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POLAR-ORBITING ENVIRONMENTAL SATELLITES

Project Risks Could Affect Weather Data Needed by Civilian and Military Users

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Highlights of GAO-03-987T, a testimony before the Subcommittee on Environment, Technology, and Standards, Committee on Science, House of Representatives

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Why GAO Did This Study

Polar-orbiting environmental satellites provide data and imagery that are used by weather forecasters, climatologists, and the military to map and monitor changes in weather, climate, the ocean, and the environment. The current polar satellite program is a complex infrastructure that includes two satellite systems, supporting ground stations, and four central data processing centers. In the future, the National Polar-orbiting Operational Environmental Satellite System (NPOESS) is to merge the two current satellite systems into a single state-of-the-art environment monitoring satellite system. This new $7 billion satellite system 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 2018. In its testimony GAO was asked, among other topics, to discuss risks to the success of the NPOESS deployment.

www.gao.gov/cgi-bin/getrpt?GAO-03-987T.

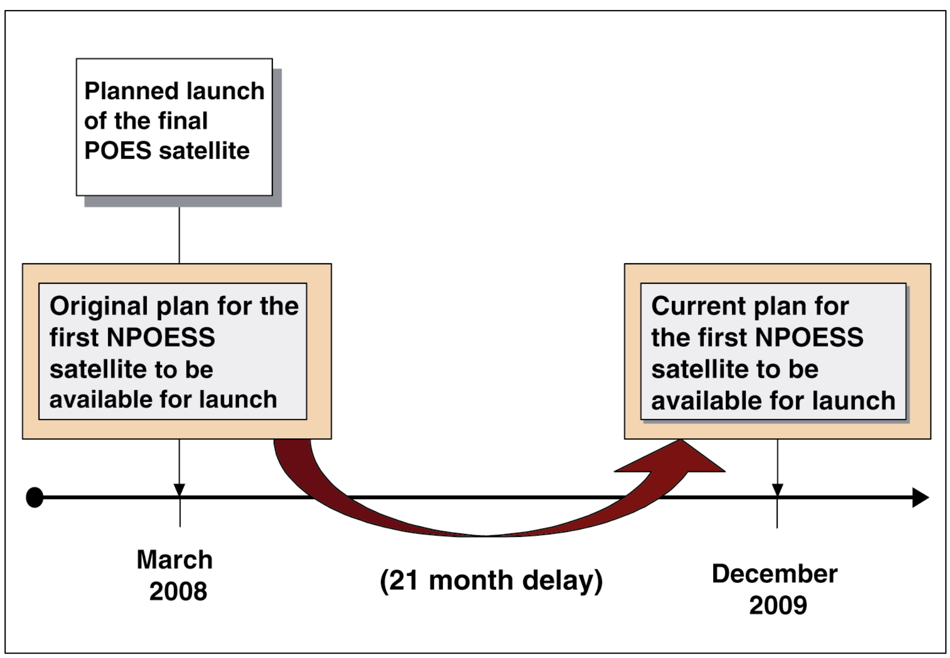
To view the full product, including the scope and methodology, click on the link above. For more information, contact David Powner at (202) 512-9286 or pownerd@gao.gov.

What GAO Found

The NPOESS program faces key programmatic and technical risks that may affect the successful and timely deployment of the system. The original plan for NPOESS was that it would be available to serve as a backup to the March 2008 launch of the final satellite in one of the two current satellite programs—the Polar-orbiting Operational Environmental Satellite (POES) system. However, changing funding streams and revised schedules have delayed the expected launch date of the first NPOESS satellite by 21 months. Thus, the first NPOESS satellite will not be ready in time to back up the final POES satellite, resulting in a potential gap in satellite coverage should that satellite fail. Specifically, if the final POES launch fails and if existing satellites are unable to continue operations beyond their expected lifespans, the continuity of weather data needed for weather forecasts and climate monitoring will be put at risk. Moreover, concerns with the development of key NPOESS components, including critical sensors and the data processing system, may cause additional delays in the satellite launch date.

The program office is working to address the changes in funding levels and schedule, and to make plans for addressing specific risks. Further, it is working to develop a new cost and schedule baseline for the NPOESS program by August 2003.

Timeline of Delay in Launch Availability



Source: GAO.

Mr. Chairman and Members of the Subcommittee:

We appreciate the opportunity to join in today's hearing to discuss our work on the planned National Polar-orbiting Operational Environmental Satellite System (NPOESS). At your request, we will provide an overview of our nation's current polar-orbiting environmental satellite program and the planned NPOESS program. We will also discuss key risks to the successful and timely deployment of NPOESS.

In brief, today's polar-orbiting environmental satellite program is a complex infrastructure encompassing two satellite systems, supporting ground stations, and four central data processing centers that provide general weather information and specialized environmental products to a variety of users, including weather forecasters, military strategists, and the public. NPOESS is planned to merge the two satellite systems into a single state-of-the-art environment monitoring satellite system. This new satellite system, currently estimated to cost about $7 billion, 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 2018.

However, the NPOESS program faces key programmatic and technical risks that may affect the successful and timely deployment of the system. Specifically, changing funding streams and revised schedules have delayed the expected launch date of the first NPOESS satellite by 21 months. Thus, the first NPOESS satellite will not be ready in time to back up the final POES satellite, resulting in a potential gap in satellite coverage should that satellite fail. Specifically, if the final POES launch fails and if existing satellites are unable to continue operations beyond their expected lifespans, the continuity of weather data needed for weather forecasts and climate monitoring will be put at risk. In addition, concerns with the development of key NPOESS components, including critical sensors and the data processing system, could cause additional delays in the satellite launch date.

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This statement builds on work we have done on environmental satellite programs over the last several years.[1] An overview of the approach we used to perform this work—our objectives, scope, and methodology—is provided in appendix I.

Existing Polar Satellite Infrastructure

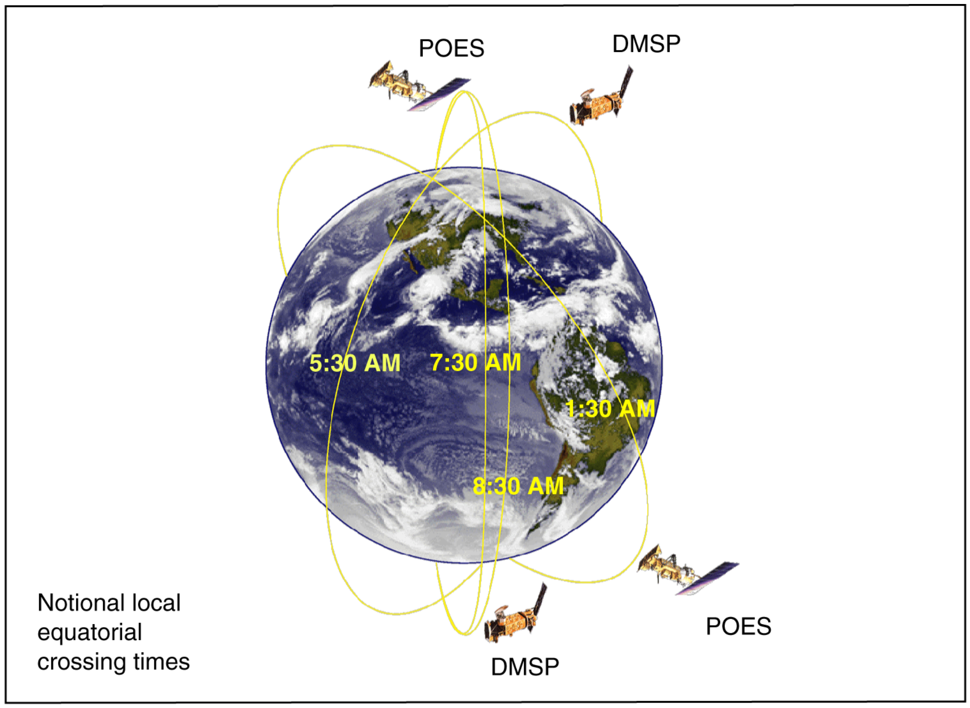
Since the 1960s, the United States has operated two separate operational polar-orbiting meteorological satellite systems. These systems are known as the Polar-orbiting Operational Environmental Satellites (POES), managed by the National Oceanic and Atmospheric Administration's (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS), and the Defense Meteorological Satellite Program (DMSP), managed by the Department of Defense (DOD). These satellites obtain environmental data that are processed to provide graphical weather images and specialized weather products, and that are the predominant input to numerical weather prediction models—all used by weather forecasters, the military, and the public. 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 above 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. Today, there are two operational POES satellites and two operational DMSP satellites that are positioned so that they can observe the earth in early morning, mid-morning, 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, there are five older satellites in orbit that still collect some data and are available to provide some limited backup to the operational satellites should they degrade or fail. In the future, both NOAA

[1] U.S. General Accounting Office, *Polar-orbiting Environmental Satellites: Status, Plans, and Future Data Management Challenges*, GAO-02-684T (Washington, D.C.: July 24, 2002); *National Oceanic and Atmospheric Administration: National Weather Service Modernization and Weather Satellite Program*, GAO/T-AIMD-00-86 (Washington, D.C.: Mar. 29, 2000); and *Weather Satellites: Planning for the Geostationary Satellite Program Needs More Attention*, GAO-AIMD-97-37 (Washington, D.C.: Mar. 13, 1997).

and DOD plan to continue to launch additional POES and DMSP satellites every few years, with final launches scheduled for 2008 and 2010, respectively.

