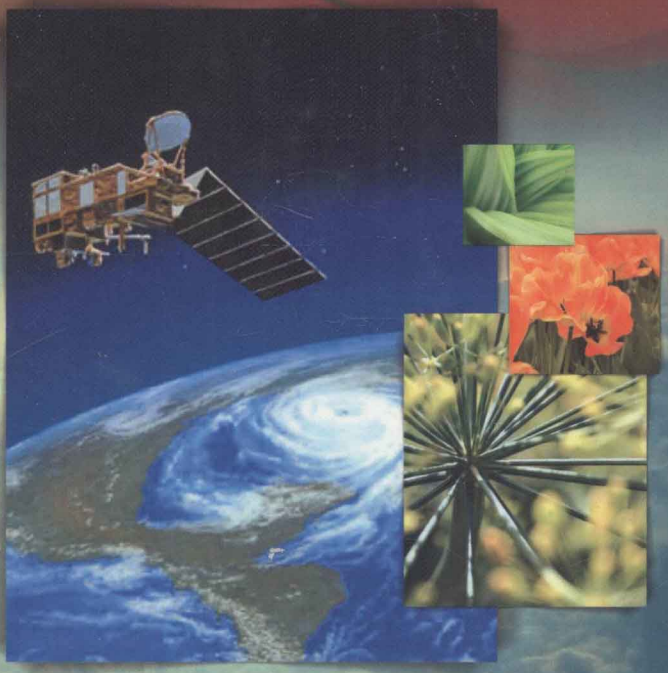
Environmental Satellites

Weather and Environmental Information Systems

Vincent L. Webber
Editor



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Space Science, Exploration and Policies Series

ENVIRONMENTAL SATELLITES: WEATHER AND ENVIRONMENTAL INFORMATION SYSTEMS

VINCENT L. WEBBER
EDITOR

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PREFACE

This book provides information on the planned National Polar-orbiting Operational Environmental Satellite System (NPOESS) program which is expected to be a state-of-the-art, environment-monitoring satellite system which will replace two existing polar-orbiting environmental satellite systems. The NPOESS program is considered critical to the United States' ability to maintain the continuity of data required for weather forecasting (including severe weather events such as hurricanes) and global climate monitoring through the year 2026. Furthermore, this book evaluates the NPOESS program office's progress in restructuring the acquisition, evaluates their progress in establishing an effective management structure, and assesses the reliability of the life cycle cost estimate and proposed schedule. This book also identifies the status and key risks facing the program's major segments and evaluates the adequacy of the program's efforts to mitigate these risks.

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Chapter 1

POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITES: RESTRUCTURING IS UNDER WAY, BUT TECHNICAL CHALLENGES AND RISKS REMAIN*

United States Government Accountability Office

WHAT GAO FOUND

The NPOESS program office has made progress in restructuring the acquisition by establishing and implementing interim program plans guiding the contractors' work activities in 2006 and 2007; however, important tasks leading up to finalizing contract changes remain to be completed. Executive approvals of key acquisition documents are about 6 months late—due in part to the complexity of navigating three agencies' approval processes. Delays in finalizing these documents could hinder plans to complete contract negotiations by July 2007 and could keep the program from moving forward in fiscal year 2008 with a new program baseline.

The program office has also made progress in establishing an effective management structure by adopting a new organizational framework with

* This is an edited, reformatted and augmented version of a United States Government Accountability Office Report 07-498 to Congressional Requesters publication, dated April 2007.

increased oversight from program executives and by instituting more frequent and rigorous program reviews; however, plans to reassign the recently appointed Program Executive Officer will likely increase the program's risks. Additionally, the program lacks a process and plan for identifying and filling staffing shortages, which has led to delays in key activities such as cost estimating and contract revisions. Until this process is in place the NPOESS program faces increased risk of further delays.

The methodology supporting a June 2006 independent cost estimate with the expectation of initial satellite launch in January 2013 was reliable, but recent events could increase program costs and delay schedules. Specifically, the program continues to experience technical problems on key sensors and program costs will likely be adjusted during upcoming negotiations on contract changes. A new baseline cost and schedule reflecting these factors is expected by July 2007.

