S. HRG. 110–1129

U.S. WEATHER AND ENVIRONMENTAL SATELLITES: READY FOR THE 21ST CENTURY?

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

JULY 11, 2007

Printed for the use of the Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE

74–320 PDF WASHINGTON : 2012

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
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ONE HUNDRED TENTH CONGRESS

FIRST SESSION

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U.S. WEATHER AND ENVIRONMENTAL SATELLITES: READY FOR THE 21ST CENTURY?

WEDNESDAY, JULY 11, 2007

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Committee met, pursuant to notice, at 10:03 a.m. in room SR–253, Russell Senate Office Building, Hon. Bill Nelson, presiding.

OPENING STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Senator NELSON. Good morning. We're here to discuss an issue that has captured the imagination of a lot of Americans, particularly at this time of year, as we come into the hurricane season. Thus far, we have been mercifully spared. It didn't seem that way, because on the very first day of hurricane season, a hurricane started brewing that actually got close to 75 miles per hour before hitting, fortunately; an unpopulated part of the Florida Coast. But a lot of the issues that we're going to discuss today have to do with the Nation's weather satellites and also the satellites that have to do with the delicate measurements of the climate.

Naturally, we take for granted all our detailed, real-time pieces of information about the weather. We take that for granted 365 days a year. Since the first weather satellite was launched, in 1960, we've planned our daily lives informed by weather forecasts derived, in large part, from satellite data. Farmers, mariners, pilots, and countless others depend on this accurate and timely weather information.

Naturally, residents, particularly in coastal areas, well understand the importance of weather satellite data. Fifty percent of the U.S. population now lives within 50 miles of the coastline. Hurricane losses averaged $36 billion in each of the last 5 years. The cost to the Federal Government on Katrina alone has been in excess of $100 billion. By comparison, we spend less than a billion dollars each year on weather satellites and hurricane research.

Uninterrupted data from our weather satellites is vital to protect the lives, property, and the commerce of our country. And yet, these major satellite weather programs are undergoing major changes and experiencing some serious problems. We're going to dig into those problems today.

The flagships of our satellite fleet are the GOES spacecraft that provide a continuous view of North America from fixed positions in geostationary orbits. GOES is approximately 22,000 miles out, so they stay in a given fixed position over the Earth at the same level of the Earth's rotation. The next-generation of GOES satellites, the R and S, have nearly doubled in cost from $6 billion to $11 billion, and a key sensor has been dropped in the effort to control the cost. The R satellite will now be the first GOES spacecraft in 30 years to fly without a dedicated sounder to measure the detailed profiles of the temperature and the moisture of the atmosphere. This is what we're facing. This Committee wants to know why, and what are we going to do about it.

While the GOES satellites have provided a macro view of our hemisphere from stationary points 22,000 miles out, our Polar-orbiting satellites, the ones that are going around the poles as the Earth rotates underneath, they make lower passes, about every 6 hours apart, to measure the atmospheric parameters, and they do it in a lot more detail. In 1993 the NOAA POES program—and that's Polar-orbiting Operational Environmental Satellite—was combined with the military satellite to create another acronym, NPOESS. And that's the National Polar-orbiting Operational Environmental Satellite Series. Its implementation has been a disaster. The cost of NPOESS has doubled, while the number of satellites has been cut by 50 percent; the number of instruments, cut by a third. Many of the canceled instruments measure atmospheric properties essential to understanding global climate change, and were to continue the long-term measurements that had been taken by earlier missions.

Without these sensors, this new generation, a combination of NOAA and NPOESS, will be unable to measure certain properties important to hurricane forecasting, including the sea-level winds and ocean altitudes.

The long and short of it is that NOAA has failed to capitalize on promising new technologies that have already been demonstrated in NASA programs.

QuikSCAT, a mission to measure sea-level winds, has proven quite useful, and it's now 4 or 5 years beyond its design life. It wasn't an operational satellite, it was a research satellite. While ACE, an acronym for the Advanced Composition Explorer, measures solar wind from its location in deep space, about a million miles from the sun. ACE provides, when there is a solar explosion emitting radiation, about an hour advance warning when that explosion occurs. Explosions that may disrupt our communications and our power grids, it may expose the astronauts in space to getting fried, and airline passengers, this is something that very few people know, flying over the poles where the magnetic fields of the Earth that protect us from that radiation are not present, it gives a 1-hour warning in order to respond. That satellite is 10 years old, with no replacement in the pipeline. A possible successor, another acronym, called DSCOVR, sits unused in a storage hangar at the Goddard Space Flight Center without the appropriated monies to fund a launch of that completed satellite.

