NWSMC agrees with the implication in the MARD Plan that, if MARD achieves its stated goals and objectives, MARD will satisfy the requirement in Public Law 102-567, Section 703(a)(4) for "a multistation operational demonstration which tests the performance of the modernization in an integrated manner for a sustained period."

MARD GOALS AND OBJECTIVES

The committee believes that the planned MARD will address all three MARD goals to a limited extent prior to AWIPS commissioning and more fully afterward. But the results will be conditioned by the state of the technical systems and operations in effect at the MARD sites. The adequacy of the one-tier concept, including the end-state staffing model, cannot be fully tested until the transition has been completed from a combination of modernized and legacy systems to modernized systems alone. Similarly, the goal of refining new operational procedures and resolving implementation issues cannot be fully met before the transition has been completed. The goal of demonstrating (or documenting) that there has been no degradation in the quality of warnings and forecasts cannot be fully met until AWIPS is in use for disseminating these products, but the AWIPS dissemination functions will not be used until AWIPS is commissioned.

The committee believes that AWIPS commissioning at the MARD sites will be necessary before the three MARD goals can be fully met. A reasonable period of operation relying on modernized systems, including AWIPS, for office operations will be essential for a successful demonstration.

DESIGN AND METRICS OF THE MARD EVALUATION

Capturing Site-Specific Variability

The MARD plan does not have an explicit provision for planned experiments, or controlled tests, of systems and procedures. Without planned tests, the MARD results will be limited to whatever system stresses or unusual conditions (severe weather events, power outages, etc.) happen to occur at participating offices during the demonstration period. The response to these conditions will be limited by the systems and procedures in use at the time. Therefore, it is essential that each participating office document the systems and technologies in use at that site, especially the legacy systems and experimental systems that are used concurrently with the modernized systems (even if the former are used only to supplement, confirm, or back up the modernized systems).

It is also imperative that each MARD site document (1) the specific staffing configuration at the site, (2) the specific procedures for coordinating operations with other offices during routine and stressed operations, and (3) the internal (intra-office) and interoffice backup systems and procedures actually in place and (as need arises) actually used. The committee anticipates that there will be a great deal of variability among MARD sites in these and other respects, which should be captured in the MARD documentation and considered in the evaluation of results.

Evaluating Operational Effectiveness and Quality of Service

The metrics that will be used to evaluate operational effectiveness and quality of service rely heavily on subjective assessments by office staff and the immediate recipients of an office's products and services (i.e., its primary customers). These subjective assessments will be supplemented by statistics on NWS warning and forecast skills. Drafts of questionnaires and other evaluation forms for surveying staff and customers are included in the MARD Plan as appendices. In addition, the plan mentions other potential data sources (for example, forecast data from adjacent sites and the Product Availability Monitoring System) that could be used as supplements to subjective surveys.

The MARD Plan states that the NWS will obtain assistance in refining the MARD design and in collecting and analyzing the data. The committee strongly encourages the NWS to use outside resources (e.g., a support contractor) to assist in these areas.

Surveys

The surveys appear to be adaptations of the surveys used in the AWIPS OT&E service evaluation. The adapted surveys focus on staff assessments of internal office operations; customer assessments of NWS and RFC products; and managerial assessments of the support from national and regional NWS offices and, when backup services are required, from other field offices. The MARD surveys would benefit from a close review by experts in survey design and program evaluation to assess their relevance to MARD objectives and analytic goals; parallelism between surveys; and the structure and clarity of survey questions, instructions, and formats for data collection, statistical analysis, and interviews.

Analysis Plan

The MARD Plan includes many variables, questionnaires, and respondents, spread across different time frames. But it does not explain how data will be analyzed and used to address the MARD goals. Streamlining the questionnaires and data collection processes will minimize the burden on respondents and administrative personnel. Specifying the methodology and objectives of analyzing data will help the NWS recognize which variables and data are essential and which are just "nice to have."

Logistics of Data Collection

The plan presumes that the numerous surveys will be collected by WFO and RFC staff. The committee strongly advises the NWS to consider the use of outside support services for this task to ensure that data are collected independently and systematically and that the staff is not unduly burdened.

