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Briefing Report to Congressional Requesters

January 1993

WEATHER FORECASTING

Important Issues on Automated Weather Processing System Need Resolution

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Congressional Requesters

The National Weather Service's (NWS) ability to forecast the weather affects the lives and property of every American. To better meet this challenge, NWS, which is part of the National Oceanic and Atmospheric Administration (NOAA), is spending an estimated $4.6 billion to modernize its observational, information processing, and communications systems. The centerpiece of this modernization is the Advanced Weather Interactive Processing System (AWIPS)—an information system that will acquire, integrate, analyze, display, and disseminate data from advanced observational systems (e.g., radars, satellites, and ground-based sensors), as well as data from NWS field offices, regional and national centers, and other sources. NOAA estimates that AWIPS will cost $467 million to develop and deploy.

As you requested, we reviewed the AWIPS acquisition to (1) determine how effectively NOAA has analyzed and defined its system requirements, (2) identify key risks associated with this acquisition, and (3) determine whether any identified risks were severe enough to warrant delaying the scheduled award of the AWIPS contract in late 1992. We briefed your respective offices in October 1992 on the results of our work. As agreed, this report documents the results presented at those briefings, and provides additional information concerning AWIPS. The briefing charts are included in appendix I. A more detailed explanation of our objectives, scope, and methodology is in appendix II.

Results in Brief

NOAA has effectively involved users in analyzing and defining AWIPS requirements. AWIPS' baseline requirements are grounded in a description of AWIPS functional requirements that were defined by a diverse cross section of the NWS user community. In addition, NOAA has continued to work closely with these users in refining AWIPS functional and interface requirements through two extensive prototyping efforts.

Despite its commendable approach to defining requirements, NOAA still faces significant risks in its endeavor to acquire, operate, and maintain AWIPS. In particular, the respective roles and responsibilities of the contractor and the government are not clear, the requirements for system portability are not specific, security requirements have yet to be analyzed and defined, a configuration management plan for locally developed

software has yet to be established, a standardized and structured environment for all AWIPS software developers has not been established, and government involvement in testing is limited. While we do not believe that any of these risks warranted delay of the AWIPS contract award, failure to resolve each risk before extensive AWIPS software development begins could cause unnecessary cost increases, schedule delays, and performance problems.

Background

NWS's basic mission is to provide storm and flood warnings, weather forecasts, and advisories primarily for the protection of life and property. To carry out its mission, NWS uses a variety of systems and manual processes, most of which are outdated, to collect, process, and disseminate weather data to and among its network of field offices and national centers.

NWS currently operates a nationwide office structure comprised of 3 national centers, 249 field offices (52 forecast offices and 197 smaller service offices), and 13 River Forecast Centers (RFC).[1] The forecast offices combine weather guidance from national centers with local data to prepare and issue severe weather and flood warnings and general public weather forecasts, as well as more specialized aviation, marine, and agriculture forecasts. The RFCs provide flood forecasts and long-term water supply outlooks.

Since the early 1980s NWS has been modernizing its systems so it can more accurately and quickly predict the weather. Moreover, according to NWS, productivity and efficiency gained from modernizing its systems will allow it to streamline operations—consolidating its 249 field offices into 115 offices and reducing its staffing levels by over 17 percent. In December 1991 we issued a report describing the four systems under the modernization program.[2] Briefly, the program provides for the acquisition of the following observational systems:

- Next Generation Weather Radar (NEXRAD): An advanced Doppler weather radar network that is expected to allow early detection of tornadoes, thunderstorms, and other important weather phenomena.

[1]The national centers are the National Meteorological Center, the National Severe Storms Forecast Center, and the National Hurricane Center.

[2]Weather Forecasting: Cost Growth and Delays in Billion-Dollar Weather Service Modernization (GAO/IMTEC-92-12FS, Dec. 17, 1991).

- Automated Surface Observing System (ASOS): An automated surface sensing network that will provide data on pressure, temperature, wind direction and speed, runway visibility, cloud ceiling heights, and type and intensity of precipitation.
- Next Generation Geostationary Operational Environmental Satellite (GOES-Next): Orbiting satellite sensors that provide imageries of clouds and the earth's surface, and measurements of the atmosphere.

The program also provides for AWIPS, an information system that is to integrate data from these observing systems and other sources; produce rich graphical displays to aid forecaster analyses and decision-making; and disseminate weather information to the national centers, other weather offices, the media, and other federal, state, and local government agencies. NWS plans to install an AWIPS system at each of the 115 planned weather offices and other selected locations.[3] NOAA estimates the cost to develop and deploy AWIPS to be $467 million, and it plans to have these systems installed by 1998.