Earlier this year, the National Academy of Sciences released its first Decadal Survey on Earth Science. Our Space Subcommittee, and this Committee, have held a hearing to determine the report's recommendations. We commended those recommendations from the National Academy of Sciences to NASA and to NOAA for their analysis. Well, today we expect to hear from those agencies on their progress toward incorporating the priorities of the survey in their mission plans.

It's essential that our weather and Earth Science programs remain in existence. Since they're considerably off track it's important that they receive adequate resources to keep the public informed when dangerous weather threatens.

All right, let me turn to our other colleague on the Committee. Senator Sununu?

STATEMENT OF HON. JOHN E. SUNUNU, U.S. SENATOR FROM NEW HAMPSHIRE

Senator SUNUNU. Thank you, Mr. Chairman.

I'm certainly interested in the hearing today, not necessarily in as direct and local way as you are. These weather satellites are obviously extremely important to Florida, and we, in New England, can appreciate that. But, as you mentioned in the later portion of your comments, they're part of the broader science mission, our country's science mission, that collects information and provides data regarding the Earth and climate, the oceans, but also provides observation and information regarding solar activity and observations in deep space. Whether it's NOAA or NASA or the National Science Foundation, that broader science mission is extremely important, and it's important that we allocate resources effectively across all of those areas.

As you know, in this Committee we've had hearings on the broader NASA science mission, and I have been consistently concerned by the crowding out of resources, the cost of our manned space effort, some of the long-term goals regarding the mission to Mars. It's really put a great strain on NASA's science budget, and that remains a concern. And I think we need to make sure we're allocating resources effectively, whether it's for that basic research or the applied science mission of these weather satellites.

They're all important, and I look forward to the testimony today from all of our witnesses, who are—I hope, will provide expertise as to what is working, what isn't working, and where our resources can be best applied to deal with the problems you talked about in your opening statement.

Thank you.

Senator NELSON. Thank you, Senator.

We're pleased to be joined by our colleague from the House of Representatives, Congressman Klein, who wishes to make a statement because of his involvement in this area.

So, Congressman, welcome, and thank you for coming today.

STATEMENT OF HON. RON KLEIN, U.S. REPRESENTATIVE FROM FLORIDA

Representative KLEIN. Thank you very much, Senator Nelson.

I would like to, certainly, thank you, Chairman Inouye and Vice Chairman Stevens, for holding this important hearing on an issue that is timely—unfortunately so, to be very frank. It's timely, because our Nation's weather satellites are critical tools that forecasters use during hurricane season, which we're in the middle of, to help locate and track hurricanes and other deadly storms. And the timing, of course, is also unfortunate, because one such satellite, the Quick Scatterometer, otherwise known as QuikSCAT, has been at the center of a controversy involving the National Hurricane Center and its former director Bill Proenza, who was dismissed from his duties a few days ago.

During many meetings with representatives from the National Oceanic and Atmospheric Administration, I've learned that NASA originally designed QuikSCAT to provide detailed snapshots of the winds swirling above the world's oceans. Launched in 1999, as Senator Nelson indicated, it was expected to last 3 to 5 years. Now in its eighth year of service, the satellite's demise is not a matter of "if," but "when." Compounding the problem is that there are no plans to launch a replacement satellite, and launching this satellite when it does get commissioned would take a minimum of 5, and maybe up to 7, years.

As a Member of Congress with over 75 miles of coastline in my district in Florida, I, along with others, have felt the responsibility to ask NOAA how we got to this point where a potentially valuable satellite is on its last legs, and why we did not have another one that was as good, if not better, on the launching pad, ready to go when QuikSCAT went down. I'm very pleased that my good friend Senator Nelson, Chairman Inouye, Vice Chairman Stevens, and other members of this Committee share that concern and are holding this hearing to examine QuikSCAT and the status of our Nation's other weather satellites.