Data Utilization

The plan does not specify how the MARD results will be incorporated into refinements of procedures and the resolution of implementation issues. The NWS should establish specific mechanisms for incorporating the MARD results into organizational practices.

ONGOING OPERATIONAL TEST AND EVALUATION PROCESS

An expanded OT&E process would provide a continuing assessment and improvement process for all of the modernized systems, not just for AWIPS. Periodic assessments after future AWIPS builds or other significant changes to one or more of the technical systems should be standard practice for the NWS. The end of Section 1 in the MARD Plan refers to "future operations program evaluation," which the committee interprets as a reference to the AWIPS OT&E process expanded to cover all of the modernized systems and operations.

The OT&Es should include designed experiments to supplement observations from naturally occurring events. The sites selected for the MARD do not seem to provide for demonstrations of coastal marine or mountain weather forecasts and warnings. As a practical matter, these sites have a relatively low level of significant fire incidents to support. Thus, the network of sites in the MARD area will not provide a fair evaluation of marine, fire weather, or mountain weather operations, interoffice operability between these programs and other programs, or interoffice backup responsibilities for these programs. Successive OT&Es should therefore focus on different regions of the country (as is already being done for the AWIPS OT&Es) to assess operations for different weather regimes and seasons and different responsibilities.

Expertise from outside the NWS should be brought in to supplement in-house capabilities. Outside expertise can be useful for solving technical and substantive problems, as well as for assuring managers in NWS, NOAA, the U.S. Department of Commerce, and Congress that the evaluations are independent and credible.

The expanded OT&E process (or operations program evaluation) should include the following elements:

- the development of plans and rehearsal of procedures for interoffice backup (see discussion below)
- assessments of staffing configurations (including shift structures, staffing combinations, and variations in the discretion allowed local staff in modifying procedures) under different types of weather conditions
- examinations of methods of network coordination under different conditions (including routine interactions among the WFOs, RFCs, and NCEPs and interactions during severe weather or periods of system stress)
- service assessments that include the systematic collection and evaluation of customer inputs, including customer satisfaction with dissemination and receipt of products and services from backup WFOs and RFCs, and customer comments on new ways to provide or improve products and services (local offices should identify current and potential customers from whom feedback should be obtained)
- the systematic collection of staff perceptions of operational and technical issues

Finally, NWS should establish processes for incorporating OT&E results into operating procedures at field offices and national centers.

INTEROFFICE BACKUP AND OPERATIONAL RISK MANAGEMENT

Field offices have long had procedures for backing up a failure of a key system with an alternative or work-around within the office. They have also established procedures for another field office (or offices) to take over the essential duties of an office incapacitated by a long-term power outage, loss of communications lines, or a similar event that would prevent an office from handling its full complement of routine responsibilities. The modernization provides many approaches for continuing, replacing, and extending these service backup capabilities, both within an office (intra-office backup) and between offices (interoffice backup).

In the past, service backup procedures were developed by individual offices. With the completion of the NWS modernization, it is technically feasible to achieve much greater standardization and depth in backup and recovery procedures, particularly in the speed and effectiveness of interoffice backup. However, the MARD Plan does not specify whether procedures have been developed, tested, or rehearsed to ensure that the operational system of multiple field offices, central facilities (such as the Network Control Facility), and communications links (such as the AWIPS wide-area network) can use these new technical capabilities for effective interoffice backup.

Since the OT&E for Build 1 of AWIPS, NWS has systematically tested the intra-office backup capabilities of the new technical systems, particularly of the communications links provided by AWIPS. NWSMC members have observed these tests and followed the analysis and responses to their results. As AWIPS has progressed to its current operational version (Build 4.1), the standard capabilities and procedures (i.e., those common to all offices) for actions such as failover to a backup server have been tested and practiced under near-operational conditions.[3] In areas where alternative radar

[3] "Failover" is the transfer of operations to a reserve or backup component of a system when a component ceases to function adequately or fails completely. Ideally, the transfer should occur with minimal loss of operational capability and no loss of data or processes. For good reason, the OT&E test teams have not conducted failover and other capability-degrading tests during times of significant weather in a field office's area of responsibility. In other respects, the realism of the test conditions has increased as the AWIPS system has matured. For example, in recent OT&Es the timing of deliberate "failures" (controlled outages) of a server or other system component was unknown to the staff at the field office or the Network Control Facility, which must identify and respond to failure conditions. The test teams have also conducted operational "stress tests" by bringing down multiple components and assessing the degree of degradation in operational capability, short of closing down an office completely.