Figure 1: Configuration of Operational Polar Satellites



Source: NPOESS Integrated Program Office.

Each of the polar satellites carries a suite of sensors designed to detect environmental data either reflected or emitted from the earth, the atmosphere, and space. The satellites store these data and then transmit the data 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.

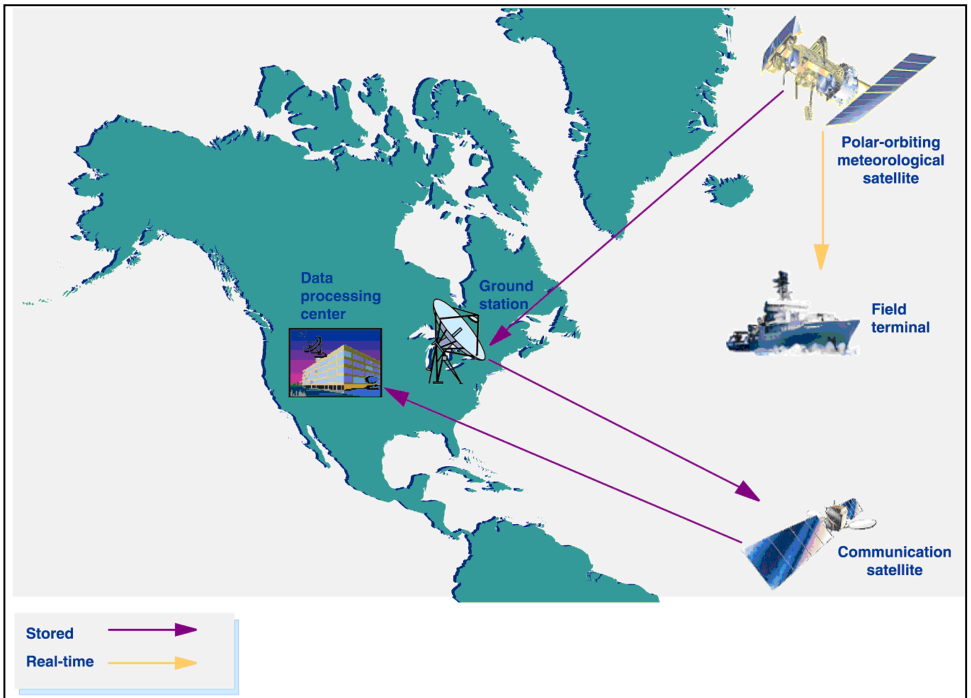
Under a shared processing agreement among the four processing centers—NESDIS,[2] the Air Force Weather Agency, Navy's Fleet Numerical

[2]Within NOAA, NESDIS processes the satellite data, and the National Centers for Environmental Prediction (NCEP), a component of NOAA's National Weather Service, runs the models. For simplicity, we refer to the combined NESDIS/NCEP processing center as the NESDIS processing center.

Meteorology and Oceanography Center, and the Naval Oceanographic Office—different centers are responsible for producing and distributing different environmental data sets, specialized weather and oceanographic products, and weather prediction model outputs via a shared network. 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. NESDIS forwards the data to NOAA's National Weather Service for distribution and use by 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.

In addition to the infrastructure supporting satellite data processing noted above, properly equipped field terminals that are within a direct line of sight of the satellites can receive real-time data directly from the polar-orbiting satellites. There are an estimated 150 such field terminals operated by the U.S. government, many by DOD. Field terminals can be taken into areas with little or no data communications infrastructure—such as on a battlefield or ship—and enable the receipt of weather data directly from the polar-orbiting satellites. These terminals have their own software and processing capability to decode and display a subset of the satellite data to the user. Figure 2 depicts a generic data relay pattern from the polar-orbiting satellites to the data processing centers and field terminals.

Figure 2: Generic Data Relay Pattern for the Polar Meteorological Satellite System



Source: GAO.

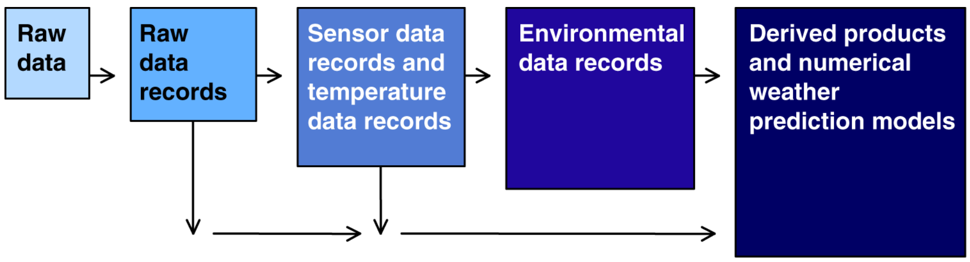
Polar Satellite Data, Products, and Uses

Polar satellites gather a broad range of data that are transformed into a variety of products for many different uses. When first received, satellite data are considered raw data.[3] 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 data sets, called sensor data records and temperature data records. These data records are then used to derive weather products called environmental data records (EDR). EDRs range from atmospheric products detailing cloud coverage, temperature, humidity, and ozone distribution; to land surface products showing snow cover, vegetation, and land use; to ocean products depicting sea surface temperatures, sea ice,

[3]NOAA uses different nomenclature for its data processing stages: raw data are known as level 0 data; raw data records are known as level 1a data; sensor data records and temperature data records are known as level 1b data; and environmental data records are known as level 2 data.

and wave height; to 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 data processing.

Figure 3: Satellite Data Processing Steps



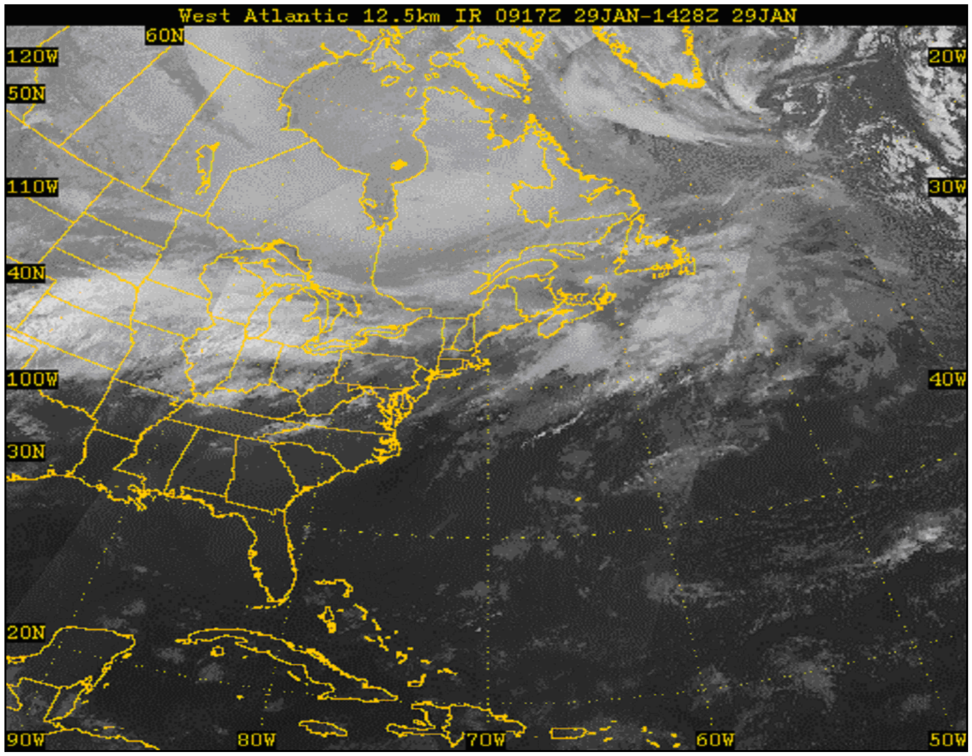
Source: GAO.