I recently, Mr. Chairman, had the opportunity to visit the National Hurricane Center in Miami, where I asked several forecasters, independently, the value of QuikSCAT's data when it comes to detecting a hurricane. They showed me how the cone used to predict the path of a storm may be altered in a positive way and a more narrow way when QuikSCAT's data is incorporated, making the cone possibly more narrow and making the timing of landfall more precise. The loss of this data, whether minute or significant, could cause dire consequences to residents living in Florida and the over 50 percent of Americans who live within 50 miles of a coastline that could also be impacted by hurricanes and other major weather storms. Longer stretches of coastline and more coastal residents under evacuation warnings place considerable strain on the resources of coastal communities. The result is not merely academic. Even a minute or incremental loss of data can result in the loss of thousands of lives and billions of dollars in property damage, crippling local communities for decades to come. Having experienced the devastating hurricanes of 2004 and 2005, I would think our goal would be to alleviate the burden of local communities, not increase it. But with proper warning and preparation, we stand a better chance of avoiding such future catastrophes. And, of course, Mr. Chairman, this should be our goal.

This is not to say that QuikSCAT is the only tool used by the National Hurricane Center to locate and track hurricanes, or that the Center will be unable to perform its job. It has always been my understanding that QuikSCAT is one vital tool, among many, used at the National Hurricane Center to keep Americans safe. There are other weather satellites, such as the one that measures water temperature, which is important when gauging storm intensity, along with weather buoys, other types of equipment, and "Hurricane Hunter" aircraft.

To me, this is a very simple issue. Hurricane forecasters should have all the tools to help keep Americans safe. Any steps backward are simply not acceptable. If QuikSCAT provides important data for our weather forecasters, then Congress and NOAA should ensure that they not lose their ability to collect the data.

I also feel the need to dispel a concern voiced by some reports that a replacement satellite for QuikSCAT would come at the expense of "Hurricane Hunter" aircraft. Although I cannot speak for my fellow Members of the Congress, I can say that I would certainly oppose, and join others in opposing, any efforts to cut funding for the aircraft. Having toured NOAA's "Hurricane Hunter" aircraft in May here in Washington, and having met with NOAA and Air Force Reserve officials in the past, I learned, firsthand, the critical role in tracking storms that they play. Robbing Peter to pay Paul is not the case that we are going to follow with making sure the "Hurricane Hunter" aircraft are in place, or that we have an improved QuikSCAT satellite, if that's appropriate.

What should be the focus is finding more ways to keep the public safe. Although many of us have differing opinions on the role of the Federal Government, I think we can all agree that the public safety in the face of natural disasters like hurricanes, is a fundamental duty. And, unfortunately, the public's confidence has been shaken since Hurricane Andrew.

So, Mr. Chairman, I thank you for holding this hearing today and working with the House and the Senate in the overriding goal of making sure that all the tools and the environmental satellites that are all of critical importance are in place. I look forward to working with this distinguished Committee to ensure that Americans have the best and most up-to-date information to keep them safe during this hurricane season and future hurricane seasons.

Thank you very much, Mr. Chairman.

[The prepared statement of Representative Klein follows:]

PREPARED STATEMENT OF HON. RON KLEIN, U.S. REPRESENTATIVE FROM FLORIDA

I would like to thank Senator Nelson, Chairman Inouye, and Vice Chairman Stevens for holding this hearing today on an issue that is timely, unfortunately so, to be frank. It's timely because our Nation's weather satellites are critical tools that forecasters use during hurricane season to help locate and track hurricanes and other deadly storms, and the timing is unfortunate because one such satellite, the Quick Scatterometer (QuikSCAT), has been at the center of a controversy involving the National Hurricane Center and its former Director, Bill Proenza. Mr. Proenza who was dismissed from his duties at the National Hurricane Center just 2 days ago.

NASA originally designed QuikSCAT to provide detailed snapshots of the winds swirling above the world's oceans. Launched in 1999, it was expected to last three to 5 years. Now in its eighth year of service, the satellite's demise is not a matter of if, but when. Compounding the problem is that there are no plans to launch a replacement satellite, and launching this satellite would take a minimum of 5 years.

In March, Mr. Proenza alerted Members of Congress and the public about the need to replace QuikSCAT in an Associated Press article, claiming that both two-day and three-day forecasts would be affected. According to a study cited by Mr. Proenza, the two-day forecasts would be up to 10 percent less accurate, and three-day forecasts would be up to 16 percent less accurate. If valid, such seemingly small fluctuations in accuracy have great impact on hurricane forecasts.

I recently visited the National Hurricane Center, where several forecasters independently verified to me the value ofQuikSCAT's data when it comes to detecting a hurricane. They showed me how the cone used to predict the path of a storm is altered when QuikSCAT's data is incorporated, making the cone more narrow and making the timing more precise.