coverage is technically possible (a function of the phenomenon to be observed and the distance and terrain between the NEXRAD installations and the location of the phenomenon), field offices have demonstrated the ability to acquire radar products from the "backup" NEXRAD. Individual offices have also worked out "internal" procedures for using various legacy or experimental components as backups and work-arounds to improve their intra-office backup capability.

According to the latest draft statement of AWIPS Build 4.2 capabilities, this version should provide a great deal of the planned technical capability for enhanced inter-office backup (Box 2-1). The OT&E for Build 4.2 seems to be a logical alternative to MARD for controlled, but progressively strenuous, testing of interoffice backup capabilities and operational effectiveness, similar to what earlier OT&Es provided for testing intra-office capabilities. As further capabilities and incremental improvements become operational after Build 4.2, the OT&E process can be used to continue to validate, rehearse, and stress-test the expanding operational procedures and technical system capabilities for interoffice backup. For example, in the midst of certain severe weather events of limited areal extent the NWS could go into a simulated backup mode. This would require that the backup WFO not have any significant amount of severe weather (convective or winter storm-related) in progress within its primary area of responsibility. In this mode the actual public products would be issued by the responsible office (as normal), while the backup office simultaneously went through a mock exercise issuing forecasts and warnings that would not be publicly distributed. This type of exercise would yield valuable experience "under fire" for the backup office without increasing risk to the public.

The NWSMC has previously discussed some of the technical capabilities of AWIPS that require testing and validation to ensure that site backup and recovery procedures operate as expected (NRC, 1997). The following suggestions for ensuring that backup is *operationally effective*, as well as technically demonstrated, should be added to those recommendations:

- The NWS should develop (or review and update) a list of situations in which an office might need partial or

BOX 2-1
AWIPS Build 4.2 Capabilities That Support Interoffice Backup

Backup

Provide ability for the site that provides backup to access WSR-88D for the area being backed up (if available) via radar dial-up.

Provide the ability for the site that provides backup to acquire local data for the area being backed up, via dial-in to or dial-out from its LDAD [local data acquisition and dissemination].

Provide the ability for the site that provides backup to receive and process ASOS, microART, and ROSA [dial-in reporting facility for Cooperative Observers] for locations in the backup area.

Provide the ability for the site that provides backup to acquire routinely all SBN [Satellite Broadcast Network] data needed for the backup area.

Provide the ability for the site that provides backup to display all local data and SBN data acquired for the site being backed up. The data will be displayable on the AWIPS local scale (state scale) with appropriate map backgrounds.

Provide the ability for the site that provides backup to create all assigned text products for the area being backed up. This includes warnings, watches, and statements generated by Warngen [the AWIPS warning generation utility], and other products created manually on the text workstation. All products will have appropriate header information automatically prepended. Normally product IDs [identification numbers] and headers will be the same as those generated at the site being backed up, except that the "issued by" line will indicate the office preparing the product.

Message Handling and Communication

Provide capability to request/reply for either NCF [Network Control Facility] or nearby WFO and RFC.

During transition from AFOS [the legacy communications system] to AWIPS, provide ability to send products to AFOS and corresponding products to AWIPS WAN [wide area network] as appropriate.

Automated test message to test load on system.

Send subset of radar products via the WAN to limited number of nearby sites.

Source: NWS, 1999

full backup from another office or offices, up to and including the complete failure of a field office (either a WFO or an RFC).