EDRs can be either images or quantitative data products. Image EDRs provide graphical depictions of the weather and are used to observe meteorological and oceanographic phenomena to track operationally significant events (such as tropical storms, volcanic ash,[4] and icebergs), and to provide quality assurance for weather prediction models.

The following figures demonstrate polar-orbiting satellite images. Figure 4 is an image from a DMSP satellite showing an infrared picture taken over the west Atlantic Ocean. Figure 5 is a POES image of Hurricane Floyd, which struck the southern Atlantic coastline in 1999. Figure 6 is a polar-satellite image used to detect volcanic ash clouds, in particular the ash cloud resulting from the eruption of Mount Etna in 2001. Figure 7 shows the location of icebergs near Antarctica in February 2002.

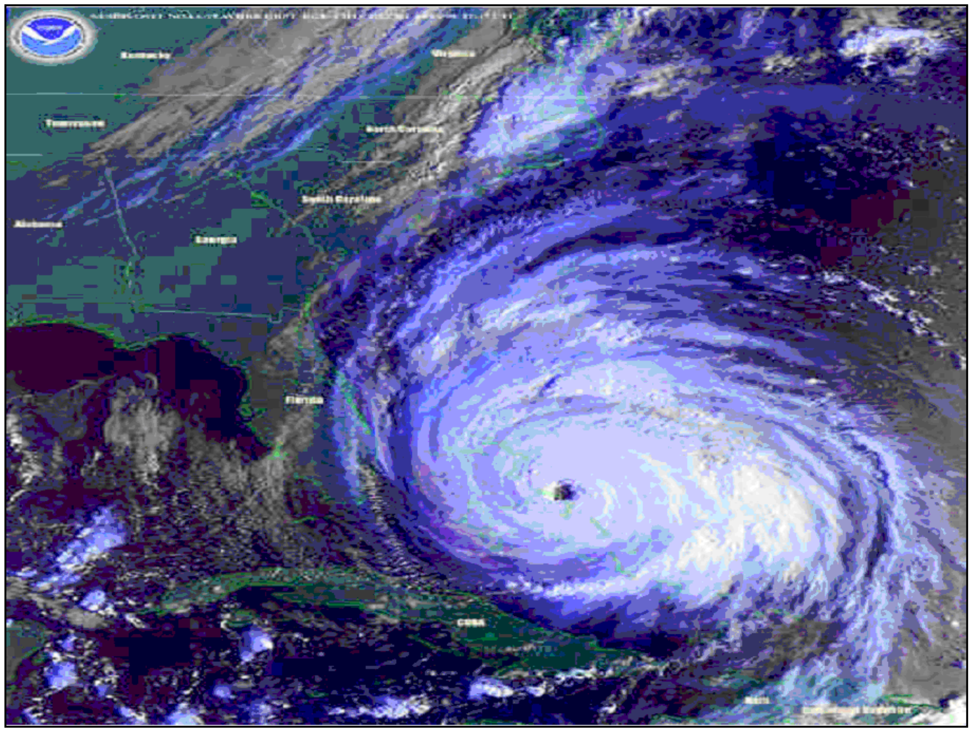
[4]Volcanic ash presents a hazard to aviation because of its potential to damage engines.

Figure 4: DMSP Image of the West Atlantic Ocean



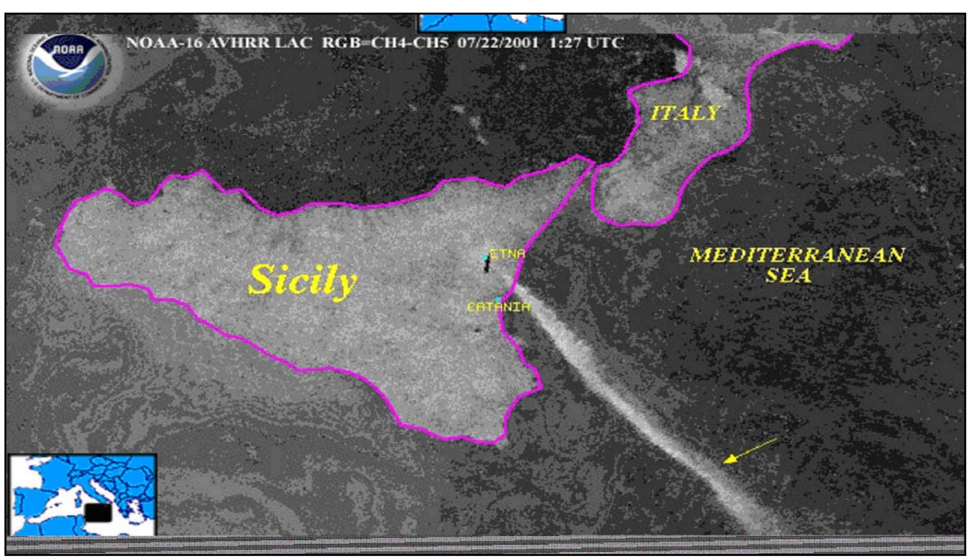
Source: Navy Fleet Numerical Meteorology and Oceanography Center.

Figure 5: POES Image of Hurricane Floyd in 1999



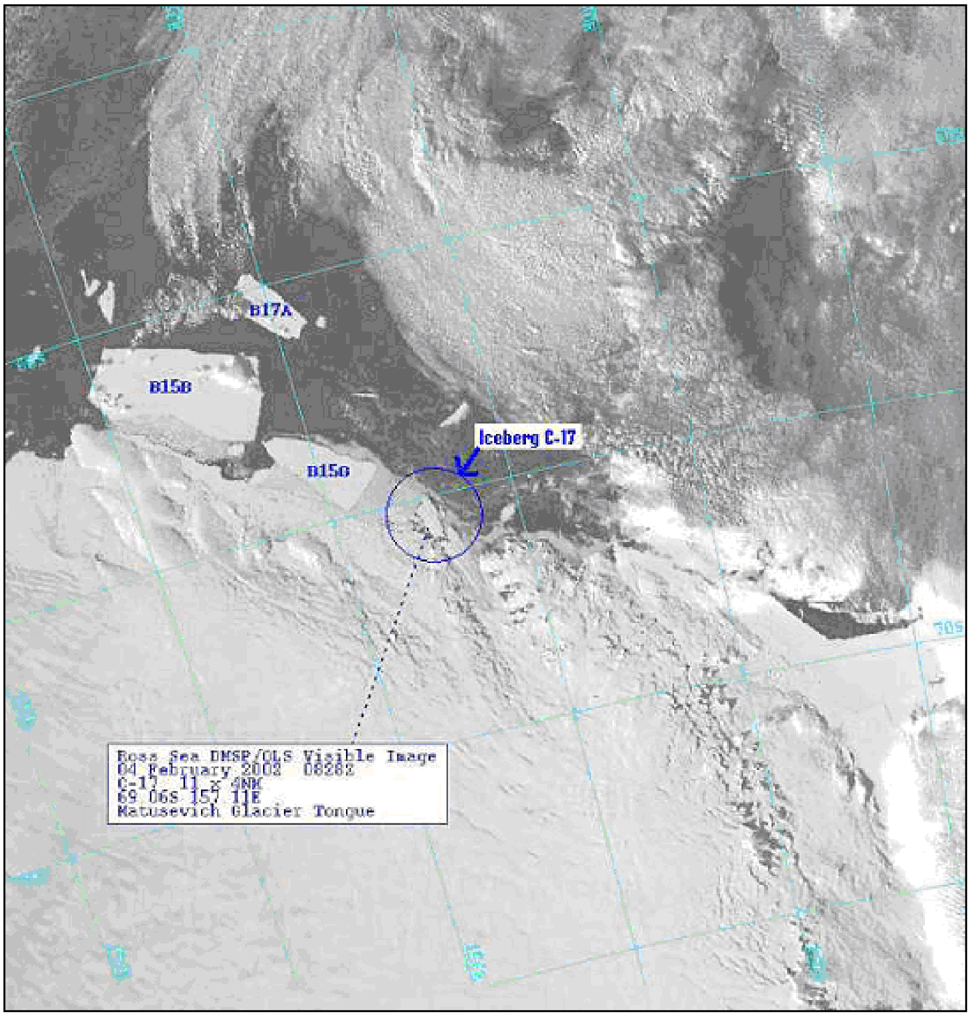
Source: NOAA.