The loss of this data—whether minute or significant—could cause dire consequences to residents living in South Florida, and the over 50 percent of Americans who live within 50 miles of a coastline. Longer stretches of coastline and more coastal residents under evacuation warnings place considerable strain on the limited resources of coastal communities. After the devastating hurricanes of 2004 and 2005, I would think our goal should be to alleviate their burden, not increase it.

This is not to say that QuikSCAT is the only tool used by the National Hurricane Center to locate and track hurricanes, or that the Center will be unable to perform their job. It has always been my understanding that QuikSCATis one vital tool among many used at the National Hurricane Center to keep Americans safe. There are other weather satellites, such as one that measures water temperature, which is important when gauging storm intensity, along with weather buoys and hurricane hunter aircraft.

This last resource has interested me as well. In May, I met with Col. Michael Lograndе and Lt. Col. Lou Ortiz of the Air Force Reserve to discuss the mission and capability of the Hurricane Hunter aircraft. They informed me that the Air Force Reserve is installing a new system to their aircraft called a Stepped Frequency Microwave Radiometer (SFMR). This system will accurately measure sea surface wind speed and rainfall rates, thereby providing a more precise forecast of the severity and direction of a storm.

This report was encouraging and the bravery of the Reserve pilots flying into the heart of deadly storms impressive. But the fact remains that SFMR cannot measure wind direction like QuikSCAT, and only two of the ten Hurricane Hunter aircraft operated by the Air Force Reserve are equipped with the new equipment.

After carefully examining QuikSCAT's background and the Hurricane Center's other resources, I became concerned that the National Oceanic and Atmospheric Association (NOAA), which oversees the National Weather Service and the National Hurricane Center, lacked a coherent and decisive alternative plan when QuikSCAT inevitably fails. On May 17, I sent a letter to Vice Admiral (Ret.) Conrad Lautenbacher, Under Secretary of Commerce for Oceans and Atmosphere, asking him to provide me with both long and short-term alternative to address the inevitable loss of QuikSCAT.

To me, this is a very simple issue. Hurricane forecasters should have all the tools to help them keep Americans safe. Any steps backward is simply not acceptable. If QuikSCAT provides important data for our weather forecasters, then Congress and NOAA should ensure that they not lose their ability to collect the data.

I also feel the need to dispel a concern voiced by some reports that a replacement satellite for QuikSCAT would come at the expense of hurricane hunter aircraft. Although I cannot speak for my fellow Members of Congress, I can say that I would oppose any efforts to cut funding for the aircraft.

Having toured the aircraft in May and having met with NOAA and Air Force Reserve officials in the past, I learned firsthand their critical role in tracking storms nearing landfall. Robbing Peter to pay Paul, or in this case robbing hurricane hunter aircraft to pay for a new or improved QuikSCAT satellite, is unacceptable and should not be an option.

What should be the focus is finding more ways to keep the public safe. Although many of us have differing opinions on the role of the Federal Government, I think we all can agree that the public's safety in the face of natural disasters like hurricanes is a fundamental duty. Unfortunately, I think it's also safe to say that the public's confidence has been shaken since Hurricane Katrina.

It should be our goal to win back the public's trust by doing more, not less, in the way of storm tracking and prediction. That means providing the experts at the National Hurricane Center and the National Weather Service will all the tools and resources available and not sacrificing one for another. We have made great strides in hurricane research over the past twenty years, and it is important that we not take any steps backward. This hearing taking place today is an important first step in evaluating the status and usefulness of our Nation's weather and environmental satellites.

I applaud Senator Nelson, Chairman Inouye and Vice Chair Stevens and this committee for their leadership, and I look forward to working with them to ensure that Americans have the best and most up-to-date information to keep them safe. Thank you.

Senator NELSON. Thank you, Congressman. And the testimony from our experts will bring out, later on, that, if QuikSCAT goes on the blink, there is a European satellite that has some ability to help us, although not as extensive; that the aircraft—there are two research aircraft in NOAA that have a Doppler radar that can gather—that fly into the hurricane, that can gather some of this information; and that there is a fleet of Air Force aircraft, C–130s, that have a lesser technology, called "smurf" on it that is being installed no a series of these aircraft. And the question is, should the Doppler radar be put on those, later on? So, those are some of the things that we'll be discussing here today in this testimony, and I thank you for coming in.

And if I may call up the panel, please.

[Pause.]