- The NWS should prioritize the list, based on likelihood, importance, similarity, and other pertinent factors. For similar situations, the NWS should choose one or more planning scenarios, based on their likelihood and importance (and perhaps additional factors).
- For each scenario, the NWS should think through (1) the criteria for deciding what action is necessary; (2) the steps to perform that action; (3) the equipment and other resources necessary for taking each step; and (4) the preparations that should be made in advance, such as acquiring the telephone numbers of local data acquisition and dissemination users and determining alternative communication pathways.
- The NWS should develop plans and procedures for carrying out the action for each scenario and commit them to writing. Depending on the problem and the action, these written plans and procedures can be used as "templates" to be filled in with details for individual offices. The generic plans and procedures should be useable by all offices with minimal modifications.
- The NWS should provide the template plans and procedures, along with the categorization of potential circumstances, to each field office. Each office should be required to study the plans, make adjustments for local conditions, and develop written office-specific versions. If the written version is stored as an electronic file, each office (and its backup[s]) must also have hard copies available in case of power outage or other mishap that would interfere with electronic access.
- The NWS should train office personnel by scheduling near-real operational exercises and simulations when local weather activity is minimal.

The guiding principle for the amount of detail in the procedures and the number of rehearsals should be to preclude encountering an emergency for the first time when lives may depend on proper actions being taken. In terms of preparedness, much of the benefit would be derived from the planning and preparation of nearly realistic exercises and simulations.

3

Conclusions and Recommendations

CONCLUSIONS

Conclusion 1. If MARD achieves the goals and objectives stated in the MARD Plan, it will meet the requirement in the public law for a multistation operational demonstration that tests the performance of the modernization in an integrated manner for a sustained period.

Conclusion 2. The MARD evaluation plan is intended to assess a wide range of local office capabilities, operations, and services. Before this plan is implemented, it will require refinement to link proposed evaluation variables to the evaluation and analysis objectives, provide directions for documenting actual site conditions during MARD, and minimize the burden on staff and operations.

Conclusion 3. Controlled tests of multistation capabilities, such as interoffice backup, that progressively stress the system up to and including total failure of a field office are needed to ensure system robustness. Tests of this kind for routine coordination and for interoffice backup during failure, covering both system capabilities and operational procedures, can be incorporated into the ongoing process of operational program evaluation, beginning with the Build 4.2 operational test and evaluation (OT&E) for the Advanced Weather Interactive Processing System (AWIPS).

RECOMMENDATIONS

Recommendation 1. The National Weather Service should test failure modes at progressive levels of failure, including the complete failure of a field office (for both weather forecast offices and river forecast centers). These tests should be conducted during the Build 4.2 operational test and evaluation and demonstrated during MARD. The tests should focus on the effectiveness of capabilities and procedures for inter-office backup and intra-office recovery and document site configurations.

Recommendation 2. The National Weather Service should continue to make periodic assessments of technical, operational, and service capabilities as part of the ongoing operational program evaluation by expanding the operational test and evaluation process being used for AWIPS builds to include the integrated suite of technical systems. The assessments should include service programs such as coastal marine, fire, and mountain weather forecasts and warnings, which are not likely to be fully tested in the MARD area.

Recommendation 3. To ensure adequate evaluation of a stable system configuration, MARD should be continued for a reasonable period of time (several months at least) after AWIPS is commissioned at the MARD sites. During this period, the MARD sites should use the modernized systems without significant reliance on legacy systems.

Recommendation 4. The National Weather Service should use outside experts in program evaluation and survey design:

- to review the MARD evaluation plan, survey questionnaires, and other data forms
- to assist in developing a plan for analyzing the evaluation
- to assist in the collection of evaluation data in local offices

Surveys used in the service assessments of future operational program evaluations should also be reviewed by outside experts.

Recommendation 5. The National Weather Service should use an independent evaluator or evaluation board to assist in assessing MARD results.

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Acronyms

AWIPS Advanced Weather Interactive Processing System

MARD Modernization and Associated Restructuring Demonstration

NCEP national center for environmental prediction

NEXRAD next generation radar (common name for the WSR 88-D radar [weather service radar, 1988 Doppler model])

NOAA National Oceanic and Atmospheric Administration

NWS National Weather Service

NWSMC National Weather Service Modernization Committee (of the National Research Council)