Figure 6: POES Image of Volcanic Ash Cloud from Mt. Etna, Sicily, in 2001



Source: NOAA.

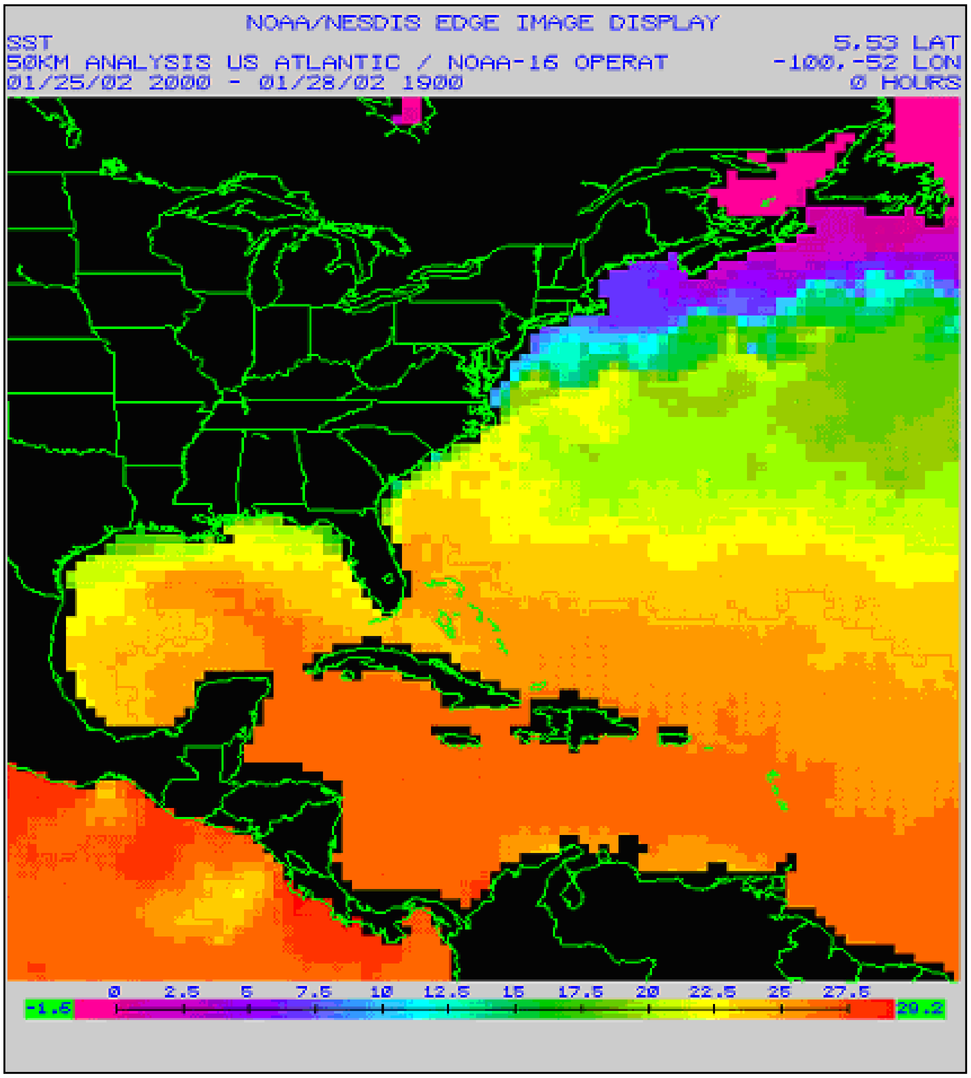
Figure 7: DMSP Image of Icebergs Near Antarctica



Source: Naval/National Ice Center.

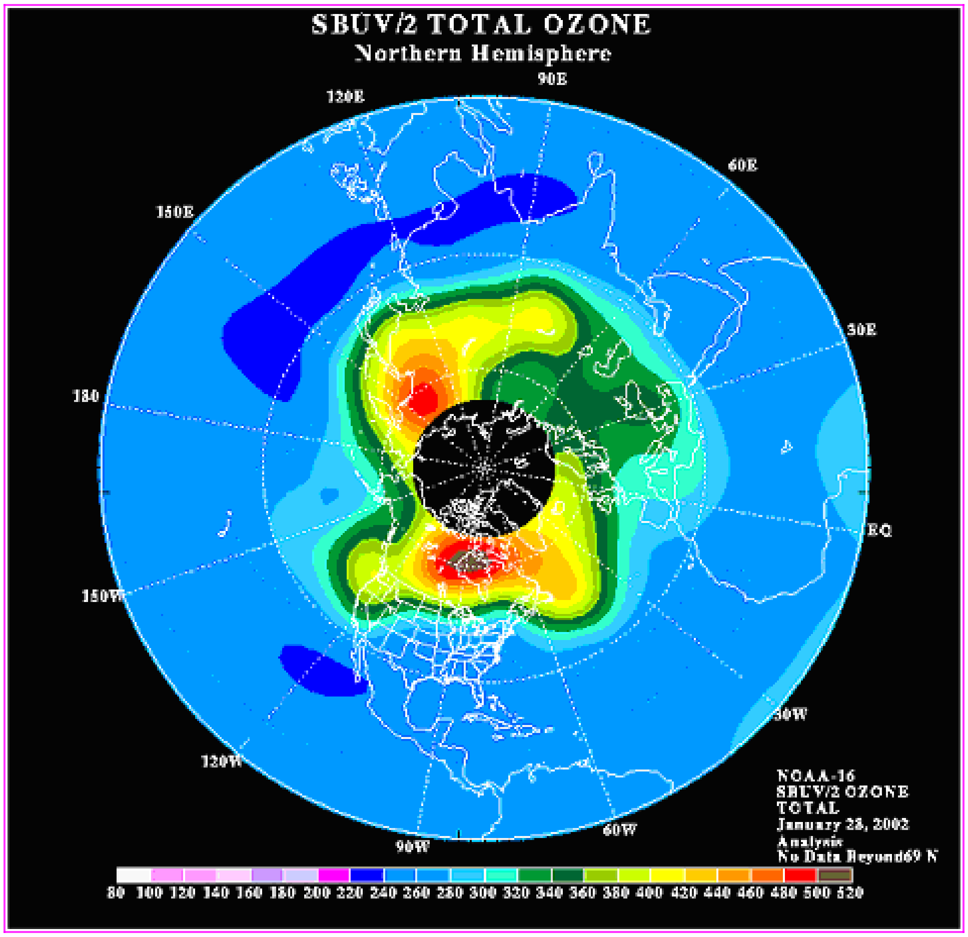
Quantitative EDRs are specialized weather products that can be used to assess the environment and climate or to derive other products. These EDRs can also be depicted graphically. Figures 8 and 9 are graphic depictions of quantitative data on sea surface temperature and ozone measurements, respectively. An example of a product that was derived from EDRs is provided in figure 10. This product shows how long a person could survive in the ocean—information used in military as well as search and rescue operations—and was based on sea surface temperature EDRs from polar-orbiting satellites.