Senator NELSON. We are pleased to have Ms. Mary Ellen Kicza, the Assistant Administrator for Satellite and Information Services in NOAA; Dr. Michael Freilich, Director of the Earth Science Division of the Science Mission Directorate of NASA; Mr. David Powner, Director of the Information Technology Management Issues of the GAO; Dr. Greg Holland, Director of the Mesoscale and Microscale Meteorology Division of Earth and Sun Systems Laboratory, in the National Center for Atmospheric Research; and Dr. Antonio Busalacchi, Professor and Director of the Earth System Science Interdisciplinary Center at the University of Maryland.

Now, if we can't figure it out with all of you high-powered folks, I'm not sure we can figure it out. So, let's see if we can.

And we'll go in the order in which I introduced you. And your written testimony will be put in as part of the record. And I don't want you reading it to the Committee, I want you—I mean, we can read it for ourselves. What I want you to do is talk to us.

So, Mrs. Kicza, we'll start with you, as an Assistant Administrator of the National Oceanic and Atmospheric Administration, NOAA. Welcome.

STATEMENT OF MARY ELLEN KICZA, ASSISTANT ADMINISTRATOR FOR SATELLITE AND INFORMATION SERVICES, NOAA, DEPARMENT OF COMMERCE

Ms. KICZA. Thank you, Mr. Chairman.

I appreciate the opportunity to discuss NOAA's environmental satellite programs, and to highlight their importance to the Nation, its forecasting and warning capabilities, and to our climate mission, as well.

Satellites provide an unparalleled capability to take images and precise measurements of many aspects of vast areas of land, sea, and air. Their data are essential in our ability to provide and understand and predict changes in the Earth's environment.

We currently have two major satellite programs within NOAA: the geostationary satellites, known as GOES, and the Polar-orbiting satellites, known as POES. I'm pleased to inform the Committee that NOAA's fleet operational GOES and POES satellites are in good health and they're closely monitoring the oceans and atmosphere for everyday weather forecasting, including any hint of tropical storm activity. As you said, my written testimony has been submitted.

We're currently developing our next generation of geostationary and polar satellites. As you had indicated, in 1994 the Federal Government decided to merge the polar satellite programs of the Department of Defense and NOAA into one program, with NASA also providing critical technical support and risk-reduction activities. This new program, called NPOESS, is one of the most complex environmental operational satellite systems ever developed. And recently, under the Department of Defense Nunn-McCurdy process, the NPOESS program was restructured, resulting in two fewer satellites, fewer sensors, and less risk to the program. The first NPOESS satellite is scheduled for 2013 launch, and the system will provide operational coverage through 2026.

While the main instruments on NPOESS will provide about 50 percent of the desired climate-related observations and data, a number of secondary climate sensors were removed because of cost and complexity, and NOAA and NASA are providing Fiscal Year 2007 funding to restore one of those sensors to the NPOESS risk-reduction satellite, the NPP satellite managed by NASA.

The White House has asked NASA and NOAA to work together to identify what could be done to assure continuity of key climate measurements. We provided a preliminary report to OSTP in January of 2007, and an update is due this summer. We've also asked the National Academy of Sciences, which provided us the recent Decadal Survey, to provide input as we develop the path forward.

We are also in the early stages of the acquisition process for a significantly advanced capability in the next generation of GOES satellite, called GOES–R. We're applying the lessons learned from the NPOESS program, as well as the lessons learned from other satellite programs, and, as a result, have made significant changes in this program, both in terms of program management and oversight, including the budgeting of more money for the program. GOES–R is scheduled for a late 2014 launch and will provide operational coverage through 2026.

I do want to talk about the QuikSCAT satellite, but I also want to explain the system that NOAA uses to monitor hurricanes.

Over the open oceans, continual images from our GOES satellites are the first reliable indicators of any storms or inclement weather. GOES provides near-real-time critical data to help our forecasters determine a storm's location, its size, its intensity, and its movement. These satellites are so important that we always keep a spare in orbit, and, as tropical systems come closer to land, information from NOAA and DOD aircraft and ocean buoys provide real-time direct measurements of that storm. Within 200 miles of the coast, ground-based radars are used to track the storm, and computer models are used to predict storm track and intensity. These require extensive amounts of data, and these are mostly provided by NOAA and NASA and DOD polar satellites. Together, these systems provide the forecasters with layers of information that are critical to help them make their forecast.

QuikSCAT is a NASA satellite. It's a research satellite that's demonstrated the ability to measure ocean wind speed and direction from space. And, according to forecasters at the National Hurricane Center, QuikSCAT has become an important tool, especially for estimating the intensity and size of tropical storms and other strong marine storms.