Three NOAA organizations are the principals in the AWIPS acquisition. The Systems Program Office is primarily responsible for managing AWIPS' acquisition and development. The Forecast Systems Laboratory is responsible for prototyping parts of AWIPS, and is to be responsible for developing part of the AWIPS software. As the user of AWIPS, NWS is responsible for defining AWIPS requirements. It is also responsible for prototyping and developing parts of AWIPS.

Unusual Approach Chosen for Acquisition of AWIPS

System acquisitions typically provide a clear distinction between the government as the system acquirer and user and the contractor as the system developer. That is, the government agency normally specifies its needs and a contractor designs and develops a system to meet these needs. The AWIPS acquisition, however, follows a different approach. Specifically, NWS is both the user and a developer of the system. In fact, NWS is to supply about 1 million of the system's approximately 3 million lines of code. The contractor is to integrate this government-furnished software with the software it develops.

Another unusual feature is that each AWIPS system at the 115 weather offices will be customized (i.e., site-specific software applications will be added to each system), based on unique weather environment and

[3]These locations include the National Meteorological Center in Camp Springs, Maryland; the National Hurricane Center in Coral Gables, Florida; the National Severe Storms Forecast Center in Kansas City, Missouri; and regional headquarters sites.

forecasting requirements of each office. Such customization may result in up to 115 different versions of AWIPS.

NOAA Has Employed User-Centered Analysis and Extensive Prototyping to Define AWIPS Requirements

In 1984 NWS formed an AWIPS requirements task team made up of a wide array of users to analyze and define requirements. This task team worked closely with (1) NWS meteorologists and hydrologists throughout the country to obtain scientific expertise and feedback on forecasting needs, preferences, and improved scientific methods for forecasting; and (2) competing contractors to obtain feedback on requirements that would be very costly or unachievable, to produce a functional description of AWIPS.

To refine and validate requirements, NOAA engaged in extensive prototyping of system functions and interfaces. In 1984 NOAA began the Denver AWIPS Risk Reduction and Requirements Evaluation (DAR^3E) program to develop a functional prototype of AWIPS and place it in an operational NWS environment for comprehensive analysis and evaluation. In 1986 the initial DAR^3E system was installed to fully support the operations in the Denver weather office. Observation of and feedback from forecasters yielded suggestions concerning data integration, access, animation, presentation, and workstation performance and resulted in prototype changes and subsequent revisions to the AWIPS requirements and specifications. For example, due to frequent interaction with the display system, more reliable interface devices and more convenient features were incorporated into the AWIPS requirements. In addition to prototyping AWIPS in Denver, NWS installed the DAR^3E system in the Norman, Oklahoma, weather office in 1990 to test the system's ability to incorporate data from NEXRAD and the central offices.

NWS is also prototyping AWIPS capabilities to satisfy hydrological requirements. In January 1985 it installed its Prototype RFC Operational Test, Evaluation, and User Simulation (PROTEUS) at its Tulsa, Oklahoma, RFC to evaluate and refine its river forecasting and flood warning requirements. Additionally, interactions between a modernized weather office and an RFC are being evaluated by studying the Norman and Tulsa offices. The Tulsa RFC relies on data that the Norman weather office collects, such as precipitation data, to run its river forecasting model to produce river forecasts. These data are in turn used by the Norman weather office to issue flood warnings.

Important Issues on AWIPS Not Yet Resolved

AWIPS still faces some important issues that have yet to be resolved. They are (1) unclear government versus contractor responsibilities, (2) vague portability requirements, (3) unspecified security requirements, (4) no configuration management plan for locally developed software, (5) no standardized and structured approach to guide software development, and (6) limited government involvement in testing.

Government Versus Contractor Responsibilities Not Clear

The technical and legal impact of NOAA's unusual role in developing AWIPS is unclear. To illustrate, NOAA has assigned the contractor total responsibility for delivering a system that meets specified functional, performance, availability, and maintainability requirements. However, NOAA also expects the contractor to accomplish this by using large amounts of NOAA-developed software. While the contractor can request permission from NOAA to modify the government-furnished software, it is NOAA's option, not the contractor's, to grant or deny this request. This raises the possibility that the contractor may be asked to do something that is impossible and therefore not contractually enforceable—to integrate NOAA-developed code into AWIPS "as is" and still meet specified requirements. Moreover, the contractor may also accept NOAA-developed code only to later discover that it contains a latent error. Further, in fixing software errors, new errors are commonly created. Whether the government or the contractor will bear responsibility for problems that result from fixing an error in government-furnished code is not clear.