Development and testing of major NPOESS segments—including key sensors and ground systems—are under way, but significant risks remain. For example, while work continues on key sensors, two of them experienced significant problems and are considered high risk (see table). Additionally, while progress has been made in reducing delays in the data processing system, work remains in refining the algorithms needed to translate sensor observations into useable weather products. Given the tight time frames for completing this work, it will be important for program officials and executives to continue to provide close oversight of milestones and risks.

Key NPOESS Components and Corresponding Risk Levels

NPOESS component	Risk level
Visible/infrared imager radiometer suite	High
Cross-track infrared sounder	High
Ozone mapper/profiler suite	Moderate
Advanced technology microwave sounder	Low
Command, control, and communications system	Low
Interface data processing system	Moderate

Source: GAO analysis of NPOESS Integrated Program Office data.

ABBREVIATIONS

ATMS	advanced technology microwave sounder
CMIS	conical-scanned microwave imager/sounder
CrIS	cross-track infrared sounder

DMSP	Defense Meteorological Satellite Program
DOD	Department of Defense
EDR	environmental data record
IDPS	interface data processing system
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite Data and Information Service
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
POES	Polar-orbiting Operational Environmental Satellites
OMPS	ozone mapper/profiler suite
VIIRS	visible/infrared imager radiometer suite

April 27, 2007

The Honorable Nick Lampson Chairman
The Honorable Bob Inglis Ranking Republican Member
Subcommittee on Energy and Environment
Committee on Science and Technology
House of Representatives
The Honorable David Wu

House of Representatives
The Honorable Vernon J. Ehlers House of Representatives

The planned National Polar-orbiting Operational Environmental Satellite System (NPOESS) program is expected to be a state-of-the-art, environment-monitoring satellite system that will replace two existing polar-orbiting environmental satellite systems. Polar-orbiting satellites provide data and imagery that are used by weather forecasters, climatologists, and the military to map and monitor changes in weather, climate, the oceans, and the environment. The NPOESS program is considered critical to the United States' ability to maintain the continuity of data required for weather forecasting (including severe weather events such as hurricanes) and global climate monitoring through the year 2026.

Three agencies share responsibility for the NPOESS acquisition: the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), the Department of Defense (DOD)/United States Air Force, and the

National Aeronautics and Space Administration (NASA). To manage the NPOESS program, these agencies established a triagency integrated program office. In recent years, this program has experienced escalating costs, schedule delays, and technical difficulties, leading to a June 2006 decision to restructure the program. This decision decreased the complexity of the program by reducing the number of satellites and sensors, increased the estimated cost of the program to $12.5 billion, and delayed the launches of the first two satellites by 3 to 5 years.

This report responds to your request that we (1) evaluate the NPOESS program office's progress in restructuring the acquisition, (2) evaluate the program office's progress in establishing an effective management structure, (3) assess the reliability of the life cycle cost estimate and proposed schedule, and (4) identify the status and key risks facing the program's major segments and evaluate the adequacy of the program's efforts to mitigate these risks.

To evaluate the program office's progress in restructuring the acquisition, we assessed program documentation, attended management status briefings, and interviewed program officials.

To determine progress in establishing a new management structure, we assessed the status of efforts to implement past recommendations regarding the management structure and staffing, attended senior-level management review meetings, reviewed program documents, and interviewed program officials.

To assess the cost estimate, we evaluated the methodology and assumptions used to develop the estimate and interviewed program officials to identify any assumptions that may have changed. To determine the status, risk, and risk mitigation efforts for the program, we analyzed monthly program management documents and interviewed NOAA, NASA, and DOD officials to determine concerns with these mitigation efforts. In addition, this report builds on other work we have done on environmental satellite programs over the last several years [1]

We conducted our work at the NPOESS Integrated Program Office headquarters and at DOD, NOAA, and NASA facilities in the Washington, D.C., metropolitan area. We performed our work from July 2006 to April 2007 in accordance with generally accepted government auditing standards. Appendix I contains additional details on our objectives, scope, and methodology.

RESULTS IN BRIEF

The NPOESS program office has made progress in restructuring the acquisition by establishing and implementing interim program plans guiding the

contractors' work activities in 2006 and 2007; however, important tasks leading up to finalizing contract changes remain to be completed. While the program office developed key acquisition documents, including a memorandum of agreement on the roles and responsibilities of the three agencies, a revised acquisition strategy, and a system engineering plan, the responsible executives in the three agencies have not yet approved these documents—even though they were due by September 1, 2006.

