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OVERSIGHT HEARING ON
UNITED STATES WEATHER AND ENVIRONMENTAL SATELLITES,
FOCUSING ON THEIR READINESS FOR THE 21ST CENTURY

BEFORE THE
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

JULY 11, 2007

Introduction

Mr. Chairman and members of the committee, I am Mary Kicza, Assistant Administrator for Satellite and Information Services in the National Environmental Satellite, Data, and Information Service (NESDIS). NESDIS is a line office of the National Oceanic and Atmospheric Administration, within the Department of Commerce (DOC).

NOAA's work touches the daily lives of every person in the United States and in much of the world. From hurricane forecasts to fisheries management, from remote sensing to climate research and ocean exploration, NOAA's products and services contribute to the foundation of a healthy economy. I appreciate the opportunity to discuss with you today NOAA's environmental satellite programs and to highlight their importance to our hurricane and other severe weather forecasting and warning capabilities.

Satellites provide an unparalleled capability to take images and precise measurements of many aspects of vast areas of the land, sea, and air in very rapid succession. Data obtained from these observing systems are essential to our ability to understand and predict changes in the Earth's environment. These data are key enablers for NOAA in meeting its public safety, economic, and environmental mission requirements.

Although their payoff is great, satellites are also an inherently risky endeavor. Not only is there the "rocket science" involved, but the instruments carried on these satellites must be sensitive enough to measure very small differences in the characteristics of the oceans, land, and atmosphere while being able to withstand the extreme vibrations of a launch and the extreme heating and cooling of the space environment.

NOAA currently operates and manages two major satellite programs: the Geostationary Operational Environmental Satellites (GOES) and the Polar-orbiting Operational Environmental Satellites (POES).

<u>What Are GOES Satellites?</u>

NOAA has operated geostationary satellites since the 1970s. These satellites, orbiting 22,240 miles above the equator, mirroring the Earth's rotation, provide constant images and data on atmospheric, oceanic, land, and climatic conditions over the Western Hemisphere with major focus on the continental United States, Hawaii, the western Atlantic Ocean and the eastern Pacific Ocean. These satellites provide the hurricane and other severe storm moving displays, called "loops," that you see on television and are best known for the images used in television weather forecasts. More importantly, GOES satellites often provide the first images and information indicating severe weather is imminent to the forecasters so they can provide the early warnings — think of GOES satellites as sentinels in the sky.

NOAA operates two geostationary satellites, one over the East Coast and the other over the West Coast. Given the absolutely critical role these satellites play in our nation's ability to forecast weather, especially severe weather, we maintain a spare satellite on-orbit that can quickly be activated should a primary satellite fail. We also have a fourth GOES satellite, near the end of its mission life, which is being used by South American nations for weather forecasting and could be used in an emergency. The final two GOES satellites in the current GOES-N series have been built and are scheduled for launch in 2008 and 2009; each of these satellites has an expected lifetime of 5 years.

The GOES satellites have unique environmental sensors —an imager and a sounder — that provide a wide range of capabilities related to weather, water, and climate observations that include tsunami, wildland fire, volcanic ash detection, and storms. The satellites also have a data relay function that is used for stream and reservoir monitoring. A search and rescue instrument supports mariners and aviators in trouble. Two of the GOES satellites have an additional sensor onboard that gathers information on space weather.

The GOES satellites provide forecasters frequent images of clouds circulation, and monitor the Earth's surface temperature and water vapor fields. In addition, these satellites measure the vertical thermal and moisture structures of the atmosphere. When combined, this information allows forecasters to better understand and monitor the evolution of atmospheric phenomena and ensure real-time coverage of dynamic events that directly affect public safety, protection of property, and ultimately, economic health and development.

In addition, GOES satellites also transmit emergency communications for NOAA's National Weather Service to the Emergency Managers Weather Information Network. This network provides emergency management communities, including the Department of Homeland Security, and the Federal Emergency Management Agency, with warnings, watches, and forecasts issued by NOAA's National Weather Service (NWS).

The Geostationary Operational Environmental Satellite (GOES-R)

We are in the early stages of the acquisition process for the next generation of GOES satellites, called GOES-R. Given the long lead time needed for satellite development and launch, acquisition work has already begun to ensure continuity of satellite coverage into the future.