Figure 8: Analysis of Sea Surface Temperatures from POES Satellite Data



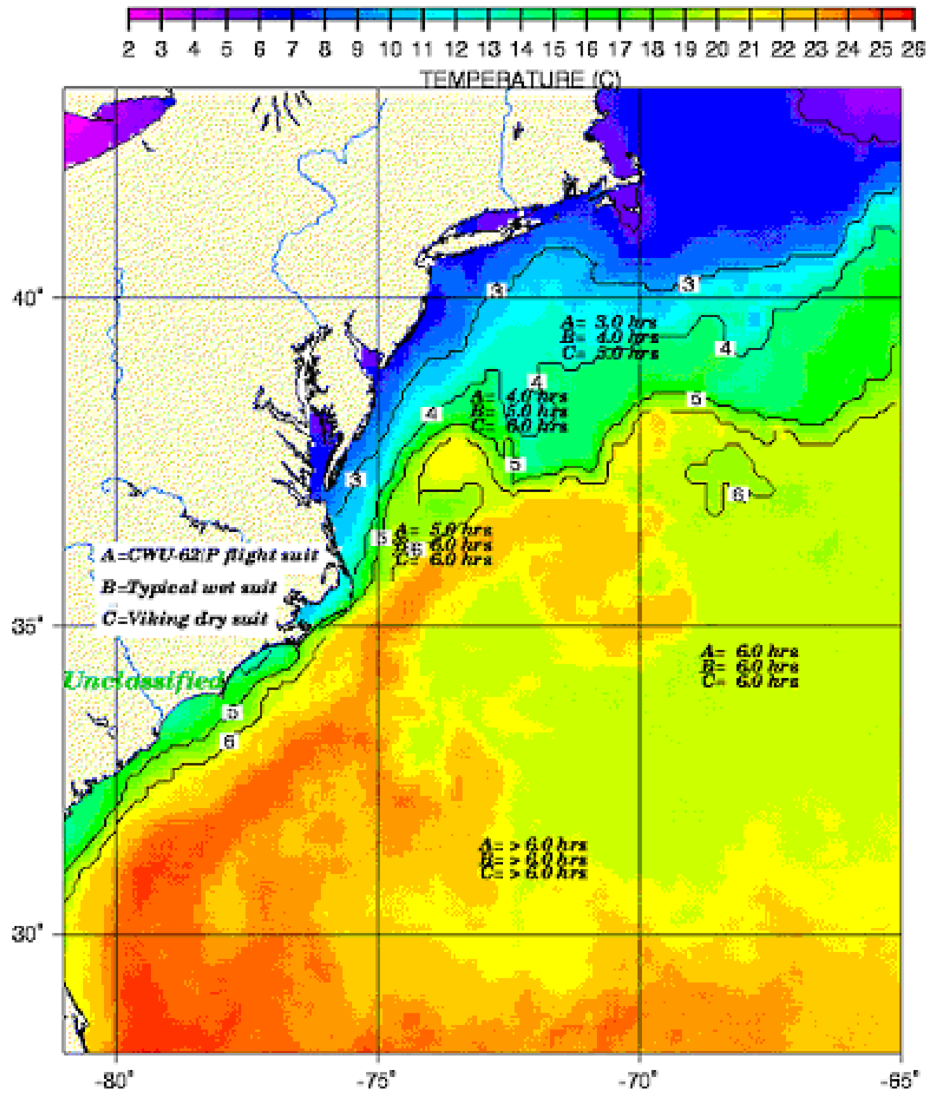
Source: NOAA/NESDIS.

Figure 9: Analysis of Ozone Concentration from POES Satellite Data



Source: NESDIS.

Figure 10: Analysis of Water Survivability off the Atlantic Seaboard, January 2002



Source: Naval Oceanographic Office.

Note: Contour lines with blocked numbers depict survival time, in hours, without a survival suit..

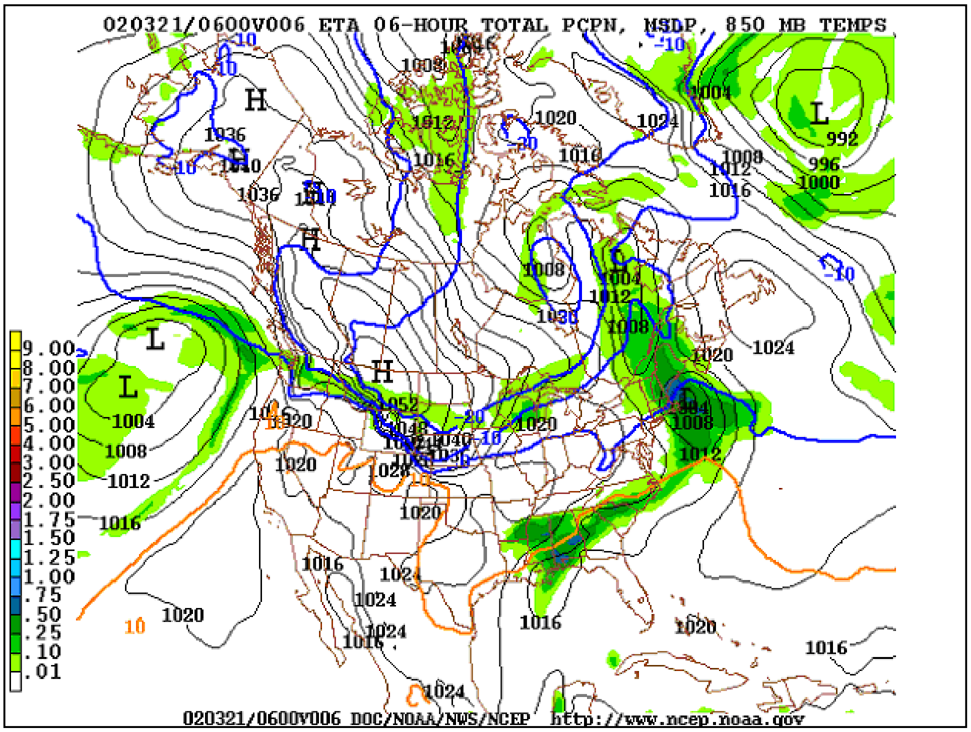
Another use of quantitative satellite data is in numerical weather prediction models. Based predominantly on observations from polar-orbiting satellites and supplemented by data from other sources such as geostationary satellites, radar, weather balloons, and surface observing systems, numerical weather prediction models are used in producing hourly, daily, weekly, and monthly forecasts of atmospheric, land, and ocean conditions. These models require quantitative satellite data to update their analysis of weather and to produce new forecasts. Table 1 provides examples of models run by the processing centers. Figure 11 depicts the output of one common model.

Table 1: Common Numerical Weather Prediction Models Used by Processing Centers

Model	Purpose	Processing center
Global Forecast System	Global weather forecasts	NESDIS/NCEP
Eta Model	Regional weather forecasts	NESDIS/NCEP
Mesoscale Model 5	Regional forecasts	Air Force Weather Agency
Advect Cloud Model	Global cloud forecast and analysis	Air Force Weather Agency
Navy Operational Global Atmospheric Prediction System	Global weather forecasts	Navy Fleet Numerical Meteorology and Oceanography Center
Coupled Oceanographic and Atmospheric Mesoscale Prediction System	Regional weather forecasts	Navy Fleet Numerical Meteorology and Oceanography Center
Wave Model	Regional oceanographic forecasts	Naval Oceanographic Office

Source: NOAA and DOD.

Figure 11: Model Output Depicting a 6-Hour Precipitation Forecast



Source: NOAA/NCEP.

All this information—satellite data, imagery, derived products, and model output—is used in mapping and monitoring changes in weather, climate, the ocean, and the environment. These data and products are provided to weather forecasters for use in issuing weather forecasts and warnings to the public and to support our nation's aviation, agriculture, and maritime communities. Also, weather data and products are used by climatologists and meteorologists to monitor the environment. Within the military, these data and products allow military planners and tactical users to focus on anticipating and exploiting atmospheric and space environmental conditions. For example, Air Force Weather Agency officials told us that accurate wind and temperature forecasts are critical to any decision to launch an aircraft that will need mid-flight refueling. In addition to these operational uses of satellite data, there is also a substantial need for polar satellite data for research. According to experts in climate research, the research community requires long-term, consistent sets of satellite data collected sequentially, usually at fixed intervals of time, in order to study many critical climate processes. Examples of research topics include long-term trends in temperature, precipitation, and snow cover.

The National Polar-orbiting Operational Environmental Satellite System

Given the expectation that merging 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. The converged program is called the National Polar-orbiting Operational Environmental Satellite System (NPOESS), and it is considered critical to the United States' ability to maintain the continuity of data required for weather forecasting and global climate monitoring. To manage this program, DOD, NOAA, and the National Aeronautics and Space Administration (NASA) have formed a tri-agency Integrated Program Office, located within NOAA.

Within the program office, each agency has the lead on certain activities. NOAA has overall responsibility for the converged system, as well as satellite operations; DOD has the lead on the acquisition; and NASA has primary responsibility for facilitating the development and incorporation of new technologies into the converged system. NOAA and DOD share the costs of funding NPOESS, while NASA funds specific technology projects and studies.

