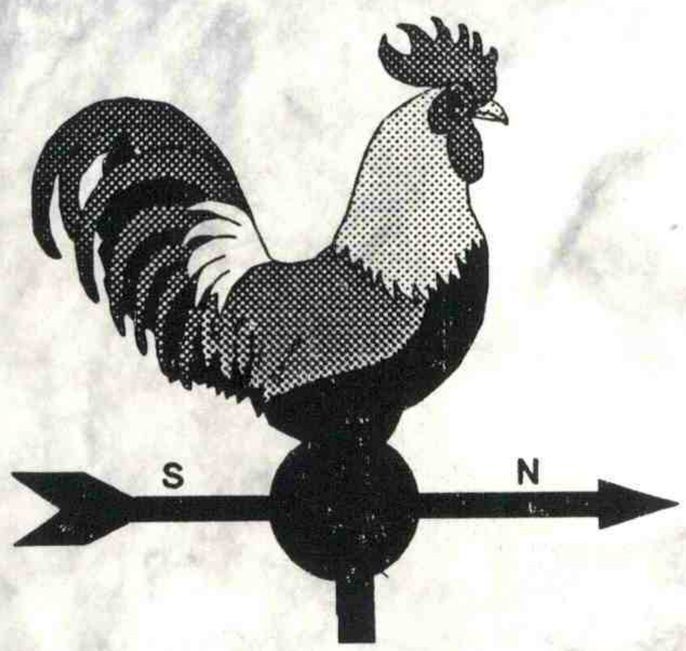
Toward a New
National Weather Service

NATIONAL WEATHER SERVICE MODERNIZATION COMMITTEE

ANNUAL REPORT 1997



National Research Council
Commission on Engineering and Technical Systems

Toward a New National Weather Service

ANNUAL REPORT 1997

Prepared by the

Committee on National Weather Service Modernization

of the

Commission on Engineering and Technical Systems
National Research Council

Washington, D.C.
1998

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CONTENTS

Introduction

Purpose: This annual report for 1997 is provided in response to paragraph 4.2 of the Statement of Work, Attachment J.1.1, Contract No. 50-DGNW-5-00004 of March 21, 1995, between the U.S. Department of Commerce, NOAA, and the NRC, National Academy of Sciences. The report summarizes the activities of the committee during the year but does not include findings or recommendations arising from the continuing work of the NWSMC except as references from previously published reports.

In early 1995 the National Oceanic and Atmospheric Administration (NOAA) awarded a second five-year contract to the National Research Council (NRC) to continue analysis, study, and review of the National Weather Service (NWS) modernization and associated restructuring program. The NRC authorized the National Weather Service Modernization Committee (NWSMC), which is a standing committee under the Commission on Engineering and Technical Systems, to accomplish these tasks. The NWSMC was given two broad areas of responsibility:

- to help ensure a successful and cost-effective transition to the modernized and restructured NWS envisioned in the NOAA Strategic Plan to improve weather services to the nation
- to ensure a continuous modernization to capitalize on the substantial investment already made in new technology and opportunities available from emerging scientific research and technological development that would complement and enhance modernization

NOAA further asked the NRC to continue its analysis, study, and review throughout the national deployment of the new technology and the phase-over to the new NWS operating structure, a time period extending through 1999.

The modernization involves new observational technology, new information and forecast systems, and a new organizational structure. The new observing systems include the weather surveillance radar-1988 Doppler (WSR-88D), more commonly referred to as the next generation weather radar (NEXRAD); the automated surface observing system (ASOS); and the next generation geostationary operational environmental satellites (GOES-Next). An Advanced Weather Interactive Processing System (AWIPS), now being developed and tested, will provide information processing and forecast workstations at each field forecast office as well as an interactive communications link among all the offices. Advanced supercomputers at the National Centers for Environmental Prediction (NCEP) will facilitate improvement of the timeliness and accuracy of operational numerical weather forecasts.

Restructuring of the NWS is under way and includes a consolidation of many of the field offices and supporting center operations. The structure prior to modernization included 52 weather service forecast offices, about 200 smaller offices (including weather service offices and weather service meteorological observatories), and 13 river forecast centers (RFCs). When the modernization is fully implemented there will be 119 weather forecast offices (WFOs), whose locations are determined primarily by the coverage of NEXRAD systems installed nearby, and the 13 RFCs. The new organizational structure also includes the NCEP which are comprised of nine national centers: NCEP Central Operations, Environmental Modeling Center, Hydrological Prediction Center, Marine Prediction Center, Climate

Prediction Center, Aviation Weather Center, Storm Prediction Center, Tropical Prediction Center, and the Space Environmental Center. The centers prepare and make available forecasts and outlooks of weather and climate to the public and other users and provide forecast guidance products to weather service field offices.

The modernization process is well under way with the deployment of the new NEXRAD and ASOS observational technologies and the launch and operational employment of GOES-8 and GOES-9. The NWS reached a milestone in the modernization program in 1996 by completing the planned network of 161 Doppler weather radars that were approved by Congress in 1987. In the planned network, the NWS will operate 120 weather radars, the U.S. Department of Defense (DOD) will operate 29, and the Federal Aviation Administration (FAA) will operate the remaining 12. As a result of a secretary of commerce recommendation (based on a 1995 NRC study) the NWS has installed three additional radars that are located in northern Indiana, western Arkansas, and northern Alabama. Nearly 950 ASOSs have been installed at the planned 993 NWS, FAA, and DOD locations across the country. The ASOS network provides primary surface data that is used by the NWS for severe weather, flash flood, and river forecasting, as well as for support of aviation operations. The ASOS network substantially increases the spatial resolution and frequency of surface observations (NRC, 1992). GOES-8 was launched in April 1994, GOES-9 in May 1995, and GOES-10 in April 1997. These satellites allow higher quality and more frequent atmospheric soundings and cloud images to be obtained simultaneously (only one or the other could be obtained from GOES-7 and earlier satellites). Development of the AWIPS system, initiated in 1992, is continuing. NOAA has adopted an "incremental build" approach for AWIPS that will allow forecasters to take advantage of limited capability, but highly critical, new forecasting tools, while allowing for improvements and additional capability to be added incrementally. AWIPS pathfinders (a rapid prototype) working off the AWIPS data stream (NOAAPORT) were installed at five locations in 1995. AWIPSs with the initial software "build" were installed and tested at nine operational field sites and three support sites during the summer and fall of 1996. A total of 17 development phase systems have been fielded, including upgrades of the Pathfinder sites. A total of three incremental builds have been developed and fielded. A limited deployment of another 21 sites began in November 1997. The remaining 115 systems will be installed during 1998 and 1999.

The study activities of the NWSMC have followed and built upon previous studies conducted for NOAA by the NRC since 1980. In 1997, the committee completed and published two NRC reports. Continuity of NOAA Satellites was published and briefed by the committee and panel chairs to senior NOAA and NWS officials in January 1997. An Assessment of the Advanced Weather Interactive Processing System was published and briefed to senior Department of Commerce, NOAA, and NWS officials in November 1997. A list of all of the committee's reports is provided in Appendix A.

Activities in 1997

The National Weather Service Modernization Committee (NWSMC) meets four or more times each year to monitor all aspects of the National Weather Service (NWS) modernization program and to provide in-depth reviews and assessments of selected areas where the committee's broad knowledge in meteorology, meteorological measurements, information systems, engineering systems, telecommunications, and human factors can benefit the modernization and the associated restructuring effort. The committee has established temporary panels to lead the investigation of areas of interest and to help design studies requested by the National Oceanic and Atmospheric Administration (NOAA)/NWS or identified by Congress, the committee, or other sources. Six panels were active during 1997:

- Advanced Weather Interactive Processing System (AWIPS)
- Climate Record
- Continuity of NOAA Satellites
- Hydrology
- Modernization and Associated Restructuring Demonstration (MARD)
- Road Map for the Future National Weather Service

The activities of the full committee are summarized below, followed by summaries of the activities of each of the panels.

NATIONAL WEATHER SERVICE MODERNIZATION COMMITTEE

The committee held four meetings in 1997.

January 30–31, Beckman Center, Irvine, California

Participants: Robert J. Serafin, *chair*, Richard A. Anthes, David Atlas, William Bonner, Robert Brammer, Kenneth C. Crawford, Dara Entekhabi, George J. Gleghorn, Albert J. Kaehn, Jenanne L. Murphy, Veronica F. Nieva, Paul Smith. *Advisors*: Charles L. Hosler, Jr., David S. Johnson, Arthur I. Zygielbaum. *Staff*: Floyd F. Hauth, Mercedes Ilagan. *Consultant*: Robert Katt. *NOAA*: Stuart Williams. *NWS*: Louis Boezi, Mary Glackin, Robert McLeod, Thomas Bercal, Ronald McPherson (NCEP).

Membership Update: Paul Smith, from the Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, was appointed a new member of the committee. NWSMC members William Gordon, Dara Entekhabi, and Veronica Nieva were reappointed for three-year terms; Robert Serafin completed his two-year term as chair and his seventh year as a committee member; Richard Anthes was appointed chair for a two-year term, and William Gordon was appointed vice chair for a two-year term.

Continuity of NOAA Satellites

Chairman Serafin reported on the meeting held on January 17, 1997, with D. James Baker and the NOAA staff when the report, "Continuity of NOAA Satellites," was presented.

Review of Annual Report

Chairman Serafin led a page-by-page review of the draft 1996 Annual Report of the NWSMC.

NWS Presentations

Louis Boezi presented a briefing on "Commissioning AWIPS and Decommissioning Legacy Systems." The briefing included various activities planned and factors considered as part of the commissioning of AWIPS and WFOs.

Mary Glackin and Stuart Williams reported on the status of the AWIPS program. Ms. Glackin reviewed the program mission and goals, system users, and the schedule for development and deployment. She also described activities related to the software build, preparations for interactive forecasts, and the contract status. Mr. Williams reported on satellite broadcast issues and the planned installation schedule for the 21 systems in the next deployment phase.

Robert McLeod distributed a working draft of the plan for the MARD and briefed the participants on key points of the plan. He reviewed the objectives of the MARD sites and network, evaluation methodology, pre-MARD risk-reduction activities, and proposed demonstration areas in different parts of the United States.

