NATIONAL ACADEMY OF SCIENCES
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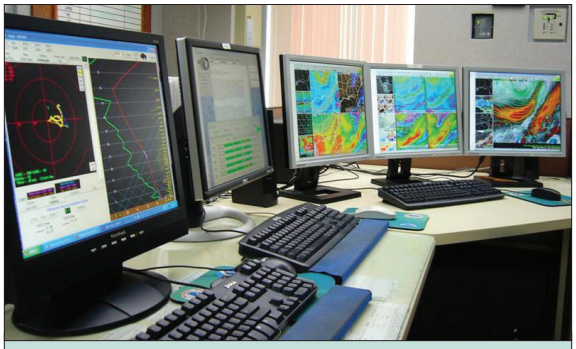
REPORT IN BRIEF

The National Weather Service Modernization and Associated Restructuring

A Retrospective Assessment

During the 20th century, the National Weather Service was unable to keep up with the pace of technological advances and as a result was nearly obsolete by the 1980s. Between 1989 and 2000, the nation invested an estimated $4.5 billion to modernize and restructure the National Weather Service. Efforts to modernize the National Weather Service succeeded in achieving major improvements for the weather enterprise. This report assesses the modernization effort and identifies lessons learned from the process.

Weather information, especially forecasts and warnings, can have significant impacts on the economy and is critical for the protection of life and property. The National Weather Service serves as the nation's authoritative source of weather information, providing routine public, marine, and aviation forecasts, as well as advisories and warnings when conditions warrant. As the primary provider of weather and climate data in the United States, it is crucial that National Weather Service operations stay at the forefront of technologies for observing, forecasting, and understanding the weather.



The Advanced Weather Interactive Processing System (AWIPS)—a technologically advanced information processing, display, and telecommunications system—was an important part of the National Weather Service modernization and restructuring.
Source: NWS Weather Forecast Office, Tallahassee, FL

The 20th century saw exponential growth in the technological capabilities of weather observations and forecasting, and it was difficult for the National Weather Service to keep pace. By the 1980s it became clear that the Weather Service would need to modernize and restructure to take advantage of new technologies and provide better weather services to the nation. Between 1989 and 2000, a national investment of $4.5 billion was used to implement the Modernization and Associated Restructuring of the National Weather Service. New observational and computational systems were planned and deployed, the network of National Weather Service field offices was redefined, and the workforce was restructured.

Until now, there has been no comprehensive assessment of the modernization project, termed Modernization and Associated Restructuring, and its impacts. At the request of Congress, the National Research Council convened a committee to evaluate the execution and impacts of Modernization and Associated Restructuring, and identify lessons learned that could support future improvements to National Weather Service capabilities. The committee assessed six specific elements of the Modernization and Associated Restructuring effort: (1) Management and Planning; (2) Modernization of Technology; (3) Restructuring of Forecasts Offices and Staff; (4) National Centers; (5) Partnerships; (6) Oversight and Advisory Groups. A follow-up report will present Phase II of this study, in which the committee applies lessons learned to develop guidance on how best to plan, deploy, and oversee future improvements to the Weather Service.

Overarching Findings

Overall, Modernization and Associated Restructuring successfully improved the weather enterprise, leading to a greater integration of science into weather service activities, and improved outreach and coordination with state and local government, emergency management, and communities. By the 1980s the National Weather Service was nearly obsolete, and, therefore, the $4.5 billion investment on modernization was both needed and generally well-spent. Furthermore, the framework left in place after the modernization allows and encourages the continued evolution

of National Weather Service technology, and to some extent the workforce composition and culture.

Lesson 1: If a science-based agency like the National Weather Service, which provides critical services to the nation, waits until it is close to becoming obsolete, it will require a complex and very expensive program to modernize.

Management and Planning

Modernization and Associated Restructuring was a large and complex project that required rigorous management. Modernization efforts were implemented during a period of rapid technological change, including the emergence of the internet, and involved the deployment of a number of major technological systems across the nation. In addition, the project involved several federal agencies and the direct participation of three National Oceanic and Atmospheric Administration line offices (the National Weather Service, the National Environmental Satellite, Data, and Information Service, and the Office of Oceanic and Atmospheric Research).

The major components of the modernization effort were well-planned and completed largely in accordance to that plan, although notable budget overruns and substantial schedule delays occurred in nearly all the project elements. Executing Modernization and Associated Restructuring brought about institutional and cultural changes at National Weather Service, largely for the better. Many of these institutional changes in management structure, culture, processes, and partner relationships have been retained, and will help National Weather Service continue to modernize. However, implementation of a rigorous systems engineering process to facilitate more effective management of the procurement and development of large, complex systems appears not to have been institutionalized with the National Oceanic and Atmospheric Administration.