All GOES-R instruments are either on contract or in source selection. The main sensor on GOES-R, the Advanced Baseline Imager (ABI), will fulfill NOAA's critical mission requirements. This sensor will offer significant advancements over the current GOES imagers by providing images five times faster and will have the ability to zoom in to view hurricanes and specific severe weather events, while at the same time continuing to monitor the rest of the United States. We currently do not have this flexibility in our zoom capability and must constantly make decisions about what to focus on, which affects our ability to forecast weather in multiple regions. The space weather instruments will provide enhanced data on solar flares and the space radiation environment that NOAA's Space Environment Center uses to issue space weather warnings critical to all satellites, power grids, GPS users, commercial aviation, and astronauts. The Geostationary Lightning Mapper is a brand new instrument, never before flown in geostationary orbit, that will help us better detect cloud-to-cloud lightning, and early precursor to a potentially dangerous weather event, and improve our capabilities to forecast and track severe weather over broad areas. Present operational lightning sensors are ground-based and provide only localized coverage of cloud-to-ground strikes.

NOAA is applying lessons learned from our other major next generation satellite program, the National Polar-orbiting Operational Environmental Satellite System (NPOESS), and other recent independent reviews and audits of national security and civil space system acquisitions. We are implementing these lessons into our management and acquisition strategy. We have made significant changes to our GOES-R program management and oversight based on the direction and reviews from the Government Accountability Office (GAO), the DOC Inspector General, the recent NPOESS Nunn-McCurdy certification process, external independent review teams and our own internal reviews.

We decided to remove one of the originally planned sensors for the GOES-R program, the Hyperspectral Environmental Suite (HES), due to a combination of development challenges, magnitude of required spacecraft accommodations, and ground product implications that presented too much risk to meet the operational requirements of the GOES-R program. This included cost growth and unacceptable delays in the launch date. We also determined that the ABI instrument can provide derived sounding products that will meet mission continuity requirements. The ABI has many of the same spectral bands and exceeds the spatial coverage rate and spatial resolution of the current sounders.

Historically, NOAA funds and manages the program and determines the need for satellite replacement, while the National Aeronautics and Space Administration (NASA) provides launch support and helps design, engineer, and procure the satellites and some ground system elements. After a satellite is launched and checked out by NASA, it is turned over to NOAA for its operation. For GOES-R, we had planned to significantly alter our management strategy from that used for previous GOES acquisitions. NOAA was going to manage the overall acquisition program, using technical support from NASA. Following the recommendations of our Independent Review Team, we decided NASA will manage the sensor and the instrument and space segment acquisitions, and NOAA will manage the ground system acquisition and integration activities while managing the overall program. GOES-R is scheduled for a late 2014 launch. The current life-cycle estimate for the program is roughly $7 billion for two satellites that will provide operational coverage through 2026.

GOES-R — Next Steps
The GOES-R program is being acquired in a phased approach. In April 2007 the second phase was completed, which involved multiple contracts with industry. In this second phase, the Program Definition and Risk Reduction Phase, three prime contractor teams were tasked with developing the definition of system concepts and the identification and mitigation of program risks. Additionally, technical, cost, schedule, and other information were generated. The final phase in the GOES-R acquisition process is the Acquisition and Operations (A&O) phase. During this phase the satellite and ground designs will be completed and the development, integration, testing, and deployment of the space and ground elements of the system will occur.

<u>What Are POES Satellites?</u>

NOAA's Polar-orbiting Operational Environmental Satellites (POES) consist of a pair of satellites that orbit over the poles at an altitude of 540 miles approximately 14 times per day, repeating this same pattern every 24 hours and providing near-global coverage every 12 hours. The POES system provides global imagery and atmospheric measurements of temperature, humidity, and stratospheric ozone. POES data are used around the world for weather monitoring and prediction, and are the foundation for global weather models needed for 3-7 day, and longer, weather forecasts.