OT&E operational test and evaluation

RFC river forecast center

WFO weather forecast office

Biographical Sketches of Committee Members and Advisors

COMMITTEE MEMBERS

Richard A. Anthes (chair) is president of the University Corporation for Atmospheric Research (UCAR), a nonprofit consortium that manages the National Center for Atmospheric Research (NCAR) and collaborates with many international meteorological institutions. Dr. Anthes received his B.S., M.S., and Ph.D. degrees from the University of Wisconsin-Madison. He has been a research scientist at the National Oceanic and Atmospheric Administration (NOAA), a professor of meteorology at Pennsylvania State University, and director of NCAR. Dr. Anthes, a fellow of the American Meteorological Society (AMS), was awarded the Meisinger and Charney awards of the AMS for his research on the theory and modeling of tropical cyclones and mesoscale meteorology. In addition to publishing more than 90 peer-reviewed articles and books, he has been a member or chair of more than 30 national committees for the National Aeronautics and Space Administration (NASA), NOAA, AMS, the National Science Foundation, and the National Research Council.

William E. Gordon (vice chair) is a member of the National Academy of Sciences and the National Academy of Engineering. His professional career has been devoted to designing and developing radio communication systems (e.g., tropospheric forward scatter) and powerful radars (e.g., incoherent scatter) for studying the Earth's atmosphere. During his military service and at the University of Texas, he studied the effects of atmospheric refraction on radars. He received a Ph.D. in electrical engineering from Cornell University for his work on radiowave propagation. Dr. Gordon is known as "the father of the Arecibo Observatory" for his work, with others, in conceiving that facility and directing its design, construction, and early operations. He was professor, dean of science and engineering, and provost at Rice University, where he is a distinguished professor emeritus. Dr. Gordon is also a member of the Japan National Academy of Engineering and a fellow of the American Association for the Advancement of Science, the American Geophysical Union, and the Institute of Electrical and Electronics Engineers (IEEE). He received the van der Pol Medal from the International Union of Radio Science (URSI), the Arctowski Medal from the National Academy of Sciences, the Centennial Medal from the IEEE, and honorary medals from the Soviet Academy of Sciences and the Bulgarian Academy of Sciences.

David Atlas is a distinguished visiting scientist at the NASA Goddard Space Flight Center, where he was formerly the director of the Laboratory for Atmospheric Sciences. He received his B.S. from New York University and his M.S. and D.Sc. from the Massachusetts Institute of Technology (MIT). He has been the chief of the Weather Radar Branch, Air Force Cambridge Research Laboratories, a professor at the University of Chicago, and a program director at NCAR. In addition to serving as president of the AMS, he received the Rossby, Meisinger, Abbe, and Remote Sensing awards of that society for his work in radio science and meteorology. He has also received awards from the American Institute of Aeronautics and Astronautics, the Royal Meteorological Society, and NASA. He was president of the Inter-Union Commission on Radio Meteorology of the URSI and the International Union of Geophysics and Geodesy.

William D. Bonner, now a senior research associate at NCAR, was previously director of programs at UCAR and director of the UCAR Cooperative Program for Operational Meteorology, Education, and Training. Prior to joining UCAR, Dr. Bonner spent 20 years with the National Weather Service (NWS), working first in the Techniques Development Laboratory and then in the National Meteorological Center. He later served as director of the eastern region, deputy director of the NWS, and director of the National Meteorological Center. His Ph.D. in geophysical sciences (meteorology) is from the University of Chicago. He has taught at the University of California, Los Angeles, and the University of Maryland. For his NWS service, he received two Senior Executive Service awards (presidential rank) and the U.S. Department of Commerce Gold Medal. An AMS fellow and past president, Dr. Bonner served twice on the AMS Council. He is co-author of a textbook, Understanding Our Atmospheric Environment, and author or co-author of 40 scientific publications.

Robert F. Brammer is currently a vice president and technical director at TASC, where he heads several inter-organizational technology programs for independent research and development, university research, and new business activities. He led the development of TASC's Computing Technology Center, where research is conducted on digital mapping, precision guidance, remote sensing, nondestructive testing, photo-sensor realistic scene generation, and computational fluid dynamics. The center also evaluates advanced computing architectures for the government and industry. In addition to a decade of work on Trident submarine programs at TASC, Dr. Brammer initiated programs to develop ground stations for meteorological satellites, which led to TASC's acquisition of WSI Corporation. TASC/WSI is the largest private-sector provider of value-added meteorological and oceanographic information services. Prior to joining TASC, Dr. Brammer worked on real-time software and ground-station engineering for Apollo and Skylab at NASA Goddard Space Flight Center. He also did research on adaptive control, coherent communications, and precise time transfer. Dr. Brammer received his B.S. from the University of Michigan and his M.A. and Ph.D. in mathematics from the University of Maryland. He is a member of a number of professional and honorary societies.