After contract award, NOAA plans to establish teams to work with the contractor to see that any confusion between the government and the contractor is resolved as it arises. NOAA officials, however, expressed uncertainty as to how the contract could be modified to clarify government versus contractor roles and responsibilities and thus plan no formal change to the contract.

Requirements for System Portability Not Specific

NOAA requires that AWIPS be portable. Portable software can be transferred from one vendor environment to another without making massive changes. Portability is very important because it will allow NOAA to (1) upgrade AWIPS technology without losing the huge investments already made in software development, and (2) incorporate equipment from many vendors.

NOAA's specification of the standards it wanted the contractor to adhere to in providing a portable system were too vague. As a result, NOAA now finds

itself having to exercise extensive contractor oversight to guard against receiving a proprietary system and being vendor dependent. Specifically, NOAA's request for proposals basically left selection of specific standards up to the contractor. It did not, for example, specify the Portable Operating System Interface for Computer Environments (POSIX) standard, nor did it exclude vendor-specific extensions to federal standards. As a result, NOAA has no assurance that offerors will not choose nonstandard features that decrease portability.

NOAA officials stated that because they required compliance with all applicable Federal Information Processing Standards, of which POSIX is one, they have in effect specified POSIX. We do not agree and believe that had NOAA clearly specified POSIX it would not now have to carefully guard against proprietary implementations of the operating system.

Security Requirements Not Specified

Office of Management and Budget (OMB) Circular No. A-130 requires that agencies define and approve security requirements and specifications prior to acquiring or starting formal development of applications.[4] These activities help an agency ensure data and system integrity and availability.[5] However, no one knows what the threats against AWIPS are or where the system is vulnerable. As a result, NOAA has yet to fully develop its security requirements. Without a knowledge of these threats or a comprehensive plan to counteract them, AWIPS may be vulnerable to compromises in data integrity (e.g., data destruction or unauthorized modification) and system availability (e.g., slow system response or system crashes).

NOAA officials acknowledged the need for further study in this area and plan to perform a security risk assessment about 5 months after the contract is awarded.

Configuration Management Plan for Locally Developed AWIPS Applications Is Lacking

Configuration management is a process for maintaining and controlling changes to hardware and software. This process is especially important for AWIPS since site-specific software customization by local forecasters—needed to address unique geographical weather forecasting needs—may produce up to 115 distinct AWIPS systems. Effective software configuration management will help ensure that (1) conflicting software

[4]OMB Circular No. A-130, App. III, Dec. 12, 1985.

[5]Data integrity means ensuring that information and programs are changed only in a specified and authorized manner. System availability means ensuring that authorized users have continued access to information and resources.

development and software releases do not occur, (2) responsibility is assigned for maintaining locally developed software that is distributed to several sites, (3) new releases of core AWIPS software can be integrated with locally developed software, and (4) duplication of software development effort does not occur.

NOAA, however, has not developed a configuration management plan for controlling changes to AWIPS at the local level. The agency now plans to delegate control over local software development to each weather office site manager. Leaving such latitude to local site managers will likely lead to inconsistencies in how effectively local software is controlled and managed.

NOAA officials agreed that configuration management of locally developed AWIPS applications is an issue that needs to be addressed. NOAA expects to have a configuration management plan within 60 days after contract award.

Standardized and Structured Approach for Developing AWIPS Software Is Lacking

Developing a system like AWIPS, which is not only large and complex but that also involves the integration of software developed by different organizations, requires rigorous software engineering discipline. Methodologies and standards for designing, coding, testing, and documenting software must be adopted and used by all software development organizations. The languages to be used and how the software is to be structured should also be specified.

Although the AWIPS contractors have proposed standardized and structured environments for the software they are to develop, NOAA has yet to establish such an environment for all AWIPS software. The code that NOAA is developing in-house has been, and continues to be, produced in several languages by multiple developers without a software development plan that specifies software product and process standards. To further complicate this situation, NOAA software development personnel are primarily meteorologists and hydrologists who, while very knowledgeable in the functions being automated, generally lack formal education and training in software engineering. This unstructured development approach by inexperienced software developers could produce problems when the contractor begins to integrate government- and contractor-developed code.