The launch of NOAA-N (currently operated as NOAA-18) inaugurated a new era of international cooperation and introduced a new model for polar-orbiting environmental satellite systems. Today, the three satellite constellation consists of a Defense Meteorological Satellite Program satellite in the early morning orbit, the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) MetOp-A satellite in the mid-morning orbit and the NOAA-18 in the afternoon orbit. Both the NOAA and EUMETSAT satellites carry instruments that collect and provide global data on cloud cover; surface conditions such as ice, snow, and vegetation; atmospheric temperatures, moisture, aerosol, and ozone distributions; and collect and relay information from fixed and moving data platforms. As part of the EUMETSAT-NOAA partnership, NOAA provided several key sensors that are being flown on the MetOp series satellites.

NOAA currently has one additional POES to launch (NOAA-N Prime), which is expected to provide continuity in the afternoon orbit until NPOESS is launched. NOAA also has three additional POES on-orbit that no longer meet mission specifications due to orbital drift and instrument degradation or failures, but they can provide limited capability and additional observations when available. Most notably these degraded satellites are used to increase coverage and reduce the amount of time it takes to receive and relay search and rescue alerts and animal tracking data. Their direct broadcast signals are also used by other governments to detect and track wildfires and other environmental events.

The National Polar-orbiting Operational Environmental Satellite System (NPOESS)

Since the early 1960s, the United States had maintained two distinct polar satellite programs, one for military use and one for civilian use. While data from both programs were exchanged, each program operated independently. In 1994, after a thorough review and serious consideration, President Clinton directed the merger of the military and civilian operational polar-orbiting satellite programs. This new program, NPOESS, is responsible for developing the next generation of polar-orbiting satellites and sensors.

NPOESS is a unique program in the federal government. It is jointly managed by the DOC, the Department of Defense (DOD), and NASA with direct funding provided by DOC and DOD. At the senior level, the program is overseen by an Executive Committee (EXCOM), which includes VADM Conrad Lautenbacher, Administrator of NOAA, Dr. Michael Griffin, Administrator of NASA, and Dr. Ron Sega, Under Secretary of the Air Force. The EXCOM recently assigned a Program Executive Officer to provide more frequent senior oversight of the program and reports back to the EXCOM. The NPOESS program is managed, on a day-to-day basis, by an Integrated Program Office (with staff from all three agencies). NPOESS is being acquired using DOD acquisition authorities. In 2002, Northrop Grumman was selected as the NPOESS prime contractor for spacecraft development, ground systems, sensor integration, and operations.

NPOESS is one of the most complex operational environmental satellite system ever developed. The NPOESS program was designed as a series of six satellites with new environmental sensors that represent significant advances over current operational satellite technology. The new NPOESS sensors will provide higher quality data, increase our ability to see through clouds, and transmit the information back much faster than with our current polar-orbiting satellites. These improvements will translate into more sophisticated weather models, which will lead to better forecasts and warnings. NPOESS also will enhance the data and products used for climate and ocean research and operations as well as monitoring space weather. The first NPOESS satellite will be launched in 2013, with an expected lifetime of 7 years.

The NPOESS Preparatory Project (NPP) is a risk reduction mission directed by NASA. NPP provides risk reduction for the NPOESS system by demonstrating several new NPOESS sensors in space, ensuring the ground control systems work properly, and allowing us time to assimilate the new data into computer weather models before launch of the first operational NPOESS satellite. The NPP mission will also collect and distribute remotely-sensed land, ocean, and atmospheric data to the meteorological and global climate communities as the responsibility for these measurements transitions from NASA's existing Earth-observing missions (e.g., Aqua, Terra and Aura) to the NPOESS. NPP will provide atmospheric and sea surface temperatures, vertical profiles of moisture, land and ocean biological productivity, and cloud and aerosol properties.

The NPOESS program has presented numerous technical and management challenges. In March 2005, the contractor informed the government NPOESS would not meet cost and schedule, mostly because of the technical challenges with the main sensor, the Visible Infrared Imager Radiometer Suite (VIIRS). In November 2005, it was determined the projected cost overruns for the program would exceed the 25 percent threshold triggering a breach of the Nunn-McCurdy statute. This required a full six-month review of the program by the DOD, with the participation of NOAA and NASA as full partners in the certification process.