In most cases, however, QuikSCAT has little or no demonstrated impact on hurricane intensity forecasts, because it usually cannot distinguish winds above 75 miles per hour in a hurricane, due to the effects of heavy rains.

Track forecasts for U.S. landfalling hurricanes will not be significantly degraded if QuikSCAT were to fail. The hurricane forecasters, instead, rely heavily on the real-time data provided by the reconnaissance aircraft which measures the air column and other characteristics of the storm that are critical to forecast—track forecasts. Any degradation would be most noticeable for open ocean storms, when aircraft data are not available.

Although QuikSCAT is past its design life, as you know, NASA has indicated that QuikSCAT currently appears healthy and has fuel to last until 2011. If QuikSCAT were to fail today, the National Hurricane Center would still receive ocean wind speed and direction from space. We're now receiving data from a new instrument aboard a European satellite. This is call the ASCAT instrument. It has similar technology to QuikSCAT.

We acknowledge that ASCAT will not provide the same quality of data as QuikSCAT, especially in terms of coverage and resolution; however, we are going to——

Senator NELSON. We need you to wrap up.

Ms. KICZA. OK.

Senator NELSON. I should have said, at the outset, I'm going to give each of you 5 minutes. We've got——

Ms. KICZA. Sure.

Senator NELSON.—a big panel. So, instead of repeating a lot of what's been said, just say what you want to say within the 5 minutes——

Ms. KICZA. OK.

Senator NELSON.—and then we'll get into extensive questions.

Ms. KICZA. OK. What I'd like to close with is, we've recently held a workshop at the National Hurricane Center. Our hurricane forecasters have indicated the value of QuikSCAT, and have also indicated where we need to improve QuikSCAT in a replacement satellite, and we're working very closely with the forecast center and with NASA to examine ways to do that.

I thank you for the time.

[The prepared statement of Ms. Kicza follows:]

PREPARED STATEMENT OF MARY ELLEN KICZA, ASSISTANT ADMINISTRATOR, SATELLITE AND INFORMATION SERVICES, NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE, NOAA, U.S. DEPARTMENT OF COMMERCE

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).

What Are GOES Satellites?

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.

What Are POES Satellites?

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 Academies' 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 canceled. 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/fcmp36.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 10 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 8 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 1,000 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 65 mph, 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 5 years, it is now in its eighth year. The primary transmitter lasted 7 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.

Senator NELSON. Thank you, Ms. Kicza.

Dr. Freilich?

STATEMENT OF DR. MICHAEL H. FREILICH, DIRECTOR, EARTH SCIENCE DIVISION, SCIENCE MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. FREILICH. Thank you very much.

Mr. Chairman and members of the Committee, I welcome this opportunity to discuss Earth Science and NASA's collaborations with NOAA.

Data from NASA research satellites improve NOAA's forecasts. Accurate NOAA operational products are used in NASA research to advance scientific understanding. Thus, there are strong reasons for us to collaborate; and collaborate, we do.

We work in many ways to try to transition NASA-proven measurements and capabilities to operations. Among these are NOAA researchers that often serve on NASA mission science teams; the NASA–NOAA Joint Working Group provides strategic guidance on transition and wider use of technologies, missions, and data. Committees such as the Interagency Altimeter Working Group examine technical and programmatic issues for specific measurements. NASA, as the Nation's civilian space agency, serves in development and acquisition roles, with reimbursable funding from NOAA. NASA will continue to serve in that capacity for the space-borne segments of the GOES–R missions that Ms. Kicza discussed.

Over the past year, we've collaborated very productively to address the challenges of NPOESS and the Decadal Survey. Nunn-McCurdy focused NPOESS on weather forecasting, as you pointed out, and the loss of NPOESS climate sensors affects researchers and both agencies.

A potentially less capable microwave instrument on NPOESS could reduce our ability to get measurements of all weather sea-surface temperature and surface wind direction. Together, NASA and NOAA quantified the impacts and developed recovery priorities, as Ms. Kicza mentioned. We're now jointly investigating mitigation scenarios, examining climate freeflyers, as well as mounting instruments on NPOESS.

In April, NASA and NOAA jointly funded the restoration of the OMPS Limb ozone profiling capability onto the NPOESS Preparatory Program Spacecraft.

Again, as both of you have mentioned, NASA and NOAA jointly commissioned and participated in the June NRC community workshop to examine the scientific impacts of the NPOESS changes and to consider recovery scenarios.