Geosynchronous Advanced Technology Environmental System (GATES)

The committee was shown a video provided by Dennis Chesters (NASA-GSFC) describing a NASA feasibility study for a geosynchronous advanced technology environmental system (GATES). GATES is envisioned as a high performance imager on a dedicated satellite with a complete ground system. GATES would fly in the era of the Earth observing system (EOS, circa 1999–2004 A.D.) and would be a prototype for NOAA's next generation of operational satellites (GOES-R, circa 2008 A.D.). In addition to monitoring storms, GATES is being designed to fill in the space-time gaps in cloud observations from polar-orbiting satellites and to serve as a cross-reference between polar-orbiting satellite radiometers.

National Centers for Environmental Prediction (NCEP)

Ronald McPherson (NWS/NCEP) briefed the committee on NCEP in the twenty-first century. Major topics covered were: improving the credibility of science-based forecasts; opportunities for science and service; advances in modeling; advances in services; and outreach to users of products and services. Dr. McPherson discussed examples of one-week, one-month, and five-month forecasts of rainfall that would characterize NWS capabilities in the twenty-first century. He also described opportunities to extend services by providing more accurate, longer range forecasts of precipitation and severe weather.

Advances in modeling will include higher resolution (5 km) models, more ensembles, better coupling of the atmospheric and water sources, the assimilation of data sets, more cooperative development efforts, improved local and centralized models, and space weather. Advances in services will include the central generation of forecasts beyond 24 hours, operational forecasts of atmospheric constituents, and the extension of model-based predictions to space weather.

North American Atmospheric Observation System (NAOS)

Ronald McPherson updated the NWSMC on the NAOS. He presented a review of the NAOS program, provided preliminary test results, and previewed the next phase of the observing system.

June 2–3, National Center for Atmospheric Research, Boulder, Colorado

Participants: Richard A. Anthes, *chair,* William E. Gordon, *vice chair,* David Atlas, William Bonner, Kenneth C. Crawford, Dara Entekhabi, George J. Gleghorn, Albert J. Kaehn, Dorothy C. Perkins, Paul Smith. *Advisors*: David S. Johnson, Robert J. Serafin, Arthur I. Zygielbaum. *Staff*: Floyd F. Hauth, Mercedes Ilagan. *Consultant*: Robert Katt. *NOAA*: Stuart Williams, Richard Jesuroga. *NWS*: Louis Boezi, Andrew Horvitz. *National Center for Atmospheric Research (NCAR):* Roger Pielke, Jr., James Wilson, Thomas McKee (Colorado State University (CSU)); Thomas Lockhart (Meteorological Standards Institute).

Economic Aspects

Roger Pielke, Jr., (NCAR) gave a presentation on economic aspects of weather products and services. He discussed seven techniques that can be used to quantify the economic value or impact of weather on society.

Radar Research

David Atlas (NWSMC) presented a paper he helped author, "On the Variability of Tropical Rain Microphysics and Radar Rain Retrievals." He summarized past research on this topic, which described the microphysical changes responsible for the Z-R variability. A goal of this research is to improve the retrieval of rain by ground, airborne, and spaceborne radar. He described the limitations of existing radar and the role of evaporative cooling in estimates of rainfall rates. Primary conclusions from this research are: that tropical rain has four sequential types; convective rain has nearly constant drop size, but the size varies from storm to storm; short-term, local rains lead to big errors in estimating rainfall amounts; and polarimetry is promising for improved sensing of clouds and rainfall at short ranges (< 100 km).

Polarimetric Radar

James Wilson (NCAR) presented information on polarimetric radar and bi-static radar displays, discussed the differences between NEXRAD and polarimetry and the factors that make polarimetric data more accurate and useful. He concluded that for an expenditure of about $30,000 per radar, the NWS could improve their estimates of rainfall, improve hail detection, and obtain more accurate wind information out to 100–150 km from the radar.

NWS Operations in the Twenty-First Century

Louis Uccellini (NWS) presented (via teleconference) his views on "Moving the NWS into the Twenty-First Century." He reviewed the transformation of the forecast process over the past 50 years from an art to a mathematically-based science and the establishment of an end-to-end forecast process. He noted that NWS priorities are based on the science-service linkage. The top five priorities for the twenty-first century are quantitative precipitation forecast; topographical influence (mountains, coasts, Great Lakes); tropical storm track and intensity; fire weather; and marine cyclogenesis.

Impact of NOAA's Budget

Louis Boezi (NWS) updated the committee on the latest NOAA budget hearings in Congress and on the response by NOAA and Congress to letters from individuals and organizations protesting cuts in the FY 1997 operational budget. Mr. Boezi also informed the committee about problems with the GOES-10 motor that drives the solar panel and noted that a study of the problem by NOAA and National Aeronautics and Space Administration (NASA) engineers is under way.

Advanced Weather Interactive Processing System (AWIPS)

Stuart Williams (NOAA/Systems Acquisitions Office) updated the committee on the program status of AWIPS. Most of the problems identified in the Build 1 OT&E have been resolved. Build 2 is being installed and implemented at Build 1 test sites. The Forecast Systems Laboratory (FSL) developed WFO-Advanced is being integrated into Build 3 of the AWIPS software releases.

Local Data Acquisition and Dissemination

Richard Jesuroga (FSL) discussed the dissemination of weather data and products. The primary objectives of the FSL dissemination project are to determine how advanced weather information can be used and how it can be sent to the user. The FSL approach is to tailor weather information to the non-meteorologist. Mr. Jesuroga showed some examples, including displays for the Colorado Department of Transportation (DOT), Denver Urban Drainage and Flood Control, and the Boulder County Operations Center. The examples included ways to display snow and rainfall information for emergency managers and fire weather officials. He also described how Intranet and the Internet could be used to disseminate data.

Continuity of Climate Data

Andrew Horvitz (NWS) introduced the topic of the continuity of climate data and summarized studies of ASOS temperature and precipitation data. These studies show that the ASOS temperature measurements are more accurate than those of previous sensors although they are lower by about .79°F. Mr. Horvitz discussed concerns about how changes in the 30-year normals would affect utility companies. Initial precipitation measurements from 13 sites with the new heated tipping bucket rain gauges are encouraging.

Comparisons of Precipitation Measurements

Thomas McKee (CSU) briefed the committee on comparisons of ASOS with data from the universal gauge. He described the instrument characteristics, the procedures used in the comparisons, the volume of data, and other issues. Preliminary conclusions are that the performance of the heated tipping bucket has improved; the collection rates of ASOS rain gages to universal rain gages are within specifications of plus or minus 0.04 inches; the summary of the day information changes for some stations; and local biases and site differences have been identified.

Wind Measurements

Thomas Lockhart (Meteorological Standards Institute [privately owned]) provided a brief summary of his study on wind measurements from ASOS. He reported on the

results of a workshop held by the Office of the Federal Coordinator for Meteorology (OFCM) in 1992 where a consensus agreement among agency representatives was reached. The conferees agreed to ASOS reports of 10-minute averages and peak values at three seconds and one minute. Lockhart's studies are continuing, and preliminary indications are that ASOS wind values are generally slightly lower than those of the previous (F 420) system.

Road Map Study

Louis Boezi (NWS) explained that NWS would like the road map study to assess science and technology for future use in the NWS. The study should examine potential societal changes, including the changing needs of state and local governments for weather services. The study should advise NWS on emerging science and technology they should consider using in the future and how they can avoid obsolescence. The NWS wants guidelines for determining what is doable and the potential pitfalls and cautions. NWS expects to use this study for future program development and acquisitions that will lead to better services.

Panel Reports

Updates on panel activities were provided by chairpersons of the AWIPS, Climate Record, and Road Map panels.

September 15–16, J. Erik Jonsson Woods Hole Center, Woods Hole, Massachusetts

Participants: Richard A. Anthes, *chair*, William E. Gordon, *vice chair*, David Atlas, William Bonner, Robert F. Brammer, Kenneth C. Crawford, Dara Entekhabi, George J. Gleghorn, Albert J. Kaehn, Jenanne L. Murphy, Veronica F. Nieva, Dorothy C. Perkins, Paul Smith. *Advisors*: Charles L. Hosler, David S. Johnson, Robert J. Serafin, Arthur I. Zygielbaum. *Staff*: Floyd F. Hauth, Mercedes Ilagan. *Consultant*: Robert Katt. *NOAA/NWS*: John J. Kelly, Jr., Robert Winokur, Louis Boezi, Louis Uccellini, Mary Glackin, Stuart Williams, Thomas Bercal, Ronald Gird, Robert Leffler, Andrew Horvitz.

Update on NWS Budget and Programs

Robert Winokur (acting director of the NWS) provided a status report on NOAA satellites and an update on NWS budgets and programs.

Advanced Weather Interactive Processing System (AWIPS)

Mary Glackin and Stuart Williams provided an update on AWIPS. Topics covered were system development, deployment issues and schedules, and contract status. They also discussed the status of major system segments at deployment sites and for the network; development responsibilities of the contractor and the government; and key subsystems in the overall software architecture. They then described the Build-3 operational test and evaluation (OT&E) objectives and system and service evaluations at the seven test sites. Also included in the presentations were the status of the satellite broadcast network, the readiness of network control facilities, and Build-4 functionalities and development tasks assigned to Planning Research Corporation and to the government.

Operational Issues in the Modernized NWS

Louis Uccellini described a requirements process that includes meetings with user communities, such as emergency managers, users

of flood forecasts and warnings, aviation users, and users of fire weather forecasts. Information gathered at these meetings is linked to a requirement template for each major service area, such as hydrometeorology, aviation, and fire weather. A service-science linkage has been established through programs such as the United States Weather Research Program (USWRP) and cooperative programs in science, technology, and applied research. The end-to-end process extends from observations to models to forecast products and provides a bridge to the dissemination of information to user communities. The requirements process has also helped the NWS establish research priorities.

Continuity of NOAA Satellites

Ronald Gird provided the NWS response to NRC (NWSMC) report recommendations on the continuity of NOAA satellites. Specifically, he described NWS's efforts to incorporate GOES sounding data (high density winds) into operational products. This work is being done at NCEP's Environmental Modeling Center and at the Tropical Prediction Center. GOES sounding data are also routinely used to augment ASOS cloud data. NWS is also monitoring and working with National Environmental Satellite, Data, and Information Service (NESDIS) and NASA to establish a backup facility at Wallops, Virginia. Mr. Gird also provided information in a handout covering the latest launch schedule for GOES satellites, the status of procurements for GOES N, O, P, and Q, and studies in progress or planned for advanced GOES systems and an overall architecture.