Finalizing these documents is essential to ensure interagency agreement and will allow the program office to move forward in completing other activities related to restructuring the program. These activities include conducting an integrated baseline review with the contractor to reach agreement on the schedule and work activities and finalizing changes to the NPOESS development and production contract— thereby allowing the program office to lock down a new acquisition baseline cost and schedule. Until the key acquisition documents are approved by the appropriate executives in each agency, the program faces increased risk that restructuring activities will not be completed in time to allow it to move forward in fiscal year 2008 with a new program baseline in place. This places the NPOESS program at risk of continued delays and future cost increases.

The program office has also made progress in establishing an effective management structure by adopting a new organizational framework with increased oversight from program executives and by instituting more frequent and rigorous program management reviews; however, planned changes in executive management will likely increase program risk, and the program lacks a process and plan for identifying and filling staffing shortages. As a result, the program experienced delays in beginning key activities such as cost estimating and contract revisions. Until this process is in place and working, the NPOESS program faces increased risk of further delays.

The methodology supporting a June 2006 cost and schedule estimate was reliable, but recent events could lead to increased program costs and delay schedules. DOD's independent cost estimating group used an acceptable methodology in developing a June 2006 cost estimate of $11.5 billion for the acquisition portion of the restructured program with the expectation of initial satellite launch in January 2013. Consistent with DOD direction, this estimate did not include roughly $1 billion in operations and support costs—bringing the total life cycle cost estimate to $12.5 billion. However, the program continues to experience technical problems on key sensors, and program costs will likely be adjusted during upcoming negotiations on contract changes. The NPOESS program office is developing its own cost estimate to further refine the one developed in June 2006 to help it negotiate contract changes. A new baseline cost

and schedule will be established once the contract is finalized—an event that the Program Director expects to occur by July 2007.

Development and testing of major program segments—including key sensors and the ground systems—are under way, but significant risks remain. For example, work continues on key sensors, but two sensors— the Visible/Infrared Imager Radiometer Suite and the Cross-track Infrared Sounder—continue to experience significant difficulties. Specifically, the former encountered three significant problems with image quality and reliability during environmental testing of the engineering unit, and the latter suffered a major structural failure during vibration testing. Additionally, while significant progress has been made in reducing delays in the NPOESS data processing system, much work remains in refining the algorithms needed to translate sensor observations into usable weather products. Given the tight time frames for completing key sensors, integrating them with the demonstration spacecraft (called the NPOESS Preparatory Project or NPP) and getting the ground-based data processing systems developed, tested, and deployed, it will be important for the Integrated Program Office, the Program Executive Office, and the Executive Committee to continue to provide close oversight of milestones and risks.

We are making recommendations to the Secretaries of Commerce and Defense and to the Administrator of NASA to ensure that the appropriate executives finalize key acquisition documents by the end of April 2007 in order to allow the restructuring of the program to proceed. We are also making recommendations to the Secretary of Defense to direct the Air Force to delay reassigning the recently appointed Program Executive Officer until key program risks are resolved. We are also making recommendations to the Secretary of Commerce to ensure that NPOESS program authorities develop and implement a written process for identifying and addressing human capital needs and that they establish a plan to immediately fill needed positions.

The Department of Commerce, DOD, and NASA provided written comments on our draft report (see apps. III, IV, and V). All three agencies agreed that it was important to finalize key acquisition documents in a timely manner, and DOD proposed extending the due dates for the documents to July 2, 2007. In addition, the Department of Commerce concurred with our recommendation to identify and address human capital needs and immediately fill open positions in the NPOESS program office. Commerce noted that NOAA was taking actions in both areas. However, DOD did not concur with our recommendation to delay reassigning the Program Executive Officer, noting that the Program Director responsible for the acquisition program would remain in place for 4 years. While it is important that the System Program Director remain in place to ensure continuity in executing the