NPOESS Overview

NPOESS is a major system acquisition estimated to cost almost $7 billion over the 24-year period from the inception of the program in 1995 through 2018.[5] The program is to provide satellite development, satellite launch and operation, and integrated data processing. These deliverables are grouped into four main categories: (1) the launch segment, which includes the launch vehicle and supporting equipment, (2) the space segment, which includes the satellites and sensors, (3) the interface data processing segment, which includes the data processing system to be located at the four processing centers, and (4) the command, control, and communications segment, which includes the equipment and services needed to track and control satellites.

Program acquisition plans call for the procurement and launch of six NPOESS satellites over the life of the program and the integration of 14 instruments, comprising 12 environmental sensors and 2 subsystems. Together, the sensors are to receive and transmit data on atmospheric, cloud cover, environmental, climate, oceanographic, and solar-geophysical

[5]The fiscal year 2004 President's budget identified the $6.96 billion estimate in base year dollars.

observations. The subsystems are to support nonenvironmental search and rescue efforts and environmental data collection activities. According to the Integrated Program Office, 8 of the 14 planned NPOESS instruments involve new technology development, whereas 6 others are based on existing technologies. The planned instruments and the state of technology on each are listed in table 2.

Table 2: Expected NPOESS Instruments

Instrument name	Description	State of technology
Advanced technology microwave sounder	This sensor is to measure microwave energy released and scattered by the atmosphere, and is to be used with infrared sounding data from NPOESS' cross-track infrared sounder to produce daily global atmospheric temperature, humidity, and pressure profiles.	New
Aerosol polarimetry sensor	This sensor is to retrieve specific aerosol (liquid droplets or solid particles suspended in the atmosphere, such as sea spray, smog, and smoke) and cloud measurements.	New
Conical microwave imager/sounder	This sensor is to collect microwave images and data needed to measure rain rate, ocean surface wind speed and direction, amount of water in the clouds, and soil moisture, as well as temperature and humidity at different atmospheric levels.	New
Cross-track infrared sounder	This sensor is to collect measurements of the earth's radiation to determine the vertical distribution of temperature, moisture, and pressure in the atmosphere.	New
Data collection system	This system collects environmental data from platforms around the world and delivers them to users worldwide.	Existing
Earth radiation budget sensor	This sensor measures solar short-wave radiation and long-wave radiation released by the earth back into space on a worldwide scale to enhance long-term climate studies.	Existing
Global Positioning System occultation sensor	This sensor is to measure the refraction of radio wave signals from the Global Positioning System and Russia's Global Navigation Satellite System to characterize the ionosphere.	New
Ozone mapper/profiler suite	This sensor is to collect data needed to measure the amount and distribution of ozone in the earth's atmosphere.	New
Radar altimeter	This sensor measures variances in sea surface height/topography and ocean surface roughness, which are used to determine sea surface height, significant wave height, and ocean surface wind speed and to provide critical inputs to ocean forecasting and climate prediction models.	Existing
Search and rescue satellite aided tracking system	This system detects and locates aviators, mariners, and land-based users in distress.	Existing
Space environmental sensor suite	This suite of sensors is to collect data to identify, reduce, and predict the effects of space weather on technological systems, including satellites and radio links.	New
Survivability sensor	This sensor monitors for attacks on the satellite and notifies other instruments in case of an attack.	Existing
Total solar irradiance sensor	This sensor monitors and captures total and spectral solar irradiance data.	Existing
Visible/infrared imager radiometer suite	This sensor is to collect images and radiometric data used to provide information on the earth's clouds, atmosphere, ocean, and land surfaces.	New

Source: Integrated Program Office.

Unlike the current polar satellite program, in which the four centers use different approaches to process raw data into the environmental data records that they are responsible for, the NPOESS integrated data processing system—to be located at the four centers—is expected to provide a standard system to produce these data sets and products. The four processing centers will continue to use these data sets to produce other derived products, as well as for input to their numerical prediction models.

NPOESS is planned to produce 55 EDRs, including atmospheric vertical temperature profile, sea surface temperature, cloud base height, ocean wave characteristics, and ozone profile. Some of these EDRs are comparable to existing products, whereas others are new. The user community designated six of these data products—supported by four sensors[6]—as key EDRs, and noted that failure to provide them would cause the system to be reevaluated or the program to be terminated.

Acquisition Strategy

The NPOESS acquisition program consists of three key phases: the concept and technology development phase, which lasted from roughly 1995 to early 1997; the program definition and risk reduction phase, which began in early 1997 and ended in August 2002; and the engineering and manufacturing development and production phase, which began in August 2002 and is expected to continue through the life of the program. The concept and technology development phase began with the decision to converge the POES and DMSP satellites and included early planning for the NPOESS acquisition. This phase included the successful convergence of the command and control of existing DMSP and POES satellites at NOAA's satellite operations center.

The program definition and risk reduction phase involved both system-level and sensor-level initiatives. At the system level, the program office awarded contracts to two competing prime contractors to prepare for NPOESS system performance responsibility. These contractors developed unique approaches to meeting requirements, designing system architectures, and developing initiatives to reduce sensor development and integration risks. These contractors competed for the development and production contract. At the sensor level, the program office awarded

[6]The four sensors supporting key EDRs are (1) the advanced technology microwave sounder, (2) the conical microwave imager/sounder, (3) the cross-track infrared sounder, and (4) the visible/infrared imager radiometer suite.

contracts to develop five sensors.[7] This phase ended when the development and production contract was awarded. At that point, the winning contractor was expected to assume overall responsibility for managing continued sensor development.

The final phase, engineering and manufacturing development and production, began when the development and production contract was awarded to TRW in August 2002. At that time, TRW assumed system performance responsibility for the overall program. This responsibility includes all aspects of design, development, integration, assembly, test and evaluation, operations, and on-orbit support. Shortly after the contract was awarded, Northrop Grumman Space Technology purchased TRW and became the prime contractor on the NPOESS project.

Risk Reduction Activities Are Underway

In May 1997, the Integrated Program Office assessed the technical, schedule, and cost risks of key elements of the NPOESS program, including (1) overall system integration, (2) the launch segment, (3) the space segment, (4) the interface data processing segment, and (5) the command, control, and communications segment. As a result of this assessment, the program office determined that three elements had high risk components: the interface data processing segment, the space segment, and the overall system integration. Specifically, the interface data processing segment and overall system integration were assessed as high risk in all three areas (technical, cost, and schedule), whereas the space segment was assessed to be high risk in the technical and cost areas, and moderate risk in the schedule area. The launch segment and the command, control, and communications segment were determined to present low or moderate risks. The program office expected to reduce its high risk components to low and moderate risks by the time the development and production contract was awarded, and to have all risk levels reduced to low before the first launch. Table 3 displays the results of the 1997 risk assessment as well as the program office's estimated risk levels by August 2002 and by first launch.

[7]The five sensors include (1) the conical microwave imager/sounder, (2) the cross-track infrared sounder, (3) the Global Positioning System occultation sensor, (4) the ozone mapper/profiler suite, and (5) the visible/infrared imager radiometer suite.

Table 3: Actual Risk Levels in 1997, at Contract Award in August 2002, and Projected Risk Level by First Launch

	Risk levels in May 1997			Risk levels in August 2002			Projected risk levels by first launch (2009)		
Area assessed	Technical	Schedule	Cost	Technical	Schedule	Cost	Technical	Schedule	Cost
System integration	H	H	H	M	M	L	L	L	L
Launch segment	L	L	M	L	L	L	L	L	L
Space segment	H	M	H	L	M	L	L	L	L
Interface data processing segment	H	H	H	M	L	L	L	L	L
Command, control, and communications segment	L	L	L	L	L	L	L	L	L

Source: NOAA/Integrated Program Office.

In order to meet its goals of reducing program risks, the program office developed and implemented multiple risk reduction initiatives. One risk reduction initiative specifically targeted the space segment risks by initiating the development of key sensor technologies in advance of the satellite system itself. Because environmental sensors have historically taken 8 years to develop, the program office began developing six of the eight sensors with more advanced technologies early. In the late 1990s, the program office awarded contracts for the development, analysis, simulation, and prototype fabrication of five of these sensors.[8] In addition, NASA awarded a contract for the early development of one other sensor.[9] Responsibility for delivering these sensors was transferred from the

[8]The five program office-initiated sensors include (1) the conical microwave imager/sounder, (2) the cross-track infrared sounder, (3) the Global Positioning System occultation sensor, (4) the ozone mapper/profiler suite, and (5) the visible/infrared imager radiometer suite.