Other NWS Topics

Louis Boezi reported that the MARD framework document was sent to the regional offices for comment, but the responses have been delayed. He presented information on AWIPS commissioning evaluation procedures, general commissioning categories, criteria/elements for preparing warnings and forecasts, commissioning phases, and the removal of legacy systems.

Road Map Study

William Gordon reviewed the purpose and tasks of the Road Map subgroups, each of which reported on their progress in developing the study.

Special Study on the NWS Budget

John Kelly (B/Gen. USAF (retired)) reported on the status of the special study he is conducting on the NWS budget for NOAA.

AWIPS Report Review

Richard Anthes and Jenanne Murphy led the NWSMC in a section-by-section review of the AWIPS report.

Climate Record/Cooperative Observer Network (COOP)

William Bonner, panel chair, reported on the status of the Climate Record/COOP study.

December 3–5, National Research Council, Washington, D.C.

Participants: Richard A. Anthes, *chair*, David Atlas, William Bonner, Kenneth C. Crawford, Dara Entekhabi, George J. Gleghorn, Albert J. Kaehn, Jenanne L. Murphy, Veronica F. Nieva, Dorothy C. Perkins, Paul Smith. *Advisors*: Charles L. Hosler, David S. Johnson, Robert J.

Serafin, Arthur I. Zygielbaum. *Staff*: Floyd F. Hauth, Mercedes Ilagan, Theresa Fisher. *Consultant*: Robert Katt. *NOAA*: D. James Baker, Elbert J. Friday, William Mehuron, Richard Brooks, Stuart Williams, Gary Davis. *NWS:* Robert Winokur, Susan Zevin, Louis Boezi, Douglas Sargeant, Mary Glackin, Thomas Bercal, Robert McLeod, Lee Larson, Joseph Purpura. *NASA:* Alan Ladwig, Gordon Johnston. *Kanawha Institute:* Joseph Coates. *Oklahoma Climate Survey:* Dale Morris. *Systems Management, Inc.:* John Lasley. *Office of the Federal Coordinator for Meteorology:* Julian Wright. *Private consultant:* Steve Short.

Office of Oceanic and Atmospheric Research (OAR)

Elbert (Joe) Friday briefed the committee on the OAR, the primary research and development unit of NOAA. OAR conducts and directs research programs in coastal, marine, atmospheric, and space sciences through its own laboratories and offices, as well as through networks of university-based programs across the country. Since becoming director, Dr. Friday has emphasized meeting the needs of NWS and NESDIS. The Forecast Systems Laboratory has expanded its efforts to transition new science and technology into weather operations in recent years. He also cited examples of government and industry cooperation to address R&D needs of the NWS. About 60 to 65 percent of OAR's budget is spent on extramural R&D. An example is the new dropsonde, developed by NOAA, NCAR, and the Deutsche Forschungsanstalt fuer Luft- und Raumfahrt (DLR), which is now being used to gather hurricane data.

Uses of Weather Information

Joseph Coates (Kanawha Institute) presented a summary of "Current and Future Uses of Weather Information," a report for the NWS published in April 1997.

NWS Budget Update

Robert Winokur (acting director NWS) described the functional distribution of the NWS FY 1997 reduction/savings plan; the impacts of budget reductions (mitigating factors); operational effects; FY 1998 budget levels; and the projected impact of the FY 1998 budget on NWS operations.

Advanced Weather Interactive Processing System

Mary Glackin briefed the committee on the status of AWIPS. She described significant program accomplishments, such as the preliminary OT&E results, plans for Build 4, the status of local data acquisition and dissemination (LDAD), the status of the satellite broadcast network (SBN), and deployment. Preliminary Build 3 OT&E results were generally positive. Strengths of the system included the speed of displaying products and the functionality of the user interface. System reliability, data availability and NCF responsiveness were identified as areas for improvement. Build 4 is expected to upgrade the NCF and provide an initial LDAD capability. The purpose of LDAD is to automate interactions of field offices with local data observation systems, to acquire other data sources, such as spotters and local networks, and to disseminate warning and broadcast information to community decision makers. The initial deployment of the 21 additional systems has begun and should be completed by early April 1998. Secretary of Commerce Daley deferred decisions on the next 19 AWIPS installations until the written AWIPS OT&E report is available.

Advanced Weather Interactive Processing System Commissioning

Mary Glackin summarized AWIPS commissioning phases, pre-commissioning requirements, evaluation areas, general commissioning categories, and the criteria/elements of warning and forecast preparation.

OK-FIRST

Kenneth Crawford and Dale Morris described an initiative by the Oklahoma Climate Survey to develop a decision-support system for public safety agencies (emergency management, fire, and police) as a model for the rest of the country. OK-First provides access to customized environmental information and products from the Oklahoma mesonet, NEXRAD, and NWS text and graphic products.

Hydrometeorologic and Other Applications of Locally Developed Code

Lee Larson (NWS) described the advanced hydrologic prediction system (AHPS) as an integral component of the hydrometeorological service operations of the modernized NWS. The goal of AHPS is to improve river forecasts/warnings and water resources forecasts for all U.S. river basins and all time scales, ranging from days to months into the future.

Modernization and Associated Restructuring Demonstration (MARD)

Robert McLeod (NWS) briefed the NWSMC on accomplishments of the Kansas pre-MARD forecast initiative, the objectives of the MARD at a specific site and as a network, KMARD Step 2, and conditions necessary to begin the MARD. The restructuring of the last site should be completed about July 1998, at which time the MARD can begin. The MARD evaluation will include the accuracy of warnings and forecasts, the ability of AWIPS to support site operations, the quality of products and services, the effectiveness of WFO operations, the effectiveness of coordination activities, and the ability to provide backup service.

Responses to the Satellite Report

Gary Davis (NESDIS) presented the NOAA/NESDIS response to the NRC's recommendations from the satellite report, "Continuity of NOAA Satellites." NOAA, NESDIS, and NWS have taken steps to address each of the recommendations.

Activities of the Office of the Federal Coordinator for Meteorology (OFCM) and Initiatives toward Interagency Aviation Weather

Julian Wright briefed the NWSMC on the coordination infrastructure of the OFCM. He described the policies that govern its operation and the councils, committees, and working groups that operate under the coordination program. An example is the tri-agency program council for the recently completed NEXRAD program. According to Mr. Wright, the NRC report on Aviation Weather Services served as a catalyst for the FAA and NWS to form an interagency aviation weather program council that also includes the U.S. Department of Commerce (DOC), NASA, U.S. Department of Agriculture (USDA), the U.S. Department of Defense (DOD), and the National Transportation Safety Board (NTSB). A joint action group under the program council developed a program plan and a strategic plan and is now coordinating implementation plans for participating agencies.

National Oceanic and Atmospheric Administration (NOAA)

D. James Baker (NOAA administrator) met with the NWSMC to discuss NOAA/NWS programs and current and planned NWSMC studies. Richard Anthes opened the discussions with a description of the three NWSMC studies completed in the past year and the status of the three studies currently under way. Dr. Baker noted the value of the AWIPS report in NOAA's decision-making process for procuring and deploying more systems and pointed out the positive impact of a special study on NWS's budget for Fiscal Years 1998 and 1999 requested by the secretary of commerce and NOAA. He also discussed the need for high speed computing capability in NWS and NOAA and said initiatives for computers in future budgets should be supported. He is encouraged by the improved use of weather forecasts and warnings and cited the North Dakota floods as an example of emergency managers' willingness to accept and exploit uncertainty numbers in applying weather information in their decisions. Dr. Baker said that observations of the weather and climate can still be improved, and he noted NOAA's work on new satellites and on the potential utility of small satellites to provide valuable observations for monitoring weather and climate. He emphasized that science should be involved in determining what the uncertainties in observations and analyses are and what they mean. He added that integrated assessments will be important. Dr. Baker also expects the private sector's role in weather service to increase substantially in the next 20 years.

National Aeronautics and Space Administration (NASA) Strategic Plan 1998

Alan Ladwig (NASA) presented the goals, objectives, and rationale of the NASA Strategic Plan. He described NASA's strategic management system road map, which includes sections on vision; mission; fundamental questions; primary areas of business and crosscutting processes; near-term, mid-term, and long-term goals; and contributions to national priorities.

NASA Technology Reviews

Gordon Johnston (NASA) described some of NASA's procedures for reviewing and prioritizing technologies. The Goddard Space Flight Center has been designated as the lead center for technology development for the mission to planet Earth. Pilot programs are used to demonstrate new technologies, shorten development time, and reduce costs.

Future Surface Observing Systems

John Lasley and his associates (Systems Management, Inc., [a private company]) described possible upgrades to the ASOS (automated surface observing system).Upgrades include sensors for measuring freezing rain, reporting thunderstorms, and determining runway visual ranges.

Panel Reports

Reports on panel activities and concerns were presented by chairpersons of the AWIPS, Climate Record, Road Map, and Hydrology panels.

Special Meeting, August 11, National Research Council, Washington, D.C.

Participants: William E. Gordon, Albert J. Kaehn, Jenanne L. Murphy, Robert J. Serafin. *By teleconference*: David Atlas, William Bonner, Robert Brammer, Charles Hosler, Paul Smith, Arthur Zygielbaum. *Staff*: Floyd Hauth, Mercedes Ilagan, Wanda Priestly.

John J. Kelly, Jr., (B/Gen. USAF (retired)), special assistant to D. James Baker (NOAA) met with members of the committee, at his request, to discuss a special study he was conducting on requirements for and associated costs of current and future NWS operations.

Meeting Schedule for 1998

February 9–11, Beckman Center, Irvine, California
June 8–10, University Corporation for Atmospheric Research, Boulder Colorado
September 14–16, J.Erik Jonsson Woods Hole Center, Woods Hole, Massachusetts
December 7–9, National Research Council, Washington, D.C.

Activities Planned for 1998

- Publication of the 1997 Annual Report, March 1998
- A continuation of the study to review plans and progress in the development and implementation of AWIPS. A panel of the committee will monitor operational test and evaluation of each major build of AWIPS. One or more reports on AWIPS may be issued in 1998.
- Publication of a study, "Climate Record: Modernization of the Cooperative Observer Network," June 1998
- Evaluation of the needs and opportunities for modernization of the NWS beyond current plans, including an assessment of emerging science and technology to be incorporated into future modernization plans. A report will be issued in late 1998 or early 1999.
- Evaluation of the design of the MARD or its replacement to help ensure that the modernization and restructuring of the NWS will enhance weather services to the nation and to validate the significant investment of public funds.