Our agency studies, along with the workshop inputs, are being used to inform the development of the Administration's FY09 budget request. Let me briefly discuss NPP, one of the two space-borne elements of NPOESS.

NPP, the NPOESS Preparatory Program, aims to continue selected climate time series initiated by the NASA Earth Observing System, especially the MODIS data products that should be produced by the Visible Infrared Image Radiometer Suite, called VIIRS. Flight on NPP also reduces risk for the operational NPOESS sensors. For NPP, NASA is responsible for the spacecraft plus the launch vehicle, spacecraft integration and test, and provision of one instrument, the Advanced Technology Microwave Sounder, for all-weather global temperature and humidity profiles.

Indeed, that instrument was delivered in 2005, and is integrated onto the NPP spacecraft.

NOAA and DOD are responsible for NPP on-orbit mission operations, the ground system, the OMPS ozone suite, VIIRS, and the Cross-track Infrared Sounder instruments. Both VIIRS and the infrared sounder are facing significant development challenges. VIIRS measurements may be substantially less accurate than those obtained presently by MODIS. The NASA NPP science team is working closely with NOAA and with the NPOESS project office to evaluate the effects of these possible shortfalls on NASA's Earth Science objectives. The present VIIRS flight model probably will not support NASA ocean color, and may not support aerosol research unless some changes are made.

Let me say a few words about QuikSCAT now. QuikSCAT is a highly successful NASA research mission, as you've pointed out, measuring ocean wind speed and direction with unprecedented accuracy, spatial resolution, and coverage. QuikSCAT data have been crucial for advancing research into ocean circulation, air-sea interactions, and marine meteorology, and they've been used routinely by NOAA and other international meteorological organizations since early 2002.

As Ms. Kicza pointed out, QuikSCAT is old, but it is in decent shape. The recent NASA senior review recommended that QuikSCAT operations be extended at least through 2011, based on the present spacecraft trends and its high value for research and operations. Because scatterometry is a mature technique with operational utility, the Decadal Survey recommended that NOAA continue QuikSCAT, the time series, and fly an enhanced so-called XOVWM scatterometer, starting in the 2013 time frame. Funded by NOAA, NASA's Jet Propulsion Laboratory is conducting detailed technical and cost studies of XOVWM and related surface wind measurement missions.

So, in conclusion, NASA and NOAA are collaborating, and we're collaborating well. NASA's Earth Science research objectives and NOAA's prediction objectives both require reliable, accurate operational satellite systems. NOAA's prediction tasks and NASA's science investigations both require improved measurements. Transitioning from research to operations is challenging, but the many joint efforts of NOAA and NASA are resulting in effective solutions for the country.

Thank you.

[The prepared statement of Dr. Freilich follows:]

PREPARED STATEMENT OF DR. MICHAEL H. FREILICH, DIRECTOR, EARTH SCIENCE DIVISION, SCIENCE MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and members of the Committee, thank you for the opportunity to appear today to discuss how NASA partners with the National Oceanic and Atmospheric Administration (NOAA). As the Director of the Earth Science Division, one of four science divisions that make up the NASA Science Mission Directorate, I welcome this opportunity to discuss the important area of Earth Science and our collaborations with NOAA. This discussion is especially timely in light of the recently released National Research Council's (NRC's) Earth Science Decadal Survey, which outlines specific scientific priorities for both NASA and NOAA.

Much of the science community's present state of knowledge about global change—including many of the measurements and a significant fraction of the analyses which serve as the foundation for the recent report of the Intergovernmental Panel on Climate Change (IPCC)—is derived from NASA's Earth Science program. Using data from Earth observing satellites, NASA-supported researchers are monitoring ice cover and ice sheet motions in the Arctic and the Antarctic; quantifying the short-term and long-term changes to the Earth's protective shield of stratospheric ozone, including the positive impacts of the Montreal protocols; discovering robust relationships between increasing upper ocean temperature and decreasing primary production from the phytoplankton that form the base of the oceans' food chain; and, using a fleet of satellites flying in formation (the "A-Train"), making unique, global, near-simultaneous measurements of aerosols, clouds, radiative fluxes, and temperature and relative humidity profiles.

NASA researchers codify our improving understanding of Earth processes in sophisticated weather and climate models which can then be used to predict natural and human-caused environmental changes. Researchers often analyze the gridded "nowcast" output from these numerical prediction models as proxies for actual data, since the model predictions incorporate all available observations. Improved operational models thus aid the research endeavor as well as yield improved forecasts.