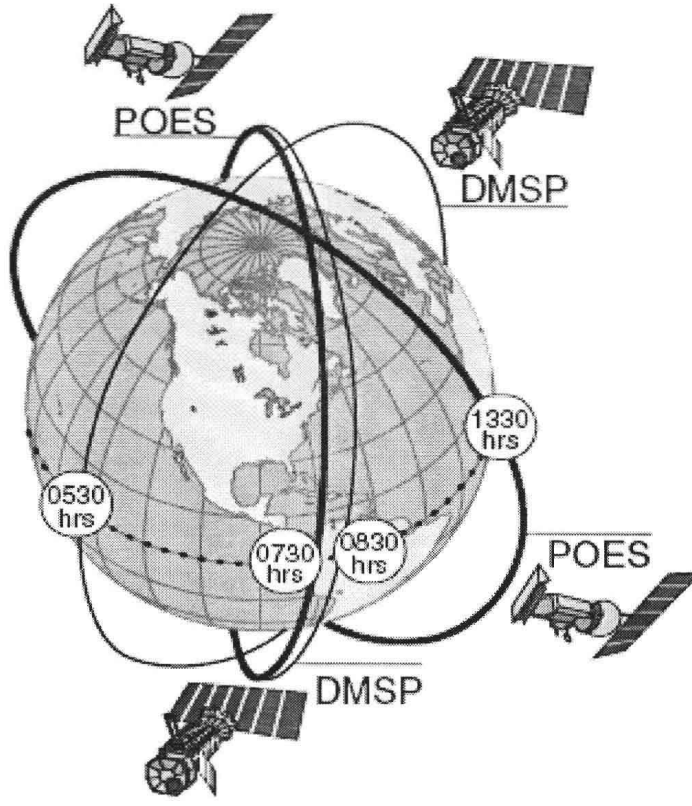
acquisition, this position does not ensure continuity in the important oversight and coordination functions provided by the current Program Executive Officer. We remain concerned that reassigning the Program Executive at a time when NPOESS is still facing critical cost, schedule, and technical challenges will place the program at further risk.

All three agencies also provided technical comments, which we have incorporated in this report as appropriate.

BACKGROUND

Since the 1960s, the United States has operated two separate operational polar-orbiting meteorological satellite systems: the Polar-orbiting Operational Environmental Satellite (POES) series—managed by NOAA, and the Defense Meteorological Satellite Program (DMSP)—managed by the Air Force. These satellites obtain environmental data that are processed to provide graphical weather images and specialized weather products. These satellite data are also the predominant input to numerical weather prediction models, which are a primary tool for forecasting weather 3 or more days in advance—including forecasting the path and intensity of hurricanes. The weather products and models are used to predict the potential impact of severe weather so that communities and emergency managers can help prevent and mitigate their effects. Polar satellites also provide data used to monitor environmental phenomena, such as ozone depletion and drought conditions, as well as data sets that are used by researchers for a variety of studies such as climate monitoring.

Unlike geostationary satellites, which maintain a fixed position relative to the earth, polar-orbiting satellites constantly circle the earth in an almost north-south orbit, providing global coverage of conditions that affect the weather and climate. Each satellite makes about 14 orbits a day. As the earth rotates beneath it, each satellite views the entire earth's surface twice a day. Currently, there are two operational POES satellites and two operational DMSP satellites that are positioned so that they can observe the earth in early morning, midmorning, and early afternoon polar orbits. Together, they ensure that, for any region of the earth, the data provided to users are generally no more than 6 hours old. Figure 1 illustrates the current operational polar satellite configuration. Besides the four operational satellites, six older satellites are in orbit that still collect some data and are available to provide limited backup to the operational satellites should they degrade or fail.



Source: GAO, based on NPOESS Integrated Program Office data

Figure 1. Configuration of Operational Polar Satellites.