ADVANCED WEATHER INTERACTIVE PROCESSING SYSTEM (AWIPS) PANEL

Panel Members: Jenanne Murphy, *chair,* William D. Bonner, Kenneth C. Crawford, Albert J. Kaehn, Dorothy C. Perkins. A*dvisors:* George J. Gleghorn, Arthur I. Zygielbaum. L*iaison*: Veronica F. Nieva.

The AWIPS Panel was established under the auspices of the NWSMC to evaluate the implementation of the AWIPS and its associated communications, as well as its interfaces with other components of the NWS modernization. A formal study on the AWIPS was approved by the Executive Committee of the NRC Governing Board on May 14, 1996.

Statement of Task

The NWSMC will assess the adequacy of current plans and activities in the design, development, testing, and evaluation of the AWIPS as an integral element of the modernization of the NWS. Specifically, the NWSMC will assess whether the methodology used by NOAA and NWS is sufficient to ensure that the AWIPS will be able to integrate high-resolution data from multiple sources and provide fast-response interactive analysis and display of the data for weather forecast and warning operations. Subtasks will include:

- Review the adequacy of the AWIPS risk-reduction activities in mitigating risks associated with national deployment.
- Review the plans for the AWIPS OT&E to ensure that established criteria are being met.

- Evaluate the adequacy of the conduct of the AWIPS OT&E and the results or actions taken by NOAA and the NWS in response to the tests and evaluations.
- Assess the AWIPS system security and robustness in light of system designs and the results of the OT&E.
- Evaluate the planned evolutionary development processes for future improvements, considering system extensibility and the ability to evolve system components.

The NWSMC has issued two reports on AWIPS. The first report summarized the committee's preliminary findings and recommendations based on an evaluation of the NWS OT&E plans and tests at field sites. The second was an assessment of the results of the first OT&E and system engineering and risk management issues (see Appendix C).

Meetings

January 23, Planning Research Corporation, McLean, Virginia

A subgroup of the panel met with NWS program managers and the contractor, Planning Research Corporation, to obtain their views on plans and progress in integrating the FSL workstation technologies into AWIPS.

January 29, Beckman Center, Irvine, California

The panel discussed the meeting held at the Planning Research Corporation and topics for the next report. The chair briefed the NWSMC on January 31 on the panel's activities and plans.

March 19, Forecast Systems Laboratory (FSL), Boulder, Colorado

Arthur Zygielbaum, advisor to the AWIPS panel, visited FSL and was updated on their advanced workstation and plans to help the NWS integrate the workstation's functionality into AWIPS.

April 23, Planning Research Corporation, McLean, Virginia

Panel members monitored the design review for Build 3 of AWIPS.

June 4, National Center for Atmospheric Research, Boulder, Colorado

The panel reviewed an outline of the next report and agreed on a schedule for drafting and reviewing the report.

September 17, J. Erik Jonsson Woods Hole Center, Woods Hole, Massachusetts

The panel reviewed the draft report in accordance with the guidelines provided during the NWSMC review of the report.

October 21–23, Weather Forecast Office, Salt Lake City, Utah; October 28–30, Weather Forecast Office, Pittsburgh, Pennsylvania; November 4–6, River Forecast Office, Pleasant Hill, Missouri, and Weather Forecast Office,Topeka, Kansas

The AWIPS panel was divided into teams and visited four sites where the OT&E was being conducted on workstations with Build 3 capabilities.

November 14 and November 25, U.S. Department of Commerce, Washington, D.C.

The NWSMC and AWIPS panel chairpersons briefed the officials from the NWS, NOAA, and the DOC on the AWIPS report.

November 21, National Weather Service, Silver Spring, Maryland

Panel representatives monitored the AWIPS Build 4 design review presented by NWS and contractor program managers.

December 4, National Research Council, Washington, D.C.

The panel reported its activities to the NWSMC and drafted and approved a letter responding to questions regarding the continuation of the AWIPS deployment. The letter was subsequently sent by the NWSMC chair to D. James Baker (NOAA).

CLIMATE RECORD/COOPERATIVE OBSERVER NETWORK PANEL

Panel Members: William Bonner, *chair,* Stanley Changnon, Kenneth Crawford, Nolan Doesken, Thomas Horst, Roy Jenne, Veronica Nieva, David Robinson. *Advisors:* Charles Hosler, Thomas McKee.

As part of the review and evaluation of NWS operations and plans, the NWSMC was informed by users of weather observations about their dependence on data from the Cooperative Observer Network (COOP). The NWS relies on the same data for hydrological and hydrometeorological aspects of their warnings and forecasts, as well as for other services they provide to a variety of user groups. The COOP network is deteriorating as equipment ages and the number of volunteer cooperative observers declines. Users of the data are very concerned that this important network is not being modernized. The NWSMC organized the Climate Record/Cooperative Observer Network Panel to investigate issues associated with the COOP. A formal study was approved by the NRC on October 8, 1996.

Statement of Task

The NWSMC's Climate Record/Cooperative Observer Network Panel will examine the status of and issues associated with NWS's plans for modernizing the COOP. Subtasks:

- Assess the applications of Cooperative Observer Network data.
- Assess the needs for continuation of this network.
- Examine the adequacy of NWS plans for network modernization. This assessment will include the impact of interagency data requirements on NOAA's program responsibility for modernizing the Cooperative Observer Network.
- Determine alternative approaches for improving the effectiveness and efficiency of the network through use of new technology or new organizational structures associated with NWS modernization.

Meetings

March 31–April 1, National Center for Atmospheric Research, Boulder, Colorado

The panel met with representatives of NOAA, the USDA, and the Western Regional Climate Center (WRCC). The following topics were discussed.

National Climatic Data Center (NCDC). John Jensen (NCDC) presented a briefing on climate data topics prepared by Tom Karl. The topics included biases introduced when instrumentation is replaced or updated, changes in observing practices that resulted in errors and biases in precipitation data, guidelines and principles for monitoring climate, NOAA initiatives for the cooperative observer network, and a white paper on "Deterioration and Disarray in Basic U.S. Climate Monitoring." Mr. Jensen then briefed the panel on NCDC data acquisition, processing, and dissemination. He summarized their budget, uses of climate data, and issues affecting NCDC operations.

Modernization Plan. Robert Leffler (NWS) discussed the NWS Cooperative Weather Observer Program and Modernization Plan. His presentation included a description of the current network, variations in equipment and observations, NOAA's split management practices, data flow and uses, changes affecting the program, deficiencies, and ways to improve the program.

U.S Department of Agriculture's (USDA) Perspective. Albert Peterlin (USDA) described the USDA partnership with NOAA/NWS and the gradual degradation in data from the COOP network. He presented a USDA historical perspective of the cooperative observer network, USDA initiatives to acquire weather and climate information, and some recommendations for modernization.

Western Regional Climate Center's Perspective. Kelly Redmond (WRCC and the Desert Research Institute) described his experiences and interactions with the COOP network over the past 15 years. His briefing included a description of uses for climate data, recent losses of daily observations primarily published by NCDC, and the importance of consistency of reports from observation sites. He also discussed desired station density, the fractured nature of network management, and automated versus manual observations.

State Climatological Perspective. Thomas McKee (Colorado state climatologist and advisor to the panel) discussed the concerns of the American Association of State Climatologists (AASC) about the COOP. He summarized the history, the purpose of the network, the primary concerns of AASC, key issues, and the potential of the network.

Weather Office Perspective. Thomas Adler (NWS, Western Region) presented the views and concerns of the WFO personnel in his region who interact routinely with cooperative observers and process and check data for local use.

Forecast System Laboratory Perspective. Thomas Schlatter (FSL) described FSL's role in organizing a regional observation cooperative (ROC) network. FSL's involvement dates back to a mesonet of stations they have operated since 1980 to support their development. He compared their initiative with other regional nets, such as the Oklahoma, Utah, and Olympic mesonets, and identified common goals. Mr. Schlatter laid out guidelines for ROCs and discussed operating ROCs in terms of data requirements, communications, data management, data processing and quality control, and products.

Mesonets. Kenneth Crawford (panel member and director of the Oklahoma Climatological Survey) briefed the panel on the Oklahoma mesonet, a joint project of the University of Oklahoma and Oklahoma State

University to provide 111 environmental monitoring stations statewide. The 111 mesonet stations are spaced about 35 km apart. Dr. Crawford discussed the equipment, the core and supplemental weather parameters measured and disseminated, financial support, data users, and the archiving reliability of the mesonet.

Automation. Thomas McKee (Colorado state climatologist and advisor to the panel) presented a briefing on automated weather systems for the cooperative observer program. He discussed components of an automated system, issues, and pros and cons of automated vs. manual sensing of temperature and precipitation.

June 16–17, National Climatic Data Center Asheville, North Carolina

The panel met with representatives of NOAA, the Southeast Regional Climate Center, and state climatologists.

U.S. Historical Climate Network (USHCN). David Easterling (NCDC) explained that the purpose of the USHCN is to provide data for a network of high quality climate observing stations within the contiguous United States for use in long-term climate monitoring. Since 1895, some 1,221 stations have reported monthly on maximum, minimum and mean temperatures, and precipitation. Dr. Easterling also described the criteria used to select these stations, the instruments used for measuring the weather elements, processing activities, and future plans.

Global Historical Climate Network, Global Climate Observing System (GCOS), and the COOP Stations Selected to be Part of GCOS. Tom Peterson (NCDC) reported that the Global Historical Climate Network provides atmospheric data for land surfaces on a monthly basis. These data include temperature (mean, mean maximum, mean minimum), precipitation, sea level pressure, and station pressure. He discussed the number of stations in each of the more than 30 source data sets, quality controls, the variety of meta data, homogeneity adjustments, the updating system, and showed maps of the reporting sites.