Lesson 2: The budget, schedule, and technological issues encountered during execution of Modernization and Associated Restructuring reflected the traditional challenges of large projects: inexperience of the government project-level leadership, shifting budget constraints, ambitious technology leaps, multi-party stakeholder pressures, cultural inertia, contractor shortcomings, and oversight burdens. Each represents important lessons for the National Weather Service with regard to future projects of a similar nature.

- Expertise in system design, procurement, and deployment is essential to successful implementation of any complex technical upgrade
- Dedicated leaders are crucial for resolving roadblocks and ensuring ultimate project success
- Clearly defined system-level requirements, and competent management of those requirements, are essential to any contractual acquisition of a major system
- Statistical indicators of forecast and warning performance are a major element for gaining and maintaining support for implementing new technologies
- It is necessary to establish comprehensive performance metrics at the beginning of a process, evaluate them throughout the process, and reevaluate them after the process is complete.

Modernization of Technologies

To modernize its operations, the National Weather Service developed five major technology upgrades (see Box 1). Problems encountered with implementing these technologies included lack of preliminary analysis and ensuing design problems, inadequate program management, and poor contractor performance. However, these problems were successfully overcome and the major technology system upgrades were successfully executed.

These technology improvements allowed more uniform radar coverage and surface observations across the United States. For example, the Next Generation Weather Radar network and Geostationary Operational Environmental Satellites dramatically improved the quantity and quality of data available to forecasters, and enhanced the numerical weather prediction capabilities of the National Weather Service. Replacing human observers with the Automated Surface Observing System introduced significant gains, despite possible adverse effects on the climate record and the loss of some important visual elements of the observation. The Advanced Weather Interactive Processing System has been a critical technological advancement that integrates data and information provided by the Modernization and Associated Restructuring elements and makes them easily accessible to forecasters.

Box 1. Modernization Technologies

Automated Surface Observing System, an automated electronic sensor instrument system to replace manual weather observations at all National Weather Service (and many other) surface observing locations

Next Generation Weather Radar (NEXRAD), a network of advanced Doppler radars to measure motion of the atmosphere responsible for severe weather such as tornadoes, detect heavy rainfall and hail, and increase lead times for prediction of severe weather events and flash floods.

Satellite Upgrades, a new series of geostationary meteorological satellites to provide higher spatial and temporal resolution imagery and data to aid shorter-range forecasts and warnings, and a new series of polar orbiting meteorological satellites to provide improved, all-weather, atmospheric data to assist in longer-term forecasting

National Centers Advanced Computer Systems, a ten-fold increase in computing power to support the National Centers. Along with numerical weather prediction model improvements, this improved national guidance for short-range forecasts and warnings and provided more reliable guidance for medium- and long-range forecasts

Advanced Weather Interactive Processing System (AWIPS), a workstation-centric, advanced computer and communications system to help forecasters integrate all sources of weather data. The system allows communication among weather forecast offices and distribution of centrally collected data and centrally produced analysis and guidance products, as well as satellite data and imagery.

The improvements were particularly evident in the forecasting and detection of severe weather such as tornadoes and flash floods. The probability of detecting these events improved over the course of, and after, the Modernization and Associated Restructuring, and the lead times of the warnings increased. However, false alarm ratios remain high.

Lesson 3: The time scale for the government system procurement process is very long compared to that for implementing major technological change. The pace of technological progress complicates planning, procurement, and deployment of large, complex systems. While technology is changing so rapidly, in every aspect of the project where it is feasible, it is crucial to:

- Establish clear metrics for evaluating improvement in forecasts and warnings at the beginning of a major technological upgrade
- Use rapid prototyping and system demonstrations.
- Evaluate such prototype systems under a variety of actual operational situations with multiple classes of users and stakeholders in order to refine the system design
- Establish the capacity for continual upgrades of complex systems, particularly those involving digital technology
- Continually assess and apply the lessons of past systems, whether successful or unsuccessful

Restructuring of Forecast Offices and Staff

Restructuring the National Weather Service involved a substantial reduction in the number of field offices, relocation and realignment of the functions performed at many offices, and staff changes including a reduction in total numbers of staff and an increase in the number of professional positions.

Prior to restructuring, the National Weather Service had a two-tiered office structure. 52 Weather Service Forecast Offices had a core component of professional meteorologists, and 204 Weather Service Offices were staffed with observers and meteorological technicians. This structure was replaced with a single-tiered system of 122 Weather Forecast Offices spread evenly across the nation.