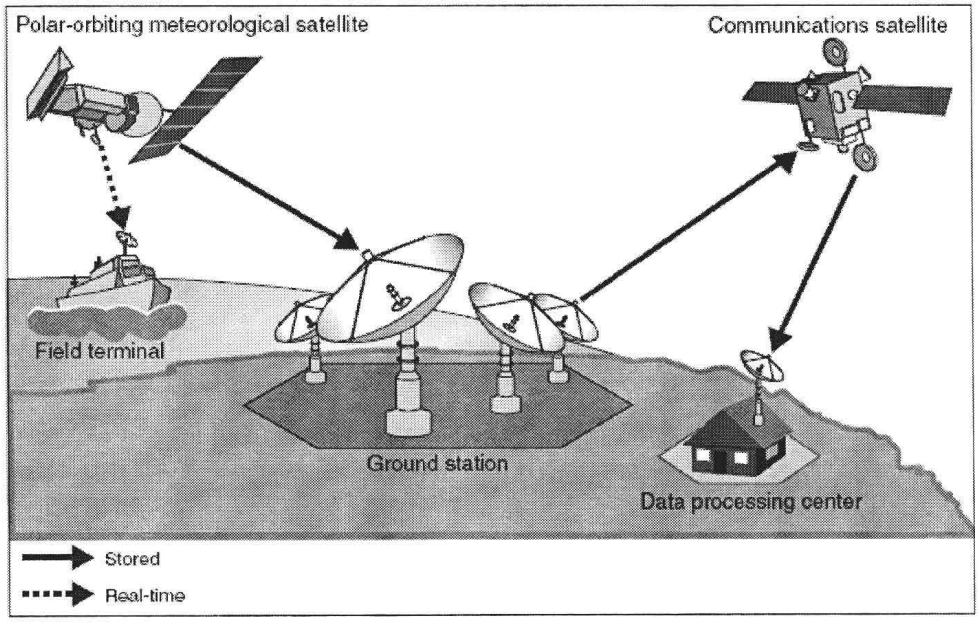
In the future, both NOAA and the Air Force plan to continue to launch additional POES and DMSP satellites every few years, with final launches scheduled for 2009 and 2012, respectively [2].

Each of the polar satellites carries a suite of sensors designed to detect environmental data that are either reflected or emitted from the earth, the atmosphere, and space. The satellites broadcast a subset of these data in real time to properly equipped field terminals that are within a direct line of sight; these field terminals are located at universities, on battlefields, or on ships. Additionally, the polar satellites store the observed environmental data and then transmit them to NOAA and Air Force ground stations when the satellites pass overhead. The ground stations then relay the data via communications satellites to the appropriate meteorological centers for processing.

Under a shared processing agreement among four satellite data processing centers—NOAA's National Environmental Satellite Data and Information Service

(NESDIS), the Air Force Weather Agency, the Navy's Fleet Numerical Meteorology and Oceanography Center, and the Naval Oceanographic Office—different centers are responsible for producing and distributing, via a shared network, different environmental data sets, specialized weather and oceanographic products, and weather prediction model outputs.

Each of the four processing centers is also responsible for distributing the data to its respective users. For the DOD centers, the users include regional meteorology and oceanography centers, as well as meteorology and oceanography staff on military bases, the Naval Fleet, and mobile field sites. NESDIS forwards the data to NOAA's National Weather Service for distribution and use by government and commercial forecasters. The processing centers also use the Internet to distribute data to the general public. NESDIS is responsible for the long-term archiving of data and derived products from POES and DMSP. Figure 2 depicts a generic data relay pattern from the polar-orbiting satellites to the data processing.



Source: GAO, based on NPOESS Integrated Program Office data.

Figure 2. A Generic Data Relay Pattern for Polar Meteorological Satellite Systems.

Polar Satellite Data and Products

Polar satellites gather a broad range of data that are transformed into a variety of products. Satellite sensors observe different bands of radiation wavelengths, called channels, which are used for remotely determining information about the earth's atmosphere, land surface, oceans, and the space environment. When first received, satellite data are considered raw data.

To make them usable, the processing centers format the data so that they are time-sequenced and include earth location and calibration information. After formatting, these data are called raw data records. The centers further process these raw data records into channel-specific data sets, called sensor data records and temperature data records.

These data records are then used to derive weather and climate products called environmental data records (EDR). EDRs include a wide range of atmospheric products detailing cloud coverage, temperature, humidity, and ozone distribution; land surface products showing snow cover, vegetation, and land use; ocean products depicting sea surface temperatures, sea ice, and wave height; and characterizations of the space environment. Combinations of these data records (raw, sensor, temperature, and environmental data records) are also used to derive more sophisticated products, including outputs from numerical weather models and assessments of climate trends. Figure 3 is a simplified depiction of the various stages of satellite data processing, and figures 4 and 5 depict examples of EDR weather products.

NPOESS Overview

With the expectation that combining the POES and DMSP programs would reduce duplication and result in sizable cost savings, a May 1994 Presidential Decision Directive required NOAA and DOD to converge the two satellite programs into a single satellite program capable of satisfying both civilian and military requirements [3]. The converged program, NPOESS, is considered critical to the United States' ability to maintain the continuity of data required for weather forecasting and global climate monitoring through the year 2026. To manage this program, DOD, NOAA, and NASA formed the tri-agency Integrated Program Office, located within NOAA.