Foreign Networks Similar to the U.S. Cooperative Observer Network (COOP). Michael Crowe (NCDC) reported that Canada is writing a network rationalization plan that is expected to be ready in six months to one year. Other countries with networks include Australia, the United Kingdom, Germany, Mexico, China, and Russia (and the other countries of the former Soviet Union). Canada has about 10,000 observers and is considering using automatic sensors. Australia has about 2,500 volunteer daily rainfall observers and 1,500 automated stations directly linked to the Bureau of Meteorology. Mexico has thousands of stations, but when payments stopped, about 60 percent of the observers stopped reporting. China has all paid observers, about 2,500 of whom take three observations per day. Russia and other countries of the former Soviet Union began taking measurements in the 1830s and eventually peaked at 13,500 stations in the 1980s. The number has now dropped to about 10,000. Germany has an extensive network with data collected, quality controlled and published on a monthly basis.

Joint NWS/Office of Hydrology and NCDC Environmental Sciences Data Information Management Project: Data Continuity and Quality. In John Jensen's (NCDC) presentation, "Process and Archive Fischer and Porter Precipitation Data Telemetered by Satellite from NWS Cooperative Observer Network Sites," he defined the goals of

the project—to develop the capacity at NCDC to process Fischer and Porter precipitation data reported via satellite. There are a total of 2,450 Fischer and Porter gauge sites that report precipitation at 15-minute intervals. Mr. Jensen described the project, the challenges involved, the accomplishments to date, the benefits, and the outlook for the remainder of FY1997.

Report on COOP Site Data. Grant Goodge (NCDC) presented an analysis of cooperative observer stations where the summary-of-the-day data had been terminated. In some cases, data were no longer received, and in others, the data were judged as being unreliable. He also presented a graph showing a decrease in the number of COOP stations from about 10,000 in 1960 to 7,000 in 1985, and increasing again to about 7,500 in 1995. He noted that when the Tennessee Valley Authority (TVA) closed their climate program in the early 1980s, about 800 to 1,000 stations were closed. He also provided some examples of the applications and benefits of COOP data for a variety of users.

WFO Interactions with Cooperative Observers. David Keller (NWS, Blacksburg, Virginia) and Alan Rezek (meteorologist, Charleston, West Virginia) reported on COOP program responsibilities at their weather offices, the COOP program before and after modernization, and responded to questions. They also relayed information gathered from other data acquisition program managers in the NWS Eastern Region.

Geographic Editing and Analysis System. Stephen Del Greco (NCDC) reviewed the responsibilities of the Data Operations Branch for data assimilation, quality control, and product generation. Mr. Del Greco described the current data streams, processing systems, branch objectives, and coordination and feedback with NWS. He discussed efforts to promote good form management, to provide assistance by phone or site visit, and to identify problems with instrumentation. He noted that 97 percent of the surface stations that make up the USHCN are cooperative observer stations.

Hourly Precipitation Data Processing (HPD) System. Gregory Hammer (NCDC) presented information about the four major steps in HPD processing: ingestion; smart filtering and data transmission; interactive quality assurance; and archiving and dissemination. NCDC receives about 2,400 weighing rain gauge paper tapes per month. Smart filtering removes nonprecipitation events from each report and translates gauge values into precipitation amounts. Questionable data are manually reviewed. The digital archive consists of 15-minute data (gauge and precipitation values) and hourly data (precipitation only).

COOP Customers. Henry J. Ray (NCDC) reported that the NCDC customer profile, based on orders for one year beginning October 1, 1995, showed that the highest percentage of requests were from legal customers (27 percent) and business customers (20 percent). When reimbursable costs are considered, the top five users were NOAA (18 percent), other government agencies (17 percent), consultants (15 percent), business (14 percent), and foreign users (14 percent). The number of NCDC customers ordering COOP data has risen from 423 in FY1994 to a projected 24,000 in FY1997.

Role of Meta Data Records. Robert Quayle (NCDC) explained that meta data include station (site) identifiers, locations, observing practices, and equipment information—all of which are essential for the interpretation of the

data. Mr. Quayle described sources of COOP data; the role of the COOP meta data at NCDC; the status of COOP station information collections; the NCDC station history database; the role of the cooperative observer station system accountability meta data in COOP modernization; and future opportunities.

Snow Climatology. Richard Heim (NCDC) discussed objectives, procedures, and the current status of snowfall and snow depth climatologies for NWS cooperative observer sites. The primary objective is to produce statistics for normal, mean, and extreme snowfalls and snow depths for approximately 4,500 non-airport NWS cooperative observer network stations (at least one per county, 3,300).

Updates on North American Atmospheric Observing System (NAOS) and the NWS Modernization Architecture. August Shumbara (NCDC) described the NAOS as a cooperative program supported by Canada, Mexico, and the United States that will issue a study recommending the configuration of a composite Upper Air Observing System over North America and adjacent waters. Following scientific evaluations, the study will identify short-term steps to improve existing systems and design a cost-effective mix of systems for the future. The NOAA NWS Architecture is an evolutionary descriptive plan for the NOAA NWS in terms of its services, functions, and performance.

Instrumentation. Tom Horst (panel member) discussed a method of upgrading the COOP data collection and transmission process by installing a general purpose data logger at each site.

June 18, NWS Weather Office, Peachtree City, Georgia

Three panel members and the study director visited the Peachtree City, Georgia, weather office. The primary purpose of this visit was to see how the cooperative observer data were obtained and used, along with data from other special networks, in the operations of the WFO and RFC. The panel also solicited the views of weather office staff on the cooperative observer program.

September 4–5, National Research Council, Washington, D.C.

The panel met with representatives of NWS, NOAA, USDA, U.S. Army Corps of Engineers (USACE), DOI, OFCM, NRC/Board on Atmospheric Sciences and Climate, the University of Maryland, and the Canadian Weather Service.

Factors Influencing COOP Program Requirements and Budget. Susan Zevin (NWS) described budget shortfalls and their effect on the NWS cooperative observer program. Factors that will influence the future of the cooperative observer program include a global reference climate network, integrated NWS hydrometeorological products, and the scope of the mission to describe a climate for agricultural and other economic purposes.

National Climatic Data Center (NCDC) Mission. Ken Davidson (NCDC) described the NCDC mission of acquiring and archiving data to describe the climate of the United States and the necessary timeliness of data to support new services and technological demands.

Office of the Federal Coordinator for Meteorology (OFCM). Julian Wright (OFCM) reported on the federal structure for coordinating meteorological services and supporting research.

U.S. Army Corps of Engineers' (USACE) Perspective. John Parks (USACE) discussed the utility of cooperative observer data for USACE. The primary use is for real-time management of flood control and multiple purpose projects. Mr. Parks described how the data are used for major flood control programs, the quality of the data, network automation, and funding issues.

U.S. Department of Agriculture (USDA) Update. Albert Peterlin (USDA) stated that the data from cooperative observer sites are very valuable and that he has gone on record as a strong advocate of the program. He recommended measures to sustain or improve the cooperative observer data in support of USDA requirements.

U.S. Department of the Interior (DOI) Perspective. Lewis Moore (DOI) discussed the utility of cooperative observer data for the Bureau of Reclamation and other components of the DOI in managing dams and reservoirs and for the Unites States Geological Survey and in the National Park Service.

National Research Council/Board on Atmospheric Sciences and Climate (NRC/BASC) Perspective. William Sprigg (NRC/BASC) discussed the need for cooperative observer data in various national and international climate research programs.

National Centers for Environmental Prediction (NCEP) Perspective. Jim Laver (NWS) discussed the use of cooperative observer data at NCEP for nowcasting, predictions, and research in weather and climate. He summarized NCEP requirements for COOP data and operational applications (such as in the end-to-end forecast process, drought indices, the verification of model precipitation predictions, climate predictions, etc.). NCEP R&D applications include gridded hourly precipitation for the United States and the GEWEX/GCIP project support.

Modernization of the Cooperative Observer Network. Thomas Karl (NCDC) (by teleconference) reviewed past efforts by NWS to modernize the cooperative observer network.

NOAA Project. Robert Reeves (NOAA) described a project for cross-NOAA collaboration that would provide NOAA's data and products to a wider constituency.

Local Data Acquisition and Dissemination (LDAD). Richard Jesuroga (FSL) described the LDAD developments at NOAA/FSL. The AWIPS LDAD system includes technology for the exchange of valuable weather information between the NWS and the public/private sector (including cooperative observers).

COOP Program Cost. Phillip Clark (NWS) summarized the costs of the cooperative observer program and the number and types of climate requests processed by NWS, NCDC, state climatologists, and regional climate centers.

Canadian Cooperative Observer Network Plan. Gary Pearson and Theodore Yuzyk

(Atmospheric Environment Service, Canada) reviewed and discussed the rationalization for the climate network for Canadian cooperative observer stations. Significant budget reductions have prompted AES to form a working group to determine requirements and strategies for a climate network in Canada.

Australian Cooperative Observer Network. William Bonner (panel chair) summarized the capabilities of the cooperative observer network and planned changes by the Bureau of Meteorology, Australia. He described the number and types of stations and plans for automation.

Climate Record/Cooperative Observer Network Panel Update. The panel reported on its study activities at the NWSMC quarterly meetings (January 31, June 3, September 16, and December 5).

CONTINUITY OF NOAA SATELLITES PANEL

Panel Members: George J. Gleghorn, *chair,* William E. Gordon, Robert J. Serafin. A*dvisor:* David S. Johnson.

At the meeting of the NWSMC on September 15, 1993, D. James Baker, undersecretary of commerce for oceans and atmosphere, suggested that the NWSMC examine the continuity of coverage of the GOES and polar-orbiting operational environmental satellites (POES). The NWSMC thus established a Satellite Panel to review coverage and to design a formal study. The satellite study was approved by the NRC in September 1995, and a report was published by the NRC in January 1997.

Statement of Task

The NWSMC will assess the adequacy of planned NOAA geostationary and polar satellite coverage in terms of system continuity and backup. This study will consist of the following tasks:

- Evaluate current NOAA and Department of Defense meteorological satellite program records and replenishment plans.
- Examine each meteorological satellite program with respect to requirements for continuity of coverage.
- Determine best estimates of continuity for current meteorological satellite programs considering strategies for satellite replacement.
- Assess the need for and timing of satellite programs not presently under contract to replenish geostationary and polar-orbiting weather satellites.

Meetings

January 18, U.S. Department of Commerce, Washington, D.C.

The NWSMC and panel chairpersons presented the satellite report to D. James Baker and his staff.

March 18, Office of Management and Budget, Washington, D.C.

The panel chair presented the satellite report and discussed it with representatives of the Office of Management and Budget.

HYDROLOGY PANEL

Panel Members: Kenneth Crawford, *chair,* Dara Entekhabi, Veronica Nieva. A*dvisor:* William Bonner.