In June 2006, the Nunn-McCurdy certification was delivered to Congress. The resulting restructure of the NPOESS program has two fewer satellites, fewer sensors, and less risk. Because of our partnership with EUMETSAT, we are able to utilize the MetOp series satellites in the mid-morning orbit to fulfill U.S. data requirements. The total cost of the program increases, but so did our confidence in a timely delivery of core weather forecasting capabilities. NPP is now scheduled to launch in 2009, and the first NPOESS satellite in 2013, at a total life-cycle program cost of $12.5 billion (FY 1995-2026).

NPOESS and Climate Change Measurements

While the main instruments on NPOESS will provide more than 50 percent of the desired climate-related observations and data, a number of secondary sensors were removed during the review process that would provide some key climate parameters such as earth radiation budget, solar irradiance, sea surface topography, and aerosol optical properties.

NOAA and NASA have already committed to provide FY 2007 funding to restore one of the sensors, the Ozone Mapping and Profiler Suite (OMPS) Limb (OMPS-limb), to the NPP satellite. By remanifesting OMPS-Limb to OMPS-Nadir, we were able to obtain total and vertically resolved stratospheric ozone measurements necessary to better monitor the Antarctic Ozone phenomenon and other events. At the initiative of the Office of Science and Technology Policy (OSTP), NASA and NOAA are continuing to work together to identify what may be done to assure continuity of key climate measurements. NOAA and NASA provided OSTP with a preliminary report in January 2007 and an update to the report will be issued later this summer. We are also asking the National Academy of Sciences, which provided us with the recent Decadal Survey for Earth Observations, for recommendations on a path forward. The National Academy hosted a workshop June 19-21 to seek input from the scientific community on the changes to the NPOESS and GOES-R programs. OSTP will work with the agencies and the Office of Management and Budget on a plan of action to best address the National Academy's recommendations.

Another of the sensors demanifested from NPOESS was the Conical Microwave Imager Sounder (CMIS). CMIS was planned to provide observations of ocean wind speed and direction along with more than 10 other environmental parameters. The project had too many technical challenges and risks and was cancelled. However, a smaller and less complex replacement sensor will be procured and integrated onto the second satellite to be launched in 2016.

Program Oversight

Following the recommendations of Independent Review Teams, the GAO, and the Inspector General from DOC, the recent Nunn-McCurdy certification process, external independent review teams, and our own internal reviews, we have made significant management and oversight changes in the program. In addition to personnel changes in both government and contractor management, we made changes to the way the program is monitored. We have put into place much more rigorous requirements to measure earned value data, key milestones, dollars spent, and contractor personnel. We are now tracking these metrics on a regular basis, which provides real-time health and status of the program.

NPOESS Status Update

The significant management changes and the reduced risk profile resulting from the Nunn-McCurdy certification and subsequent restructure have had major positive affects on the program. The program is meeting the interim budget and schedule. We are in the final stages of renegotiating the contract, which should be complete this summer.

We are performing acceptance tests on flight hardware. In this phase of development, we "test, break, fix" the hardware on the ground to be sure it will function on-orbit. This practice is the main reason that our satellites have historically performed for extended periods on-orbit. Each of the instruments is in a different phase of acceptance testing.

There are still challenges and risks associated with the main instrument, VIIRS. Corrective actions for all identified VIIRS instrument problems are underway. One major technical issue remains and we are pursing several potential solutions. This key instrument will continue to be the focus of intense management attention for the foreseeable future.

We have issued a request for information for a Microwave Imager/Sounder (MIS), a less complex sensor than the original CMIS. The MIS is still intended to provide data for a variety of products including estimates of ocean surface wind speed and direction. The MIS is scheduled to first fly on the second NPOESS spacecraft and then on all subsequent missions. A final acquisition strategy decision is anticipated by September 2007, and the contract award is anticipated in the winter of 2008.

Our number one priority throughout the Nunn-McCurdy analysis of the NPOESS program has been to ensure there is continuity of our existing data and in our ability to do weather forecasting between the old and new systems. To minimize any potential gaps in coverage, we are rescheduling launches of the remaining NOAA and DOD satellites. We do not believe there will be a gap in data used for weather forecasting under this plan. However, should the remaining NOAA POES satellite fail on launch or in orbit, we would have to rely solely on DOD, European, and NASA satellites. There would be some degradation to NOAA's weather forecasting ability until NPP or the next NPOESS satellite could be launched.