NOAA officials agreed that a standardized and structured approach to software development is both lacking and needed. NOAA is currently formulating a software development plan. NOAA officials stated that they expect to have a final plan within 90 days after contract award. In addition, NOAA plans to formally train its employees in software engineering.

Government Involvement in Software Testing Is Limited

Testing is a critical part of the software development process. While some software tests are typically devised by the developing organization, the use of independently developed test cases and data and user-conducted testing is generally recognized as a good software engineering practice. If independently developed tests are not performed, the risk is increased that significant software errors may go undetected.

NOAA plans to have the contractor perform most system testing. The request for proposals states that NOAA will conduct field tests and can supply data for contractor-sponsored testing; however, NOAA has described these field tests as limited, and it has yet to commit to providing independent test data for AWIPS testing. Further, while the request for proposals requires the contractor to submit test plans, cases, and data for approval, it has not specified any government or industry test standards against which to evaluate them. According to NOAA officials, these testing issues will be addressed in a test and evaluation master plan to be completed within 5 months of contract award.

Recommendation

To help ensure the successful development of AWIPS and minimize the risk of cost and schedule growth, we recommend that the Secretary of Commerce ensure that the actions planned by the NOAA Systems Program Office adequately resolve the outstanding issues described in this report before the AWIPS design is approved and significant software development begins.

Agency Comments

We did not obtain written comments on this report. However, we discussed this report's contents with senior Commerce and NOAA officials, including the Deputy Under Secretary for Oceans and Atmosphere, Department of Commerce; the director of the Systems Program Office, NOAA; and the AWIPS program manager, NOAA. We have incorporated their comments as appropriate. In short, the officials agreed with our findings and said that they plan to address each of the issues by June 1993.

As agreed with your offices, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time, we will provide copies of the report to the Secretary of Commerce; the Director, Office of Management and Budget; and interested congressional committees. Copies will also be made available to others upon request.

Our work was performed between February and November 1992, in accordance with generally accepted government auditing standards. This report was prepared under the direction of JayEtta Z. Hecker, Director, Resources, Community, and Economic Development Information Systems, who can be reached at (202) 512-6416. Major contributors to this report are listed in appendix III.

Ralph V. Carlone

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Assistant Comptroller General

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United States Senate

The Honorable John F. Kerry
Vice Chairman, National Ocean Policy
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Committee on Commerce, Science, and Transportation
United States Senate

The Honorable George E. Brown, Jr.
Chairman
The Honorable Robert S. Walker
Ranking Minority Member
Committee on Science, Space,
and Technology
House of Representatives

Contents

Abbreviations

ASOS	Automated Surface Observing System
AWIPS	Advanced Weather Interactive Processing System
DARE	Denver AWIPS Risk Reduction and Requirements Evaluation
FSL	Forecast Systems Laboratory
GAO	General Accounting Office
GFI	government-furnished information
GOES-Next	Next Generation Geostationary Operational Environmental Satellite
IMTEC	Information Management and Technology Division
NEXRAD	Next Generation Weather Radar
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OMB	Office of Management and Budget
POSIX	Portable Operating System Interface for Computer Environments
PROTEUS	Prototype RFC Operational Test, Evaluation, and User Simulation
RFC	River Forecast Center
RFP	request for proposals
SEI	Software Engineering Institute
SPO	Systems Program Office