This panel was formed by the NWSMC to review hydrologic and hydrometeorological activities related to the NWS modernization. The panel continued to monitor NWS plans and operations and proposed a formal study. The report was published by the NRC in December 1996.

Statement of Task

In June 1995, the Executive Committee of the NRC's Governing Board authorized the NWSMC to conduct a study of the status of and issues related to the plans of the NWS for the development and implementation of modernized hydrologic products and services. The committee was asked to fulfill the following tasks:

- Examine the plans for modernization of the NWS hydrologic and hydrometeorological products and services for the nation.
- Examine the progress made by the NWS in improving hydrologic and hydrometeorological products and services for the nation.
- Assess the effectiveness of the NWS in incorporating new technology and science in hydrologic and hydrometeorological products and services to the nation.
- Identify unmet needs in NWS hydrologic and hydrometeorological products and services for the nation.
- Explore alternative approaches for incorporating scientific and technical developments into the modernized NWS hydrologic and hydrometeorological products and services.

No formal meetings were held in 1997, but the panel continued to assess responses to its report from the NWS and NOAA.

MODERNIZATION AND ASSOCIATED RESTRUCTURING DEMONSTRATION (MARD) PANEL

Panel Members: Veronica Nieva, *chair,* David Atlas, Dara Entekhabi, Albert Kaehn. A*dvisor:* George Gleghorn.

In Stage 2 of the NWS modernization, the NWS plans to demonstrate its ability to deliver services from offices equipped with new technologies as a model for its nationwide operations. In preparing for and conducting the MARD, the NWS plans to take the following steps:

- Deploy new technologies and integrate them into operations.
- Staff restructured offices with the required number and mix of personnel.
- Develop and apply procedures related to warnings and forecasts.
- Train staff to use the new technologies and scientific advances.
- Restructure selected NWS field offices into WFOs to realign areas of service in close coordination with emergency management groups and others.
- Evaluate performance and the responses of users.
- Provide service equal to or better than the service before modernization.

The NWS will select certain offices for operational demonstration. The task of the MARD Panel, on behalf of the NWSMC, is to evaluate the design of the MARD, including its configuration and operations and to examine the planned analysis of the results.

Although the panel did not hold formal meetings in 1997, several presentations were made by NWS on the changing framework and concept for the MARD. The panel also continued

to review draft plans for the MARD and corresponded with NWS representatives to clarify pre-MARD activities and other issues.

ROAD MAP FOR THE FUTURE NATIONAL WEATHER SERVICE PANEL

Panel Members: William E. Gordon, *chair*, Richard A. Anthes, David Atlas, Robert Brammer, Kenneth C. Crawford, George J. Gleghorn, David S. Johnson, Veronica Nieva, Dorothy Perkins, Robert J. Serafin, Paul Smith and Arthur Zygielbaum.

The NWSMC, at the request of the NWS, established a panel to develop a study to guide the NWS in continuing its modernization beyond current plans. The Executive Committee of the Governing Board of the National Research Council approved this study on October 15, 1997.

Statement of Task

The purpose of this study is to provide guidelines for the NWS to exploit effectively emerging science and technology, incorporate modernization practices into operations, and continue to improve weather forecasting and related products and services for the nation well into the twenty-first century. The report will include findings and recommendations on opportunities for the NWS to exploit effectively and incorporate emerging science and technology into routine operations on a continuing basis. In addition to addressing technical issues, the study will suggest criteria to establish priorities for science and technology initiatives that would foster improvements in NWS operations and services.

Meetings

June 3, National Center for Atmospheric Research, Boulder Colorado

The NWSMC reviewed the prospectus for the Road Map Study, and William Gordon, panel chair, proposed an outline for the study, preliminary NWSMC panel subgroups, and a schedule for gathering information.

September 15–17, J. Erik Jonsson Woods Hole Center, Woods Hole, Massachusetts

The panel met in a series of workshops and in plenary sessions with the full committee to review issues regarding future NWS modernization and to gather and organize additional data for the study.

December 3–5, National Research Council, Washington, D.C.

The NWSMC and the Road Map Panel met in a joint session with representatives of NWS, NOAA, NASA, the Oklahoma Climatological Survey, the Kanawha Institute, and private sector organizations and consultants. Presentations were made on the following topics of concern to the future NWS:

- Programs of the Office of Oceanic and Atmospheric Research
- current and future users of weather information
- Oklahoma's decision support system for public safety officials
- the aviation weather initiative
- NASA Strategic Plan and technology review process
- future observing systems

ACRONYMS

AASC	American Association of State Climatologists
AHPS	advanced hydrologic prediction system
ASOS	automated surface observing system
AWIPS	advanced weather interactive processing system
BASC	Board on Atmospheric Sciences and Climate
COOP	cooperative observer network
CSU	Colorado State University
DOC	U.S. Department of Commerce
DOD	U.S. Department of Defense
DOI	U.S. Department of the Interior
DOT	Department of Transportation
EOS	Earth observing system
FAA	Federal Aviation Administration
FSL	Forecast Systems Laboratory
GATES	geosynchronous advanced technology environmental system
GCIP	GEWEX continental-scale international project
GCOS	global climate observing system
GEWEX	global energy and water cycle experiment
GOES-Next	next generation geostationary operational environmental satellite(s)
GOES-R	geostationary operational environmental satellite (first in another generation of GOES)
HPD	hourly precipitation data processing system
KMARD	Kansas modernization and associated restructuring demonstration
LDAD	local data acquisition and dissemination
MARD	modernization and associated restructuring demonstration
NAOS	North American atmosphere observing system

NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmosphere Research
NCDC	National Climatic Data Center
NCEP	National Centers for Environmental Prediction
NCF	Network Control Facility
NESDIS	National Environmental Satellite, Data, and Information Service
NEXRAD	next generation weather radar
NOAA	National Oceanic and Atmospheric Administration
NOAAPORT	Provides relay of centrally produced NOAA products (particularly satellite-derived products) to NOAA sites throughout the United States
NRC	National Research Council
NTSB	National Transportation Safety Board
NWS	National Weather Service
NWSMC	National Weather Service Modernization Committee
OAR	Office of Oceanic and Atmospheric Research
OFCM	Office of the Federal Coordinator for Meteorology
OT&E	operational test and evaluation
POES	polar-orbiting operational environmental satellite(s)
RFC	river forecast center
ROC	regional observation cooperative
SBN	satellite broadcast network
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USHCN	U.S. Historical Climate Network
USWRP	United States Weather Research Program
WFO	weather forecast office
WRCC	Western Regional Climate Center
WSR-88D	weather surveillance radar-1988 Doppler

APPENDIX A

PUBLISHED REPORTS OF THE NATIONAL WEATHER SERVICE MODERNIZATION COMMITTEE AND PANELS

FIRST REPORT

The NWSMC's 1991 report, *Toward a New National Weather Service—A First Report* (NRC, 1991a), was a broad overview of NOAA's modernization plans and development. It covered the new observational systems; new information systems; the 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. NOAA responded to this report in September 1991.

LETTER REPORT

Letter report to John A. Knauss, undersecretary of commerce for oceans and atmosphere, from Charles L. Hosler, chair, NWSMC, May 31, 1991, regarding proposed revised standards for entry-level meteorologists in the federal government (NRC, 1991b).

SECOND REPORT

The second report, in 1992, *Toward a New National Weather Service—Second Report* (NRC, 1992), raised concerns about the funding and implementation of modernization as well as the deterioration of the present NWS system; analyzed the response of NOAA to recommendations in the first report; discussed the certification process and requirements; and provided additional recommendations dealing with climatological considerations of the modernization. NOAA responded to this second report in November 1992.

MODERNIZATION CRITERIA

The report *Review of Modernization Criteria* (NRC, 1993), responded to P.L. 102-567, Sec. 704(a) (U.S. Congress, 1992). In that report the committee found NWS certification criteria to be adequate, with these qualifications regarding ASOS, verification statistics, and climate data:

- Human observers must be maintained until a database can be acquired that will allow the NWS to determine with confidence the extent to which human assistance is needed for weather observations.

- It is crucial to resolve uncertainties about the requirements of the FAA for surface aviation observations and to expedite the automation of additional observation capabilities for the ASOS.
- The NWS proposal to expand coverage to 36 diverse sites of its planned tests comparing ASOS with manual observations for a period of one year should provide a satisfactory basis for comparison of ASOS with manual observations and the degree to which the ASOS meets various observational requirements. The comparisons will provide a basis for understanding the differences between human and automated observations and help determine how much augmentation and quality control are needed and to ensure the quality of the climate database.
- Watch/warning and public/aviation forecast verification programs are appropriate and crucial for certifying that closure of NWS offices will not degrade service.
- Adequate staffing and funding for the NWS are needed to capitalize on opportunities to further improve its products and services.

EMPLOYEE FEEDBACK

In March 1994 the NWSMC issued a report, *National Weather Service Employee Feedback* (NRC, 1994a). The general objectives of this study were to:

- Determine the prevalence of concerns about modernization among NWS nonsupervisory employees in the field.
- Determine the adequacy of communication about modernization between these employees and NWS local, regional, and national managers.
- Determine if subsets of employees (such as those at certain offices, those with certain backgrounds, etc.) report different concerns or have experienced different levels of communication.

The report provided nine recommendations including suggestions for the NWS to improve communications with its employees, build a team-based culture for its operations, evaluate skill and training needs, prepare user communities for modernization, and consider ways to acquire expertise in implementing technological changes.

WEATHER FOR THOSE WHO FLY

The next report issued by the NWSMC was *Weather for Those Who Fly* (NRC, 1994b), also issued in March 1994. The objective of this study was to determine the potential impact of the NWS modernization, and related improvements being implemented by the FAA (Federal Aviation Administration), on weather services to civil aviation. The report also examined problems and opportunities in light of aviation requirements and NWS modernization.

The committee provided 11 recommendations including better cooperation between, and action by, the NWS and the FAA on technology initiatives and programs; improvements in the resolution and accuracy of aviation weather observations; new approaches to analysis and forecasting; improved presentation of weather information throughout the aviation support system; better weather education for pilots; placing higher priority on pilot weather reports; and the priorities and resources needed for progress.