NOAA’s Hurricane Forecasting

The National Hurricane Center (NHC), a key component of the NWS and NOAA, has been the centerpiece of our nation's hurricane forecast and warning program for over 50 years. The NHC, working closely with local NWS Weather Forecast Offices (WFOs) in areas affected by hurricanes and other tropical systems, saves lives, mitigates property loss, and improves economic efficiency by issuing the best watches, warnings, and forecasts of hazardous tropical weather, and by increasing the public’s understanding of these hazards.

NOAA’s forecasts and warnings for the 2005 hurricane season demonstrated the abilities of the state of the art of hurricane prediction. Our continuous research efforts at NOAA, and in partnership with universities and other federal agencies, have led to our current predictive capabilities and improved ways of describing uncertainty in prediction. The impacts of hurricane winds, storm surge and inland flooding remain major threats to the nation. Accurate and timely hurricane forecasts provide emergency managers and the public information needed to prepare for an approaching storm, including considering evacuations, if necessary.

NOAA strives to improve the reliability, accuracy, and timeliness of our predictions of hazardous weather, such as hurricanes, to help society cope with these high impact events. Over the last 15 years, hurricane track forecast errors have decreased by 50 percent, largely due to advances in hurricane modeling, an increased understanding of hurricane dynamics, improvements in computing and technology, and increased observations from the region around the hurricane. Today’s five-day forecasts of a hurricane track are as accurate as three-day predictions were 20 years ago. Hurricane predictions are better today than they have ever been and will continue to improve in the future.

To help guide future research efforts and improvements, NOAA requested that the NOAA Science Advisory Board commission a Hurricane Intensity Research Working Group to provide recommendations to the agency on the direction of hurricane intensity research. The Working Group transmitted its final report to the Advisory Board in October 2006 (http://www.sab.noaa.gov/reports/reports.html). The Federal Coordinator for Meteorological Services and Supporting Research released a report in February 2007, *Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead*, to provide a strategy for continuing to improve the effectiveness of operational forecasts and warnings through strategic coordination and increased collaboration among the major players in the operational and R&D communities (http://www.ofcm.gov/p36-isrtc/fcm-p36.htm). Both of these reports call for accelerated research investments and a deliberate focus on moving research results to operations. In response, NOAA has created a Hurricane Project Team to develop a unified approach to define and accelerate hurricane forecast improvements over the next ten years. Objectives will be focused on improved tropical cyclone forecasting (intensity, track, precipitation, and uncertainty forecasts), storm surge forecasts, flooding forecasts, and information and tools to support community and emergency planning.

NOAA Hurricane Observations

NOAA uses several systems to monitor hurricanes. Over the open oceans, images from the GOES system are the first reliable indicators of any storms or inclement weather. As hurricanes or other tropical systems come closer to land, measurements from reconnaissance and surveillance aircraft provide direct measurements of the storm, as do strategically placed "hurricane" buoys. Within 200 miles of the coast, radars are used to track the storm. Computer models used to predict storm track and intensity require extensive amounts of data about the state of the atmosphere, including wind direction and speed, temperature, moisture, and air pressure. Over the open ocean, most of these data are derived from satellite "sensing" of the atmosphere. Ships and other mid-ocean buoys provide some data, but satellites are truly the "eye in the sky." All of these data sources are part of an integrated observing system.

Satellites

Forecasters at the Tropical Prediction Center/National Hurricane Center (TPC/NHC) use images and other data provided by the GOES system to analyze the storm and its surrounding environment and help to determine the location, size, intensity, and movement of the storm. These images are also prominently shown by the media. The satellites also provide data about every eight minutes during a hurricane event. Instrumentation on the satellites (both GOES and POES) measure emitted and reflected radiation from which atmospheric temperature, winds, moisture, and cloud cover are derived. Satellites provide:

- Day (visible)/night (infrared) cloud images
- Land surface temperatures
- Sea surface temperatures
- Cloud motion winds at several levels
- Rainfall estimates
- Cloud top heights

Ships and Buoys

Ships and buoys, including drifting buoys, provide information about wind speed and direction, pressure, air and sea temperature, and wave conditions within a tropical cyclone. Ships and buoys are the only routine source of wave height and frequency in areas unobstructed by land and are often the only way to take direct measurements near the storm when a tropical cyclone is still at sea. Understandably, ships try to avoid tropical systems and we have only sparse ocean buoys to provide a level of "ground truthing" for indirect measurements (such as satellite and radar) in the marine environment.