Briefing Charts

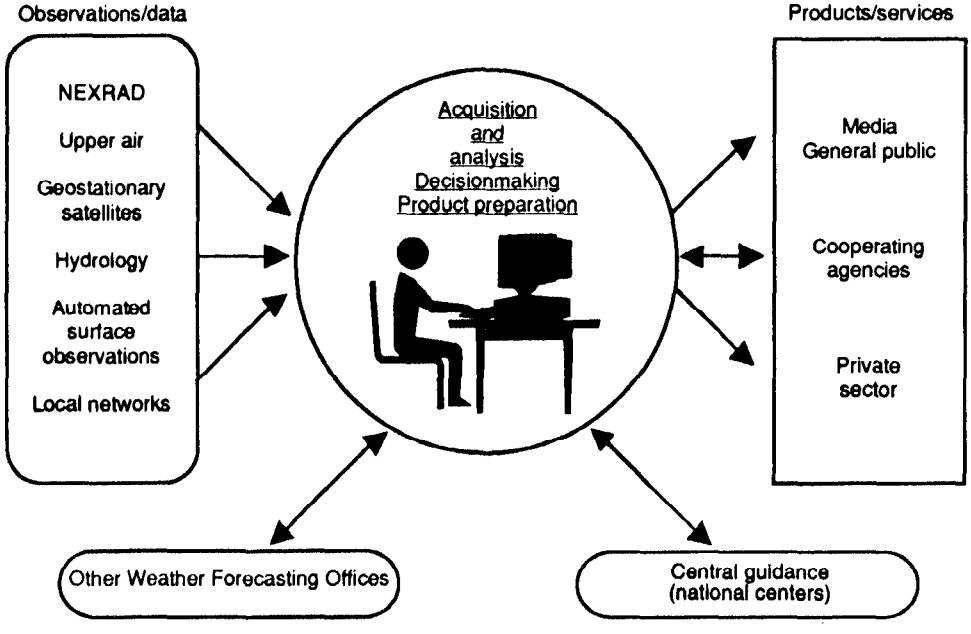
GAO

Information Management and Technology Division

Briefing on Acquisition of NOAA's Advanced Weather Interactive Processing System (AWIPS)

October 1992

GAO NWS Modernization and AWIPS



Source: NWS.

GAO Assignment Objectives

- Has NOAA effectively analyzed and defined its requirements for AWIPS?
- Is NOAA effectively planning for controlling the risks inherent in acquiring AWIPS?
- Are risks severe enough to warrant delaying contract award?

GAO Scope and Methodology

- Field Visits to FSL, Denver, Norman, Tulsa, Sterling
- Numerous interviews with NOAA/SPO and NWS personnel
- Technical analysis of RFP and BAFOs
- Consultation with NIST, MITRE, SEI, Lincoln Lab

GAO Major Observations

- AWIPS acquisition approach is unusual
- Risk reduction activities performed
- Risks affecting AWIPS development remain

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AWIPS Acquisition Approach Is Unusual

- Shared software development responsibilities (GFI extensive)
- Site-specific customization of software planned

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Risk Reduction Activities Performed

- Extensive prototyping of system functions and interfaces
- Established relationship with contractors
- Recent use of expert consultants

GAO

Risks Affecting AWIPS Development Remain

- Government versus contractor responsibilities not clear
- Portability requirements not clearly defined (POSIX not specified)
- Security risk not analyzed and requirements not established

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Risks Affecting AWIPS Development Remain

- Configuration management plan for locally developed AWIPS applications lacking
- Standardized and structured environment for developing AWIPS software lacking
- Government involvement in software testing limited

GAO Conclusions

- No reason to delay award
- Contractor/government arrangement on AWIPS is unusual but not wrong
- Each issue should be resolved before the AWIPS design is approved and significant software development begins

Objectives, Scope, and Methodology

The objectives of our review were to (1) determine how effectively NOAA has analyzed and defined AWIPS system requirements, (2) identify key risks associated with this acquisition, and (3) determine whether any identified risks were severe enough to warrant delaying the scheduled award of the AWIPS contract. To determine how effectively NOAA defined AWIPS requirements, we reviewed the system requirements specification, request for proposals, and other documentation describing the requirements-setting process. We also discussed the process for defining AWIPS requirements with NOAA program office and NWS Office of Hydrology and Office of Meteorology officials. In addition, we observed the operation of AWIPS prototypes at two weather offices and one RFC and discussed with NOAA and NWS officials how AWIPS requirements have been refined and validated based on these prototyping experiences.

To identify the key risks associated with this acquisition and whether they warranted delaying the AWIPS contract, we (1) reviewed several external AWIPS evaluations, including those conducted by the Commerce Inspector General, the National Institute of Standards and Technology (NIST), and the Massachusetts Institute of Technology's Lincoln Laboratory; (2) analyzed the request for proposals and the contractors' best and final offers; (3) interviewed NOAA and NWS software development and contracting officials associated with AWIPS; and (4) obtained expert views on AWIPS risks from officials at NIST, Lincoln Laboratory, Carnegie Mellon University's Software Engineering Institute, and the MITRE Corporation.

We performed our work at the Department of Commerce in Washington, D.C.; NOAA and NWS headquarters in Silver Spring, Maryland; NOAA's Forecast Systems Laboratory in Boulder, Colorado; the NWS weather offices in Denver, Colorado; Norman, Oklahoma; and Sterling, Virginia; the NWS RFC in Tulsa, Oklahoma; NIST in Gaithersburg, Maryland; Lincoln Laboratory in Lexington, Massachusetts; the Software Engineering Institute in Pittsburgh, Pennsylvania; and the MITRE corporation in McLean, Virginia.

Major Contributors to This Report

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