[9]NASA contracted for the advanced technology microwave sounder sensor.

program office to the prime contractor when the NPOESS contract was awarded in August 2002.[10]

Another major risk reduction initiative expected to address risks in three of the four segments with identified risks is called the NPOESS Preparatory Project (NPP).[11] NPP is a planned demonstration satellite to be launched in 2006, several years before the first NPOESS satellite launch in 2009. It is scheduled to host three of the four critical NPOESS sensors (the visible/infrared imager radiometer suite, the cross-track infrared sounder, and the advanced technology microwave sounder), as well as two other noncritical sensors. Further, NPP will provide the program office and the processing centers an early opportunity to work with the sensors, ground control, and data processing systems. Specifically, this satellite is expected to demonstrate about half of the NPOESS EDRs and about 93 percent of its data processing load.

Since our statement last year,[12] the Integrated Program Office has made further progress on NPOESS. Specifically, it awarded the contract for the overall program and is monitoring and managing contract deliverables, including products that will be tested on NPP. The program office is also continuing to work on various other risk reduction activities, including learning from experiences with sensors on existing platforms, including NASA research satellites, the WINDSAT/Coriolis weather satellite, and the NPOESS airborne sounding testbed.

NPOESS Faces Key Programmatic and Technical Risks

While the program office has made progress both on the acquisition and risk reduction activities, the NPOESS program faces key programmatic and technical risks that may affect the successful and timely deployment of the system. Specifically, changing funding streams and revised schedules have delayed the expected launch date of the first NPOESS satellite, and concerns with the development of key sensors and the data processing system may cause additional delays in the satellite launch date. These planned and potential schedule delays could affect the continuity of weather data. Addressing these risks may result in increased costs for the

[10] In the case of the advanced technology microwave sounder sensor, NASA is responsible for developing the initial sensor while the NPOESS prime contractor is responsible for subsequent production of these sensors.

[11] NPP will not address risks in the launch segment.

[12] GAO-02-684T.

overall program. In attempting to address these risks, the program office is working to develop a new cost and schedule baseline for the NPOESS program, which it hopes to complete by August 2003.

NPOESS Funding and Schedule Are Changing

When the NPOESS development contract was awarded, program office officials identified an anticipated schedule and funding stream for the program. The schedule for launching the satellites was driven by a requirement that the satellites be available to back up the final POES and DMSP satellites should anything go wrong during these satellites' planned launches. In general, program officials anticipate that roughly 1 out of every 10 satellites will fail either during launch or during early operations after launch.

Key program milestones included (1) launching NPP by May 2006 in order to allow time to learn from that risk reduction effort, (2) having the first NPOESS satellite available to back up the final POES satellite launch in March 2008, and (3) having the second NPOESS satellite available to back up the final DMSP satellite launch in October 2009. If the NPOESS satellites were not needed to back up the final predecessor satellites, their anticipated launch dates would have been April 2009 and June 2011, respectively.

However, a DOD program official reported that between 2001 and 2002, the agency experienced delays in launching a DMSP satellite, causing delays in the expected launch dates of another DMSP satellite. In late 2002, DOD shifted the expected launch date for the final DMSP satellite from 2009 to 2010. As a result, DOD reduced funding for NPOESS by about $65 million between fiscal years 2004 and 2007. According to NPOESS program officials, because NOAA is required to provide no more funding than DOD does, this change triggered a corresponding reduction in funding by NOAA for those years. As a result of the reduced funding, program office officials were forced to make difficult decisions about what to focus on first. The program office decided to keep NPP as close to its original schedule as possible because of its importance to the eventual NPOESS development, and to shift some of the NPOESS deliverables to later years. This shift will affect the NPOESS deployment schedule. Table 4 compares the program office's current estimates for key milestones, given current funding levels.

Table 4: Comparison of Key Milestones Related to the NPOESS Program

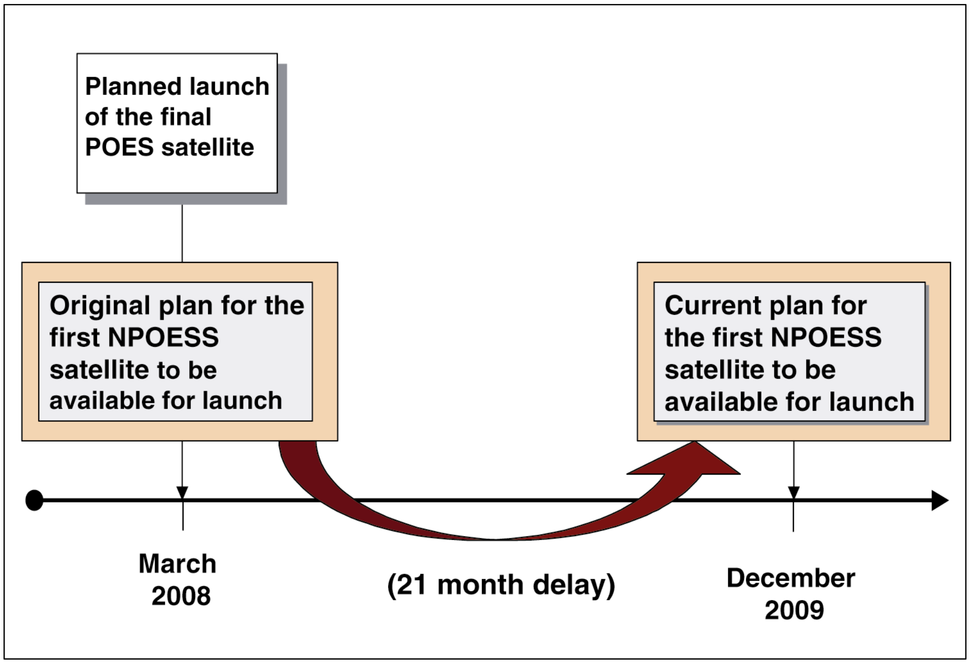
Milestone	As of August 2002 contract award	As of July 2003
NPP launch	May 2006	October 2006
Final POES launch	March 2008	March 2008
First NPOESS satellite available for launch	March 2008	December 2009
First NPOESS satellite planned for launch	April 2009	November 2009[a]
Final DMSP launch	October 2009	May 2010
Second NPOESS satellite available for launch	October 2009	April 2011
Second NPOESS satellite planned for launch	June 2011	June 2011

Source: Integrated Program Office, DOD, and GAO.

[a]A program official reported that if the first NPOESS satellite is not needed to back up the final POES launch in March 2008, the contractor will prepare the satellite to be launched in a different orbit with a different suite of sensors. These factors will allow the launch to take place earlier than if the satellite were to be used as a backup to the final POES launch.

As a result of the changes in funding between 2003 and 2007, project office officials estimate that the first NPOESS satellite will be available for launch 21 months after it is needed to back up the final POES satellite. This means that should the final POES launch fail in March 2008, there would be no backup satellite ready for launch. Unless the existing operational satellite is able to continue operations beyond its expected lifespan, there could be a gap in satellite coverage. Figure 12 depicts the schedule delay.

Figure 12: Timeline of Delay in Launch Availability



Source: GAO.

We have reported on concerns about gaps in satellite coverage in the past. In the early 1990s, the development of the second generation of NOAA's geostationary satellites experienced severe technical problems, cost overruns, and schedule delays, resulting in a 5-year schedule slip in the launch of the first satellite; this schedule slip left NOAA in danger of temporarily losing geostationary satellite data coverage—although no gap in coverage actually occurred.[13] In 2000, we reported that geostationary satellite data coverage was again at risk because of a delay in a satellite launch due to a problem with the engine of its launch vehicle.[14] At that time, existing satellites were able to maintain coverage until the new satellite was launched over a year later—although one satellite had exceeded its expected lifespan and was using several backup systems in cases where primary systems had failed. DOD experienced the loss of DMSP satellite coverage in the 1970s, which led to increased recognition

[13] GAO/AIMD-97-37.

[14] GAO/T-AIMD-00-86.

of the importance of polar-orbiting satellites and of the impact of the loss of satellite data.