Aircraft

The most direct method of measuring the wind speed and direction, air pressure, temperature, location of the eye and other parameters in a hurricane is to send reconnaissance aircraft (hurricane hunters) into the storm. Those measurements are limited given the large size of a hurricane and the time the aircraft can remain in flight. Though we only have a snapshot of small parts of the hurricane, that information is critical in analyzing the current characteristics needed to forecast the future behavior of the storm. TPC/NHC forecasters rely heavily on data from reconnaissance and surveillance aircraft.

The U.S. Air Force Reserve uses specially equipped WC-130J aircraft to conduct these reconnaissance flights. NOAA also flies its two WP-3D Orion (P-3) aircraft.

When forecasters identify a developing tropical cyclone, WC-130J aircraft fly their first missions to determine if the winds near the ocean surface are blowing in a complete, counterclockwise circle, then to find the center of this closed circulation. As the storm builds in strength, they fly various patterns to obtain as complete a picture as possible of the extent and strength of the winds and other parameters. The 2005 hurricane supplemental budget provided funding to instrument the fleet of WC-130J aircraft with Stepped-Frequency Microwave Radiometers (SFMRs), which will provide additional details on a hurricane's wind fields.

NOAA WP-3D Aircraft also fly into hurricanes with a wide variety of scientific systems onboard the aircraft providing data and information to forecasters, scientists, and modelers. Of particular interest are the two radars which provide a full 360° depiction of weather and three-dimensional horizontal wind vectors around the aircraft out to a distance of 180 nautical miles. Data from these radars, along with meteorological and position data from onboard sensors, are transmitted to the NHC in real time via high-speed satellite communications. The WP-3D aircraft also serves as a test bed for emerging technologies such as the SFMR (which now reside on both WP-3D aircraft), the Imaging Wind and Rain Airborne Profiler, and the Scanning Radar Altimeter.

Given the current limitations in satellite observations, the only inner-core wind data routinely available — derived from the SFMR (surface winds), airborne tail Doppler radar (three dimensional structure), and GPS dropwindsonde (point vertical profile) — are collected by aircraft reconnaissance (NOAA WP-3D and U.S. Air Force WC-130J). The combination of SFMR, airborne tail Doppler radar, and GPS dropwindsonde (see below) is essential for real-time interpretation of rapidly changing events, especially near landfall. The SFMR capability is especially critical to the forecasters.

In addition to the reconnaissance missions, NOAA also has a state-of-the-art Gulfstream-IV (G-4) high altitude jet aircraft, which flies missions around the storm, known as surveillance missions. NOAA's Gulfstream IV jet, which began operational hurricane surveillance missions in 1997, is used to sample the physical nature of the atmosphere from high altitude down to the surface in the region surrounding hurricanes. These data better define the environmental steering flow for potential landfalling storms and help improve track forecasts. The data are transmitted in real time to NOAA's National Centers for Environmental Prediction, where they are assimilated into the Global Data Assimilation System.

Dropwinsondes and Radiosondes
A radiosonde is a small instrument package and radio transmitter that is attached to a large balloon. As the balloon rises through the atmosphere, the radiosonde instrument provides data on air temperature, humidity, pressure and wind speed and direction. These data are relayed back to computers for use in forecast models. Radiosondes are generally only released over land, which leaves a large gap over the oceans. That's where dropwinsondes, a variation on the radiosonde, are used. Instead of being carried aloft by a balloon, the dropwinsondes, which are attached to a small parachute, are dropped into and around the hurricane from the reconnaissance and surveillance aircraft. The data from radiosondes and dropwinsondes provide an important vertical profile of the hurricane's environment, which is critical for forecast models. These data have helped forecasters make great strides in understanding and predicting hurricane behavior.

Expendable Bathythermographs
Expendable bathythermographs are instruments dropped into the water and measure water temperature and other parameters to a depth of 200 feet. These instruments provide us with an idea of the energy content of the water which fuels hurricanes.