NEXRAD COVERAGE

Assessment of NEXRAD Coverage and Associated Weather Services (NRC, 1995) was authored by the NEXRAD Panel of the NWSMC. This study responded to a request to the NRC from the secretary of commerce and the chairman of the House Science Committee to evaluate radar weather detection coverage for the contiguous United States to ensure that there would be no degradation of associated weather services related to the modernized radar network.

The report developed technical assessment criteria for hazardous weather phenomena, identified areas where radar detection may be degraded, and provided assessment criteria for the NWS to use in conducting site-by-site evaluations of warning and forecast services. It also recommended actions for the NWS to take to avoid further degradation in coverage and service. The secretary of commerce responded to the NRC study by organizing a team to conduct site-by-site evaluations of the geographical areas of concern using criteria established in the NRC report. The team's report was released in October 1995. Based on recommendations in this report and team reports by DOC, the NWS added a Doppler weather radar at three locations, established a weather office at one of these locations, continued office operations at three sites, and continued radar operations at three sites.

UNITED STATES WEATHER RESEARCH PROGRAM

The NWSMC formed a panel in June 1995 to review the United States Weather Research Program (USWRP) and the overall importance of weather research to the NWS modernization. The committee initiated a letter report to stress the importance of continuing weather research for meeting the fundamental objective of the modernization program, namely, improving short-term forecasts and warnings. The committee concluded that under current fiscal constraints it was important that the NWS identify research priorities with the USWRP and suggested priority areas for weather research (NRC, 1996a).

ADVANCED WEATHER INTERACTIVE PROCESSING SYSTEM

The letter report *Preliminary Assessment of the Operational Test and Evaluation Process for the Advanced Weather Interactive Processing System* was published by the NRC in September 1996 (NRC, 1996b). This report was part of a study undertaken in response to a request to the NRC from the undersecretary of commerce for oceans and atmosphere and the administrator of NOAA to review plans and progress on the development and implementation of the AWIPS. The letter report by the NWSMC specifically addressed the subtask of evaluating the adequacy of the AWIPS operational test and evaluation (OT&E) and actions taken by NOAA and the NWS in response to the OT&E.

HYDROLOGY REPORT

In response to a 1995 contract statement of work from NOAA, the NWSMC formed a Hydrology Panel to gather information and assess the status of hydrology operations and services in the NWS. In accordance with its charge from the NRC, the committee's report, *Assessment of Hydrologic and Hydrometeorological Operations and Services* (NRC, 1996c), identified the most critical tasks for advancing the NWS modernization program and presented analyses, findings, conclusions, and

recommendations. The committee placed a relatively higher priority on 14 of the 40 recommendations, including the precipitation processing system, precipitation forecasting, flash flood forecasting, quality assurance, research and development, and the need for advisory groups.

SATELLITE REPORT

In January 1995, NOAA requested that the NWSMC "assess the adequacy of planned NOAA geostationary and polar-orbiting satellite coverage in terms of system continuity and backup." The committee found that reliable and continuous service from the operational NOAA satellites remains a dominant national requirement. Completely redundant systems and sensors are not provided aboard each satellite; therefore, a sufficient number of GOES and POES must be launched to provide the necessary redundancy in orbit at all times. The report, *Continuity of NOAA Satellites* (NRC, 1997a), offers eight recommendations to address system backup deficiencies and to strengthen a basically adequate system of satellites and the associated launch strategy for replacements. The Executive Summary of this report is included as Appendix B.

AWIPS REPORT

When AWIPS is commissioned for operations, it will be a distributed data processing system used at field offices, regional offices, and NWS headquarters to integrate information received from all other observational and analytical elements of the modernized system. AWIPS will also provide a nationwide communications network for distributing weather data, products, and services. Based on the Build 1 operational test and evaluation (OT&E) and NWS's responses, the NWSMC concluded that the OT&E process is an effective, valuable, and necessary element in the development and deployment of AWIPS. The committee provided recommendations on NWS systems engineering and on operational risk management. The Executive Summary of this report is included as Appendix C.

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APPENDIX B

EXECUTIVE SUMMARY OF THE CONTINUITY OF NOAA SATELLITES JANUARY 1997

The National Oceanic and Atmospheric Administration (NOAA) asked the National Research Council (NRC) to assess the adequacy of planned geostationary and polar meteorological satellite coverages in terms of system continuity and backup. This report, prepared by the NRC's National Weather Service Modernization Committee (NWSMC), responds to that request. The NWSMC has not investigated the Defense Meteorological Satellite Program (DMSP) of the Department of Defense except peripherally, as it relates to the proposed National Polar-orbiting Operational Environmental Satellite System (NPOESS) program and as a backup to the polar-orbiting operational environmental satellite (POES).

The National Weather Service (NWS) is charged with providing forecasts of the weather for the United States and the adjoining oceans and with providing warnings of severe weather conditions in advance and as they occur. Satellite observations have been essential inputs in the provision of these services for more than 20 years. In addition, satellite data in many forms are used by NOAA, other government agencies, and the private and academic sectors in a broad range of applications, such as monitoring climate, planning land-use, and research. The National Environmental Satellite, Data, and Information Service (NESDIS) operates two satellite systems: the geostationary operational environmental satellite (GOES) system, which observes the same area of the Earth continuously; and the POES system, which observes the full area of the Earth in north–south strips, with the orbit height set so that each strip is observed at the same local time.

The committee's findings and recommendations are summarized in this Executive Summary, and details are provided in the report. In general, the findings show that NOAA's satellite systems are adequate and the strategy for satellite replenishment and scheduling of launches is sound. However, the committee made no attempt to evaluate the impact of incorporating improved sensors and new technology or other factors not presently included in planned programs. The committee does recognize the importance of these other factors, particularly the long lead time required for developing and integrating new sensors and other new technology. This lead time must be taken into account in planning follow-on replenishment programs for environmental satellites.

Reliable and continuous service from the operational satellites remains a dominant national requirement. Completely redundant systems and sensors are not provided aboard each satellite; therefore, a sufficient number of GOES and POES must be launched to provide the necessary redundancy in orbit at all times.

The committee's analysis of NWS requirements for satellite data led to the following findings and recommendations.

Finding 1a. At least one operational POES is needed in orbit at all times to provide data vital to global numerical-prediction models. A backup POES in orbit also is required to ensure that unacceptable degradation of service does not occur when the operational POES fails. The backup satellite may also be operated simultaneously with the first satellite, thus providing global coverage four times a day. A replacement must be available for launch when either of the orbiting spacecraft fails.

Finding 1b. At least two operating GOES satellites are needed in orbit at all times to provide the necessary coverage from the central Pacific Ocean eastward to the coast of West Africa.

Recommendation 1. To meet NWS high priority requirements for satellite coverage in support of weather forecasts and warnings, NOAA must ensure that the requisite data are available at all times from at least one POES and two GOES in orbit. To ensure this continuity, a backup POES and a backup GOES need to be available in orbit.

Finding 2. The GOES-8 and GOES-9 offer an opportunity to establish the operational utility of deriving soundings and upper air winds from GOES data and implement new techniques in operations. Field office staff visited by the committee would like to have access to sounding and wind data from GOES.

Recommendation 2. NWS/NOAA should fully support efforts to develop and demonstrate techniques for using GOES soundings and winds to improve warnings and forecasts. It is essential that the NESDIS and the NWS (particularly the National Centers for Environmental Prediction) devote adequate personnel to processing, evaluating, and applying newly available satellite data as soon as possible. Science operations officers and other field staff could also contribute to this effort.

In response to a presidential decision directive, steps are being taken to merge the present POES system and the DMSP into a single system, the NPOESS. The first NPOESS launch is planned for 2008. Negotiations are under way between the NOAA and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT); the latter will provide a replacement for one of the two POES satellites currently in orbit. The European satellites, called "meteorological operational" (METOP) satellites, will be introduced about 2002. Cooperation between NOAA and EUMETSAT is expected to continue in the NPOESS era, during which two of the nominal three satellites in orbit will be provided by NOAA. EUMETSAT will provide the third.

Examination of the launch and in-orbit performance of the POES and GOES satellites, schedules for future satellites, possible backups to POES and GOES, spacecraft availability, and ground system vulnerabilities led the committee to the following additional findings and recommendations.

Finding 3. The polar program, as presently planned, depends on the availability of European METOP satellites in polar orbit from 2002 to 2010 and the availability of NPOESS beginning about 2008.

Recommendation 3. NOAA should closely coordinate the POES program with the progress of the NPOESS and METOP satellite programs so that "gap-filler" satellites are not needed.

Finding 4. In the longer term, the replenishment strategy depends on the new NPOESS for polar-orbiting satellites and on the continued procurement of additional GOES satellites. (NOAA plans the procurement of a new design, beginning with GOES-R.) Longer lead times than normal are required when new designs, such as planned for GOES-R, METOP, and NPOESS, are being introduced.

Recommendation 4. When considering ways to develop new spacecraft and incorporate major new improvements in technology, NOAA should carefully consider the lead times dictated by the required launch schedules and the very long procurement cycle. NOAA should develop schedules for the transition from current designs to new ones, such as NPOESS and GOES-R, that adequately account for the

necessary lead times for funding approval, procurement, design and development, fabrication, and verification.

The POES ground system appears to be adequate for the foreseeable future. However, the Wallops command and data acquisition (CDA) station is a potential single point of failure for the GOES system. Any phenomenon that could shut down the station, such as a hurricane, flooding, major fire, or explosion, would result in complete data cutoff from GOES satellites. Minimum prudent backup would require—at a location geographically remote from the Wallops facility—an antenna subsystem and the necessary receiving, transmitting, data formatting, and processing subsystems to command a GOES satellite, receive telemetry, and acquire and distribute data from the sounding and imaging instruments.

Finding 5. The Wallops CDA station is a potential single point of failure for the GOES system. Shutdown of the station would result in a complete cutoff of data from the GOES satellites.

Recommendation 5. NOAA should implement an adequate backup system to the Wallops CDA station to ensure the uninterrupted operation of GOES satellites and the acquisition of sufficient data to generate basic image and sounding products to meet the NWS mission requirements.

An agreement exists between NOAA and EUMETSAT whereby, under certain circumstances, one organization may provide backup of the other's operational geostationary meteorological satellite system. At the present time, the agreement appears to offer backup of GOES that is of limited value. This supports the following findings and recommendations.

Finding 6. Although arrangements have been made for European geostationary meteorological satellite, METEOSAT, to provide backup to GOES under certain conditions, the coverage by METEOSAT or its successor is very limited compared to the coverage provided by GOES.