Field staffing changed from one-third professional meteorologists and two-thirds meteorological technicians to the reverse, and training was provided for technicians who wanted to qualify for a professional position in the new workforce structure. At the time, many of these changes were viewed negatively by some employees, but hindsight has shown that restructuring greatly improved the capability of the National Weather Service to provide weather services to the nation, and the changes are now viewed favorably by staff. Restructuring led to the addition of a Science Operations Officer, who serves to rapidly integrate advancements in the science community in to Weather Forecast Office operations, and a Warning Coordination Meteorologist, who serves as a liaison between the National Weather Service and the media and emergency management communities. Creating these positions and restructuring forecast offices has greatly improved the communication and dissemination of weather information.

Although the workforce was reduced, technical capabilities and career paths were significantly upgraded and therefore there was little or no cost savings from workforce reorganization. The staffing changes allow at least two people to be on duty for all shifts, but timely planning and coordination by field office managers and supervisors is needed to increase staffing levels at times when severe weather threatens life and property.

Lesson 4: Modernization and Associated Restructuring faced initial resistance from National Weather Service employees and, to some extent, the general public. This resistance could have been lessened by, very early in the planning stages:

- Engaging those whose career and livelihood were to be affected in planning the changes
- Better engaging a diffuse public, and to some extent Congress, regarding the benefits of improved weather forecasts and warnings as opposed to the perceived cost of losing a forecast office in their community.

The Restructuring dictated a degree of standardization between forecast offices, however it has become apparent that this needs to be effectively balanced with the flexibility needed to allow for customization at individual offices to respond to local requirements.

The Modernization and Associated Restructuring increased the overall education level of the workforce and set in place the need for routine training to keep the staff on pace with technological and meteorological advancements in the community. Staff development through in-person, hands-on training in a centralized classroom or laboratory of the type that occurred during Modernization and Associated Restructuring has great value. Where relevant, online courses or self-directed study can be a useful supplement, but can sacrifice the quality of learning and the connections made with colleagues that are essential for the overall operations of the National Weather Service.

National Centers

Concomitant with the goals of the modernization efforts was the need to implement and sustain more science-based approaches to weather, climate, and hydrological prediction and rapidly assimilate advances in information technology. To reach this goal, the National Centers for Environmental Prediction (NCEP) was established with the mission to deliver science-based environmental predictions to the nation and the global community. The numerical weather forecasts produced by NCEP improved steadily over the course of Modernization and Associated Restructuring. However, the performance of some NCEP models, particularly the Global Forecast System, continues to lag behind some other national centers, including the European Centre for Medium-range Weather Forecasts.

Partnerships

Modernizing and restructuring the National Weather Service required the involvement of many partners. Development and deployment of observational systems involved other NOAA line offices as well as other federal agencies. The National Weather Service also worked with the private sector through contracted work, and the research community played a large role in developing new technologies. In general, Modernization and Associated Restructuring strengthened relationships between the National Weather Service and other members of the weather enterprise.

These improved relationships have proven to be one of the more important outcomes of Modernization and Associated Restructuring because they have increased National Weather Service's societal impact and helped leverage its limited budget. Though issues remain, partnerships with academia and government research institutions have increased research-to-operation capabilities, and the process helped build partnerships with media and emergency management communities. Although the relationship between the National Weather Service and the private sector took longer to improve, it has now evolved into a more constructive and productive partnership.

Lesson 5: The execution of Modernization and Associated Restructuring required working with many partners, which provided cost sharing and improved understanding of user needs. However, relationships with partners were not always well conceived or managed as would have been desirable. This could have been avoided by involving all known stakeholders from the outset. The National Weather Service operational staff is also a stakeholder, and need to be involved early in the design and procurement process to ensure system functionality and practicality. Engagement with stakeholders from both inside and outside the National Weather Service would help the National Weather Service better understand user needs and secure "buy-in" to new initiatives.

Oversight and Advice

Modernization and Associated Restructuring was the focus of many oversight reviews and advisory reports. In many cases, the reviews drew attention to important issues that otherwise may have inhibited the success of the modernization project. The external oversight also provided accountability for technical, budget, and schedule issues metrics during the modernization process. National Weather Service management staff was generally receptive to oversight and able to benefit from it. Expert advice and oversight from outside National Weather Service and the receptiveness of Service staff to such advice contributed to the success of the Modernization and Associated Restructuring project.

Lesson 6: Modernization and Associated Restructuring showed that candid, yet non-adversarial, advice from outside experts and other interested parties was useful in the design and development of a large complex system. Because National Weather Service management was receptive to such oversight and advice, the outside input was effective.

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The National Academies appointed the above committee of experts to address the specific task requested by the National Oceanographic and Atmospheric Administration. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.

For more information, contact the Board on Atmospheric Sciences and Climate at (202) 334-3512 or visit http://dels.nas.edu/basc. Copies of *The National Weather Service Modernization and Associated Restructuring: A Retrospective Assessment* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.