Surface Observations
There are more than 950 Automated Surface Observation Systems (ASOS) across the country. These monitoring systems provide forecasters with surface weather observations, wind speed and direction, temperature, dewpoint (moisture), cloud cover, and conventional weather (e.g., rain, fog, snow) around the clock. However, because the systems are land-based, ASOS data is mainly useful once the hurricane has come close to shore or after it has made landfall. This information is invaluable in post-analysis.

Radar
When a hurricane nears the coast, typically within 200 miles, it is monitored by land-based Doppler weather radars. These radars provide detailed information on hurricane wind fields, rain intensity, and storm movement. As a result, local NWS offices are able to provide short-term warnings for floods, tornadoes, and high winds for specific areas. In radar images, the forecaster can pick out details about storm features, such as the location of the eye, storm motion, and intensity. The radial wind velocity product gives forecasters important information about wind speed and direction that was not available with the older style radars. These tools allow forecasters to provide much more timely and accurate warnings than were possible only a few years ago. A limitation of these

radars is they cannot "see" farther than about 200 miles from the coast, and hurricane watches and warnings must be issued long before the storm comes into range.

All of these data are assimilated into NCEP's data stream and incorporated into computer model forecasts to provide the fundamental understanding of the developing tropical cyclonic atmosphere and ocean environment, the tropical inner and outer core, and the interaction among these components. But that is just part of the value. This information is used directly by hurricane forecasters who make the predictions of the hurricane track and intensity and the decisions for any watches and warnings.

Hurricane Forecasting and Satellites

As I stated earlier, satellites, particularly GOES, provide the first indications of a tropical system. They are absolutely critical in our prediction mission. Data from GOES help our forecasters analyze the storms and its surrounding environment, and help determine its location, size, intensity, and movement. POES, with the advanced microwave-sounding unit and the advanced very high resolution radiometer, provide precipitation estimates, qualitative estimates of storm intensity trends, sea surface temperatures, storm center position, convective structure and atmospheric temperature/humidity profiles. POES are not always over the storm since these satellites orbit the globe. This is in contrast to GOES, which are stationary relative to the Earth's surface. Data from these satellites play an important role in NOAA's hurricane computer models, which are the backbone of our predictive capability.

In addition, NOAA uses data and observations gathered from several other low Earth orbiting satellites. These include:

- The Defense Meteorological Satellite Program, using the special sensor microwave/imagery suite of instruments, provides information on ocean surface wind speed, precipitation, sea surface temperatures, center position and convective structure.
- NASA's Tropical Rainfall Mapping Mission (TRMM) satellites, using the TRMM microwave imager, provide precipitation/rain rate, center position, convective structure, and sea surface temperatures.
- The NASA AQUA satellite mission using the moderate resolution imaging spectroradiometer, the advanced microwave scanning radiometer and the atmospheric infrared sounder to provide precipitable water, water vapor, sea surface temperatures, center position, convective structure and atmospheric temperature/humidity profiles.
- NASA's Research Satellite, Jason – using an altimeter sensor to provide the surface height of the oceans, a proxy for the amount of heat potentially available to help fuel a hurricane.
- European MetOp satellite sensor, ASCAT, using an active scatterometer to provide wind speed and direction, but at a low spatial resolution. Currently not incorporated into NOAA forecast models, but accessible to forecasters.

- NASA's QuikSCAT, using the SeaWinds scatterometer, provides wind speed, wind direction, center location and wind radii.

What is QuikSCAT?

Recently, concerns have been expressed about one of these satellite tools — QuikSCAT. QuikSCAT is a NASA satellite that launched in 1999 to research the ability to measure ocean wind speed and direction. Wind speed and direction are valuable pieces of information to hurricane forecasters. While data was available some months after launch, it has been a long, ongoing process to discover how to use the data optimally. The data allow for more reliable estimation of maximum intensity, especially for tropical storms, but not for major hurricanes, due to the wind speeds encountered there. QuikSCAT provides improved detection and tracking of circulation centers, and improved analysis of storm size and structure, which do affect watches and warnings.

What Is Its Limitation?