Recommendation 6. NOAA should ensure that a replacement GOES satellite can be launched and operated as soon as an operational GOES fails to continue the full level of coverage expected of this series of satellites.

Finding 7. One additional GOES is needed in orbit as a ready spare to protect against a dangerous, protracted loss of full, two-satellite coverage if one operational GOES fails. Even more severe, although far less likely, would be an outage of continual, real-time coverage if both satellites in orbit should fail before a replacement could be made operational. Dependence on commercial launches for GOES can lead to delays of well over a year, even if a spacecraft is available for launch.

Recommendation 7. To ensure the continuity of two-GOES coverage, NOAA should store a GOES in orbit, rather than on the ground, if this is technically and operationally feasible and cost effective.

Consideration of factors that determine continuity of service has led to a launch-decision process in which a group of senior managers of the NWS and NESDIS regularly review the status of the satellites in orbit, satellite production, the availability of launch times, the readiness of the next satellite in the short range, and the replenishment strategy in the long range. They also review and update satellite availability prediction studies on a regular basis.

Finding 8a. The launch-decision process used by NWS and NESDIS is appropriate.

Finding 8b. The planned GOES, POES, METOP, and NPOESS procurements are adequate to provide continuity of the NOAA geostationary and polar-orbiting satellites for at least the next 15 years, if they are funded and carried out on the current schedule.

Recommendation 8. To ensure continuity, NOAA should fund and procure the planned additional block of four GOES-Next spacecraft in a timely fashion and should avoid any further delays in the METOP and NPOESS programs.

APPENDIX C

EXECUTIVE SUMMARY OF AN ASSESSMENT OF THE ADVANCED WEATHER INTERACTIVE PROCESSING SYSTEM DECEMBER 1997

The last major technical system required to complete the decade-long modernization of the National Weather Service (NWS) is the Advanced Weather Interactive Processing System (AWIPS). When commissioned for operation, AWIPS will be a distributed data processing system used at NWS field offices, regional offices, and headquarters to integrate information received from all other observational and analytical elements of the modernized system. AWIPS will support the work of hydrologists and meteorologists by delivering state-of-the-art forecasts and warnings. AWIPS will also provide a nationwide communications network, with the NWS offices as its nodes.

In 1995, NWS adopted an incremental approach to developing and deploying AWIPS, an approach in which increasingly capable software "builds" are deployed to increasing numbers of field offices. With each build, the system grows in terms of both operable functions and the number of nodes in the operating network. Each deployment of a major new build requires a period of field testing by real users (forecasters) engaged in real operations. The results are fed back to AWIPS program managers and developers to guide subsequent incremental development and deployment (IDD). The first operational test and evaluation (OT&E) occurred in the fall of 1996 when AWIPS Build 1 was installed at 12 sites, 9 of which are NWS weather forecast offices or river forecast centers. In this report, the National Weather Service Modernization Committee (NWSM Committee) presents a retrospective evaluation of the first OT&E as an essential component in bringing AWIPS to maturity and a prospective commentary on key issues raised by the OT&E.

BUILD 1 OPERATIONAL TEST AND EVALUATION

The results of the OT&E were gathered from on-site teams; formal questionnaires prepared by AWIPS users; teleconferences among field staff, program managers, and developers; and formal reports of the network control facility (NCF), which acts as the network manager for the entire AWIPS. These mutually reinforcing modes for OT&E feedback contributed greatly to its success. The following major system improvements, made in response to OT&E results, highlight the value and effectiveness of the OT&E process:

- Intermittent problems with reception of the satellite broadcast signal that conveys satellite data, weather model data, and other information from the NCF to field sites were diagnosed and now appear to have been corrected.
- The workstation processes for retrieving weather model data for display were confirmed to be too slow for use in operations. NWS managers relied on these and other OT&E results in deciding to replace the user interface portion of the Build 1 AWIPS with an alternative that had been developed in parallel with the main design. The alternative interface will be incorporated in AWIPS Build 3.0.

- Problems with NCF performance will be addressed partly by the previously planned addition of automated trouble detection and recovery processes in later builds and partly by changes in staffing.
- The procedures and automated tools used during the OT&E to catalog and track reported problems have evolved into an effective change management process and configuration management tool for the AWIPS program.

Based on these observations, the NWSM Committee concludes that the OT&E process is an effective, valuable, and necessary element in the incremental development and deployment of a system capable of fulfilling the objectives of the NWS modernization program.

RECOMMENDATIONS ON THE OPERATIONAL TEST AND EVALUATION PROCESS

Recommendation. The AWIPS program should continue, and perhaps expand, a deployment strategy of maximizing the diversity of weather office forecasting operations to test the performance ranges and to identify site-specific and systemic improvements as early as possible.

Recommendation. The AWIPS program should, as already planned, include a formal OT&E when each major build is deployed to ensure that operational performance continues to improve.

PROSPECTIVE ISSUES

Looking beyond the Build 1 OT&E, the NWSM Committee suggests improvements in two areas as the NWS proceeds with work on AWIPS. These two areas are systems engineering and operational risk management.

Systems Engineering

An AWIPS systems engineering team was named in May 1997, but a committee-like team may not be able to perform all of the functions normally undertaken by a project systems engineer and a team of subsystem engineers who have been assigned specific responsibilities and authority. As the NWSM Committee understands the current AWIPS organization, no single individual has the assigned responsibility and the delegated authority to act as a system-wide, comprehensive systems engineer. Nor does the AWIPS program have a hierarchical systems engineering team composed of subsystems engineers. Instead, members of the systems engineering team appear to have been assigned to represent organizational entities. The AWIPS contractor's systems engineer is not a regular member of the AWIPS systems engineering team.

Among the outstanding issues that call for a strong systems engineering approach are (1) problems related to locally developed code, which is application software written by NWS field office staff for local use but attached to the AWIPS software system, and (2) the difficult task of transferring development and maintenance responsibilities for major software modules from the development group that initially writes

the software to another group (i.e., the transfer of ownership of AWIPS software). The second problem is most obvious in the transfer of ownership of the new workstation interface and data retrieval modules from the Forecast Systems Laboratory, which developed them, to the NWS Office of Systems Development.

Recommendations for Systems Engineering

Recommendation. The NWS should establish the position of AWIPS project systems engineer with system-wide, comprehensive responsibility and delegated authority for performing the functions detailed in this report.

Recommendation. The NWS should formally establish an AWIPS systems engineering team led by the AWIPS project systems engineer and composed of systems engineers for each subsystem.

Recommendation. The AWIPS contractor's systems engineer should be formally and directly included on the AWIPS engineering team, and the contractor's systems engineering processes should be included in the overall AWIPS systems engineering functions.

Recommendation. The AWIPS systems engineer should ensure that processes are in place to (1) accommodate locally developed code, including programming support, testing support, and regression testing to ensure that commissioned functions continue to perform as expected; (2) provide sufficient resource margins to accommodate a reasonably expansive scenario of local code development; and (3) manage the system configuration, including locally developed code.

Recommendation. Under the leadership of the AWIPS project systems engineer, AWIPS management should establish a process for transferring responsibility for, and the detailed knowledge of, software elements from the developing organization to the deploying organization and subsequently to the operating organization. If the complexity of the system, its components, or its interfaces precludes a complete transfer, the AWIPS project systems engineer and AWIPS managers should, through formal agreements, ensure that support will continue to be available.

Operational Risk Management

The AWIPS program has already adopted a number of risk management practices that have been valuable in reducing development risks. As work progresses for Build 4, risk management for operational performance of the full, multisite AWIPS network is becoming the focus of risk management. The NWSM Committee has specific suggestions to offer on several aspects of continuing risk management.

First, even with the current contingency plans for the AWIPS satellite broadcast network, the committee is concerned that the master ground station in this network is a potential single point of failure for the entire AWIPS. Second, although plans have already been made for improving the performance of the NCF (by addressing problems with its troubleshooting and recovery functions for active AWIPS nodes), the committee encourages the NWS to demonstrate that these corrections will provide a reasonable margin of safety for the fully implemented AWIPS. Third, the automated processes and operator procedures for a neighboring site backing up a "down" field site and for recovering operational capability at the down site should be carefully reviewed and tested for the possibility of cascading failures, which could

bring down many sites. Fourth, the mechanisms in place for emergency replacement of critical hardware components should be tested periodically. Fifth, physical threats to external communications systems that support AWIPS or unauthorized access to AWIPS can jeopardize operational performance that should be included in the risk management plan.

Recommendations for Operational Risk Management

Recommendation. A realistic operational test of the contingency plan for failure of the master ground station should be planned and conducted well before AWIPS is commissioned. The AWIPS risk management program should include (1) an exploration of scenarios under which the alternative uplink is unavailable and (2) an evaluation of remedial actions.

Recommendation. NCF performance should be watched closely to ensure that necessary improvements are forthcoming. This monitoring should be a top priority in the Build 3.0 time frame.

Recommendation. If improvements in the Build 3.0 time frame do not bring NCF performance up to operational standards, the AWIPS program should begin a risk reduction program to find a systemic solution to NCF performance problems. The NWS should consider reevaluating the design assumptions for monitoring and problem solving and should explore a wider range of solutions. At a minimum, NWS should reexamine the feasibility of the fundamental design concept for the NCF in light of experience since the Build 1.0 deployment.

Recommendation. To assess NCF performance and evaluate the NCF design concept, particularly as the number of active nodes in the AWIPS network increases, current or alternative NCF operations to perform designated emergency recovery functions should be tested under realistic conditions.

Recommendation. The AWIPS team should develop a plan to test the backup and recovery scenarios for AWIPS sites under field conditions. Documented procedures should be used to ensure that the system will perform as designed. A comprehensive analysis of failure modes for AWIPS as a system should be performed to identify all potential failure modes and develop preventive measures and recovery procedures to protect the system.

Recommendation. The site backup and recovery testing planned in the Build 4 time frame should include a thorough evaluation of the potential for the cascading failure of nodes. As many conditions under which such failures might occur as can be identified should be included in tests of the system's ability to detect and limit cascading failures.

Recommendation. Some form of periodic "drill" to test vendors' capability to replace system-critical hardware within the contractually agreed upon time should be included in the AWIPS risk management plan.

Recommendation. Detailed contingency plans for countering external threats to the integrity of the AWIPS system should be an integral part of the AWIPS risk management plan.