Kenneth C. Crawford is a professor of meteorology at the University of Oklahoma, director of the Oklahoma Climatological Survey, and the state climatologist. He came to the university after 28 years with the NWS, where he was a research meteorologist at the National Severe Storms Laboratory, an operational meteorologist, and a senior field manager. Professor Crawford is director of the Oklahoma Mesonet, a statewide network of 115 automated observing and transmitting stations, and the senior administrative official for the OK-FIRST project to improve the dissemination of weather information to local public safety officials. Dr. Crawford is a fellow of the AMS and has made numerous international presentations. He earned his B.S. from the University of Texas at Austin, his M.S. from Florida State University, and his Ph.D. from the University of Oklahoma.

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Albert J. Kaehn, Jr., retired from the U.S. Air Force with the rank of brigadier general after commanding the Air Weather Service. Prior to that, he served as commander of the Third Weather Wing at Offutt Air Force Base; as the assistant for environmental sciences in the Office of the Undersecretary, Defense Research and Engineering; and in various other command and staff positions in the Air Weather Service. He received an M.A. in mathematics from the State University of New York and a B.S. in meteorology from Pennsylvania State University. He is a fellow and past president of the AMS and has served on its executive and governing councils. For his Air Force service, he received, among other honors, the Air Force Distinguished Service Medal, the Legion of Merit, and a Bronze Star. After retiring, General Kaehn worked for Global Weather Dynamics, Inc., and Harris Corporation; he is currently a consultant on organization, management, system development, and business development. He has chaired several committees for the National Research Council.

Veronica F. Nieva is a social and organizational psychologist whose research has focused on evaluating the effectiveness of procedural, organizational, and technological interventions in public-sector organizations, military institutions, and private industry. Her consulting and research are aimed at understanding, measuring, and improving human resource and organizational functioning. She has also studied the behavior of women in relation to gender issues in the workplace at WESTAT. Dr. Nieva is a vice president and director of the Organizational and Management Research Group at WESTAT. Previously, she worked at The Urban Institute, the Advanced Research Resources Organization, and the Institute for Social Research (University of Michigan). She has taught at the Ateneo de Manila University in the Philippines and the University of Michigan. Dr. Nieva holds an M.A. and Ph.D. in organizational psychology from the University of Michigan and an M.A. in social psychology from the Ateneo de Manila University. She has published two major books and numerous articles and technical reports.

Dorothy C. Perkins is deputy associate director of flight projects for Earth Observing System (EOS) Information Systems at NASA Goddard Space Flight Center where she is in charge of implementing the EOS Data and Information System, which includes the ground systems for spacecraft control and the processing, archiving, and distribution of scientific data from the NASA Earth Sciences Enterprise missions. She previously served as deputy director of applied engineering and technology at Goddard, mission services manager for the NASA Space Operations Management Office, chief of the Mission Operations and Systems

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Paul L. Smith is professor emeritus at the South Dakota School of Mines and Technology. Dr. Smith received a B.S. in physics and an M.S. and Ph.D. in electrical engineering from the Carnegie Institute of Technology, where he subsequently was on the faculty. He worked at Midwest Research Institute before moving to the Institute of Atmospheric Sciences, where he served as director from 1981 to 1996. His major research interests are radar meteorology, cloud physics, and weather modification. Dr. Smith has held numerous other posts, including postdoctoral fellow at the National Science Foundation; visiting professor in meteorology at McGill University; chief scientist at Air Weather Service Headquarters, Scott Air Force Base; visiting scientist at the Alberta Research Council; Fulbright Lecturer in radar meteorology at the University of Helsinki; and member of the Executive Committee of the International Commission on Clouds and Precipitation. He has twice chaired the AMS Committee on Radar Meteorology and is currently on the NEXRAD Technical Advisory Committee.