While the information from QuikSCAT has proved to be an important tool, there are several limitations, specifically as it relates to hurricanes. Since QuikSCAT is a polar-orbiting satellite, and as with all such satellites (including POES and NPOESS), it circles the globe and may provide data about a hurricane at most twice a day, usually only once a day. Sometimes, it may not be at the right place at the right time. Gaps between the coverage area, or swaths, approach 1000 kilometers in the deep tropics. Because hurricane wind speeds change over relatively short distances, the 12.5-km spatial resolution of QuikSCAT's observation makes it difficult to measure winds faster than 65mph, the approximate speed at which a tropical storm becomes a hurricane. It also has significant problems seeing through the rain, which is a major portion of the hurricane environment. QuikSCAT's usefulness becomes significantly less important as the storm gets closer to continental-U.S. landfall where forecasters are able to rely on data from the hurricane reconnaissance aircraft.

What Is Its Status?

While QuikSCAT was launched in 1999, with a three-year mission, and consumables to last at least five years, it is now in its eighth year. The primary transmitter lasted seven years and failed last year, and now the satellite is operating on its backup transmitter. Like any satellite, especially one past its design life, QuikSCAT could fail at any time. However, according to NASA, the instrument is healthy and should continue to operate for several more years. It also has enough fuel to last through 2011.

What is NOAA's Plan

Since the late 1990s, NOAA has had a plan to obtain ocean wind speed and direction data from NPOESS. As stated previously, during the Nunn-McCurdy process the CMIS instrument was removed to reduce the overall risk. A replacement sensor will not be available until the launch of the second NPOESS scheduled for 2016. In June 2006, the NWS held a workshop to define new requirements for ocean surface wind speed and direction. It was determined that only the active approach used by QuikSCAT, a scatterometer, had the potential to meet the new requirements; the passive approach used by the MIS instrument aboard NPOESS did not. The Admiral redirected FY 2007 funds to be used to start a study with NASA's Jet Propulsion Lab, which built QuikSCAT, on building a satellite to replace or enhance our current capabilities. The results of that study are due in January 2008 and we plan to use it and other information to determine the best way to provide ocean surface wind speed and direction to forecasters.

What Will You Do If It Fails Today?
If QuikSCAT were to fail today, I want to assure you and the public that we are not blind to forecasting hurricanes. On the contrary, as stated earlier in my testimony, there are many tools and observations that our forecasters rely on as they make their predictions. It is the GOES satellites in particular that are the most crucial for hurricane forecasting. We have an on-orbit spare GOES and an additional two on the ground while we are developing the next generation. With regard to ocean surface wind speed and direction data, there are two other satellites, WindSat (a Navy research satellite with a passive system) and MetOp (the EUMESTAT satellite carrying the active ASCAT scatterometer), which provide data similar to, although not quite as good as, QuikSCAT. The coverage area, or swaths, of these two satellites are about 60 percent of QuikSCAT.

The European satellite was launched late last year and the NHC is just now starting to receive the data and learning how to use it in models and in their forecasts. We do not yet have any specific information on what the effect to the models or the forecasts would be through the use of ASCAT. The good news about ASCAT is that the Europeans plan to fly this sensor on a series of successive satellites until at least 2020.

We will also be exploring agreements with India and China as they are expected to launch satellites with scatterometers, with technology similar to QuikSCAT, late in this decade. We do not know the specifications of their satellites and historically these nations have not fully shared their environmental data, especially in a timely manner. However, we are exploring this option as well.

Finally, we are also examining how to increase the use of our hurricane hunter aircraft through more flight hours and outfitting the planes with more advanced technologies. We are also researching the feasibility of placing scatterometers on Unmanned Aircraft Systems.

Conclusion

Satellites are very complicated and difficult systems to design, build, and operate. However, their capabilities play an important role in NOAA's mission to observe and predict the Earth's environment and to provide critical information used in protecting life and property. Advances in hurricane prediction depend not only on improved observations such as those from satellites, but also on improved data assimilation, computer models, and continued research to better understand the inner workings of hurricanes.

I believe we are making significant strides in developing a better process for designing and acquiring our satellites. We have fully functioning operational satellites with backup systems in place, and we are working on the next generation that will provide significant improvements in our ability to forecast the weather. I would be happy to answer any questions you may have.