Key Sensor Development Efforts Are Experiencing Cost Increases, Schedule Delays, and Performance Shortfalls

In addition to the schedule issues facing the NPOESS program, concerns have arisen regarding key components. Although the program office reduced some of the risks inherent in developing new technologies by initiating the development of these sensors early, individual sensor development efforts have experienced cost increases, schedule delays, and performance shortfalls. The cost estimates for all four critical sensors (the ones that are to support the most critical NPOESS EDRs) have increased, due in part to including items that were not included in the original estimates, and in part to addressing technical issues.[15] These increases range from approximately $60 million to $200 million. Further, while all the sensors are still expected to be completed within schedule, many have slipped to the end of their schedule buffers—meaning that no additional time is available should other problems arise. Details on the status and changes in cost and schedule of four critical sensors are provided in table 5. The timely development of three of these sensors (the visible/infrared imager radiometer suite, the cross-track infrared sounder, and the advanced technology microwave sounder) is especially critical, because these sensors are to be demonstrated on the NPP satellite, currently scheduled for launch in October 2006.

[15] Program officials noted that the more recent cost estimates include items that were not included in the original estimates, such as system engineering, integration, and testing; overhead costs; on-orbit support; and additional units of one of the sensors, as well as costs to address technical issues.

Table 5: Comparison of Costs and Schedules of Four Critical Sensors[a]

	Comparison of cost estimates (millions of dollars)			Comparison of schedule estimates					
				Critical design review			First unit delivery		
Critical sensors	Original	Current	Change	Contract award	Current date	Change	Contract award	Current	Change
Advanced technology microwave sounder[b]	$78.6	$137.8	$59.2	Dec 2001	May 2002	5 months	Oct 2004	Dec 2004	2 months
Cross-track infrared sounder	$74.1	$275.3	$201.2	Jan 2003	Aug 2003	7 months	Feb 2005	Oct 2005	8 months
Visible/infrared imager radiometer suite	$297.6	$426.75	$129.15	Mar 2002	Mar 2002	0 months	Dec 2004	Nov 2005	11 months
Conical microwave imager/sounder	$298.0	$384.5	$86.5	Apr 2004	Nov 2005	19 months	Apr 2006	Apr 2008	24 months

Source: Integrated Program Office and NASA data.

[a]Program officials noted that the recent estimates include items such as system integration and testing that were not included in the original estimates.

[b]NASA is incurring all costs for the development of the advanced technology microwave sounder instrument, which is to fly on NPP. The program office expects to fund the other advanced technology microwave sounder instruments at a cost of $206.6 million.

Critical sensors are also falling short of achieving the required levels of performance. As part of a review in early 2003, the program officials determined that all four critical sensors were at medium to high risk of shortfalls in performance. Program officials recently reported that since the time of that review, the concerns that led to those risk designations have been addressed, which contributed to the schedule delays and cost increases noted above. We have not evaluated the closure of these risk items. However, program officials acknowledge that there are still performance issues on two critical sensors which they are working to address. Specifically, officials reported that they are working to fix a problem with radio frequency interference on the conical microwave imager/sounder. Also, the program office is working with NASA to fix problems with electrostatic discharge procedures and misalignment of key components on the advanced technology microwave sounder. Further, the program office will likely continue to identify additional performance issues as the sensors are developed and tested. Officials anticipate that there could be cost increases and schedule delays associated with addressing performance issues.

Program officials reported that these and other sensor problems are not unexpected; previous experience with such problems was what motivated them to begin developing the sensors early. However, officials acknowledge that continued problems could affect the sensors' delivery dates and potentially delay the NPP launch. Any delay in that launch date could affect the overall NPOESS program because the success of the program depends on learning lessons in data processing and system integration from the NPP satellite.

Level of Effort and Time Needed to Develop the Interface Data Processing System for NPP and NPOESS Is Not Known

The interface data processing system is a ground-based system that is to process the sensors' data so that they are usable by the data processing centers and the broader community of environmental data users. The development of this system is critical for both NPP and NPOESS. When used with NPP, the data processing system is expected to produce 26 of the 55 EDRs that NPOESS will provide, processing approximately 93 percent of the planned volume of NPOESS data. Further, the central processing centers will be able to work with these EDRs to begin developing their own specialized products with NPP data. These activities will allow system users to work through any problems well in advance of when the NPOESS data are needed. We reported last year that the volumes of data that NPOESS will provide present immense challenges to the centers' infrastructures and to their scientific capability to use these additional data effectively in weather products and models.[16] We also noted that the centers need time to incorporate these new data into their products and models. Using the data processing system in conjunction with NPP will allow them to begin to do so.

While the data processing segment is currently on schedule, program officials acknowledge the potential for future schedule delays. Specifically, an initial version of the data processing system is on track to be delivered at the end of July, and a later version is being planned. However, the data processing system faces potential risks that could affect the availability of NPP and in turn NPOESS. Specifically, program officials reported that there is a risk that the roughly 32 months allocated for developing the remaining software and delivering, installing, and verifying the system at two central processing centers will not be sufficient. A significant portion of the data processing system software involves converting scientific algorithms for operational use, but program officials noted that there is still uncertainty in how much time and effort it will take to complete this conversion. Any significant delays could cause the

[16] GAO-02-684T.

potential coverage gap between the launches of the final POES and first NPOESS satellites to grow even larger.

NPOESS Program Office Is Working to Address Risks

Program officials are working to address the changes in funding levels and schedule, and to make plans for addressing specific sensor and data processing system risks. They acknowledge that delays in the program and efforts to address risks on key components could increase the overall cost of the program, which could result on the loss of some or all of the promised cost savings from converging the two separate satellite systems. However, estimates on these cost increases are still being determined. The program office is working to develop a new cost and schedule baseline based on the fiscal year 2004 President's budget for the NPOESS program. Officials noted that this rebaselining effort will involve a major contract renegotiation. Program officials reported that they hope to complete the new program baseline by August 2003.

In summary, today's polar-orbiting weather satellite program is essential to a variety of civilian and military operations, ranging from weather warnings and forecasts to specialized weather products. NPOESS is expected to merge today's two separate satellite systems into a single state-of-the-art weather and environmental monitoring satellite system to support all military and civilian users, as well as the public. This new satellite system 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 2018, and the first satellite was expected to be ready to act as a backup should the launch of the final satellites in the predecessor POES and DMSP programs fail.

The NPOESS program office has made progress over the last years in trying to reduce project risks by developing critical sensors early and by planning the NPOESS Preparatory Project to demonstrate key sensors and the data processing system well before the first NPOESS launch. However, the NPOESS program faces key programmatic and technical risks that may affect the successful and timely deployment of the system. Specifically, changing funding streams and revised schedules have delayed the expected launch date of the first NPOESS satellite, and concerns with the development of key sensors and the data processing system may cause additional delays in the satellite launch date. These factors could affect the continuity of weather data needed for weather forecasts and climate monitoring.

This concludes my statement. I would be pleased to respond to any questions that you or other members of the Subcommittee may have at this time.

Contact and Acknowledgements

If you have any questions regarding this testimony, please contact David Powner at (202) 512-9286 or by E-mail at pownerd@gao.gov. Individuals making key contributions to this testimony include Barbara Collier, John Dale, Ramnik Dhaliwal, Colleen Phillips, and Cynthia Scott.

Appendix I. Objectives, Scope, and Methodology

Our objectives were to provide an overview of our nation's current polar-orbiting weather satellite program and the planned National Polar-orbiting Operational Environmental Satellite System (NPOESS) program and to identify key risks to the successful and timely deployment of NPOESS.

To provide an overview of the nation's current and future polar-orbiting weather satellite system programs, we relied on prior GAO reviews of the satellite programs of the National Oceanic and Atmospheric Administration (NOAA) and the Department of Defense (DOD). We reviewed documents from NOAA, DOD, and the National Aeronautics and Space Administration (NASA) that describe the purpose and origin of the polar satellite program and the status of the NPOESS program. We also interviewed Integrated Program Office and NASA officials to determine the program's background, status, and plans.

To identify key risks to the successful and timely deployment of NPOESS, we assessed the NPOESS acquisition status and program risk reduction efforts to understand how the program office plans to manage the acquisition and mitigate the risks to successful NPOESS implementation. We reviewed descriptions of the NPOESS sensors and interviewed officials at the Integrated Program Office, NASA, and DOD to determine the status of key sensors, program segments, and risk reduction activities. We also reviewed documents and interviewed program office officials on plans to address NPOESS challenges.

NOAA, DOD, and NASA officials generally agreed with the facts as presented in this statement and provided some technical corrections, which we have incorporated. We performed our work at the NPOESS Integrated Program Office, NASA headquarters, and DOD offices, all located in the Washington, D.C., metropolitan area. Our work was performed between April and July 2003 in accordance with generally accepted government auditing standards.

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