Arthur I. Zygielbaum is the director of research and development, as well as the assistant director, of Nebraska Educational Telecommunications, which is associated with the University of Nebraska, Lincoln. He took these posts in 1998, after 30 years at the Jet Propulsion Laboratory (JPL), where his positions included manager of Science Information Systems, deputy manager of the Information Systems Division, and co-principal investigator for the Consortium for the Application of Space Data to Education. At JPL, Mr. Zygielbaum developed systems for spacecraft navigation, measurement of solar charged particle densities, and tests of general relativity theory. He also created JPL's Minority Science and Engineering Initiatives Program. Mr. Zygielbaum holds a B.S. in physics from the University of California, Los Angeles, and an M.S. in electrical engineering from the University of Southern California. He holds several patents, has received numerous NASA awards, and is a member of the National Weather Service Modernization Committee.

ADVISORS

George J. Gleghorn retired from TRW Space and Technology Group as vice president and chief engineer. During his 37 years at TRW, he contributed to numerous "firsts" in space flight, including Pioneer I, the first NASA spacecraft; Pioneer 5, which reported the first data from interplanetary space; Intelsat III, the first satellite to broadcast live television worldwide; the Orbiting Geophysical Observatory; and NASA's tracking and data relay satellite. He also contributed to Pioneers 6, 10, and 11 and the development of the Atlas, Thor, and Titan ballistic missiles. Earlier, he worked at Hughes Aircraft and the JPL and served in Korea as a naval officer. Dr. Gleghorn holds a B.S. from the University of Colorado and a Ph.D. in electrical engineering and mathematics from the California Institute of Technology. He is a fellow of the American Institute of Aeronautics and Astronautics and a member of the National Academy of Engineering and the NASA Aerospace Safety Advisory Panel. He recently chaired two studies for the National Research Council on the effects of orbital debris on the International Space Station and has participated in design and readiness reviews for NASA spacecraft.

Charles L. Hosler is a fellow and past president of the AMS and a member of the National Academy of Engineering. From 1947 to 1991, he was on the faculty of Pennsylvania State University, where he was professor and head of the Department of Meteorology, dean of the College of Earth and Mineral Sciences, senior vice president for research, dean of the graduate school, acting executive vice president, and provost. He was chairman of the board and acting president for UCAR and has served on the National Advisory Committee for Oceans and Atmosphere, the National Science Board, and the World Meteorological Organization's panel of experts on education and training. For the National Research Council, Dr. Hosler chaired the Board on Atmospheric Sciences and Climate and the National Weather Service Modernization Committee, as well as serving on many other panels and committees. He currently chairs the board of the Pennsylvania State Research Foundation. He has an M.S. and Ph.D. from Pennsylvania State University.

David S. Johnson worked for 26 years on the U.S. operational meteorological satellite program and the cooperative international network of meteorological satellites and ground stations. He retired from NOAA as the assistant administrator for satellites. After retirement, he was a consultant on remote sensing satellite systems and served for eight years as a study director at the National Research Council for the post-Challenger evaluation of NASA's risk management and as first director of the National Weather Service Modernization Committee. Mr. Johnson received A.B. and M.S. degrees in meteorology from the University of California, Los Angeles. He is a fellow of the AMS, American Geophysical Union, and American Astronautical Society, and an associate fellow of the American Institute of Aeronautics and Astronautics. He was president of the AMS in 1974 and has received numerous awards from government agencies and professional societies.

Robert J. Serafin worked at Hazeltine Research Corporation, where he designed and developed high-resolution radar systems, and then at Illinois Institute of Technology (IIT) and IIT Research Institute. He joined NCAR as manager of the Field Observing Facility, and, in 1980, he became director of the Atmospheric Technology Division. Since 1989, he has been director of NCAR. Dr. Serafin has published more than 50 technical and scientific papers, holds three patents, and founded the *Journal of Atmospheric and Oceanic Technology*. He received B.S., M.S., and Ph.D. degrees in electrical engineering from Notre Dame University, Northwestern University, and IIT, respectively. He has served on several National Research Council committees, and was chair of the National Weather Service Modernization Committee. He is a member of the National Academy of Engineering and a fellow of the AMS and the IEEE.