There is thus a strong synergy between our Nation's research satellites and our operational spaceborne systems. Near-real-time measurements from NASA research missions such as the Tropical Rainfall Measuring Mission (TRMM), the Quick Scatterometer (QuikSCAT), the Atmospheric Infrared Sounder (AIRS) instrument on the Aqua mission, and others are used routinely by NOAA and other U.S. and international agencies to improve weather and extreme event forecasts. Similarly, high quality measurements obtained by Department of Defense (DOD) and NOAA operational weather satellites provide essential context for the scientific analyses of the NASA research mission data. As the Nation's civil space agency, NASA demonstrates and refines new measurement technologies and then works closely with NOAA in an effort to transition these research capabilities to long-term operations.

NASA joins with other Federal agencies to support an integrated Federal program of climate research. Consistent with the NASA Space Act of 1958, as amended, and the NASA Authorization Act of 2005 (P.L. 109–155), NASA's role within the broader Federal program is guided by the U.S. National Space Policy, authorized by the President on August 31, 2006. NASA's contribution to the U.S. Climate Change Science Program (CCSP) is unchanged from the FY 2007 to FY 2008 budget request, and remains the largest single contribution to the Program. NASA, NOAA, and the U.S. Geological Survey (USGS) jointly requested that the National Research Council conduct a Decadal Survey for Earth Science. The recently completed survey outlines specific scientific priorities for both NASA and NOAA.

NASA works closely with NOAA, in particular, in an effort to transition mature and proven measurement capabilities to long-term operations. In addition to the NASA–NOAA Joint Working Group (established by the NASA Authorization Act of 2005) which has addressed a wide range of issues related to transition of measurements and data products, the two agencies also meet regularly in more focused *fora* such as the Interagency Altimeter Group (NASA, NOAA, Navy). Since early summer of 2006, NASA and NOAA have worked intensely with each other and with the Office of Science and Technology Policy (OSTP) to document the impacts of, and develop mitigation strategies for, changes to the National Polar-orbiting Operational Environmental Satellite System (NPOESS) made in relation to Nunn-McCurdy recertification of the program.

Below, as requested, we address status and collaborative activities related to the three missions identified as of particular interest to the Committee: NPOESS, Geostationary Operational Environmental Satellites (GOES)–R, and QuikSCAT.

NPOESS

NPOESS was established in 1994 by Presidential Decision Directive to combine the previously separate operational, Earth-observing satellite systems operated by DOD (the Defense Meteorological Satellite Program, (DMSP)) and NOAA (the Polar-orbiting Operational Environmental Satellite program, (POES)). The primary objective of both DMSP and POES was to collect measurements in support of weather and environmental forecasting. However, as noted above, in many cases high-quality, well-validated, operational data products acquired by these systems are used extensively by the Earth Science research community as well.

The overall NPOESS program is composed of two spaceborne elements: the NPOESS Preparatory Project (NPP), presently scheduled for launch in September 2009; and, the NPOESS Operational Constellation (NPOESS), composed of a series of four spacecraft, flying two at a time in coordinated morning and afternoon orbits (the launch of the first of these spacecraft currently is scheduled for 2013).

NPP has two basic aims: (1) to continue the time series of selected climate science measurements initiated by the NASA Earth Observing System spacecraft—in particular, the suite of data products generated by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on the Terra and Aqua missions and planned to be produced by the Visible/Infrared Imager/Radiometer Suite (VIIRS) on NPP and NPOESS; and (2) to serve as risk reduction for the future operational NPOESS sensors. NASA, NOAA, and DOD all participate essentially equally in the NPP mission. NASA is responsible for development of the spacecraft bus, launch vehicle, integration and test of the instruments on the spacecraft, and provision of the Advanced Technology Microwave Sounder (ATMS) instrument that will provide all-weather, global temperature and humidity profiles. Through the NPOESS Integrated Program Office (IPO), NOAA and DOD are responsible for development and provision of the VIIRS, Cross-Track Infrared Sounder (CrIS), and Ozone Mapping and Profiling Suite (OMPS) instruments; on-orbit mission operations; and the ground system for the generation of operational products.

The NASA-supplied ATMS instrument was delivered in October 2005 and is presently integrated onto the NPP spacecraft. In response to the removal of the OMPS-Limb profiling capability from both NPP and NPOESS via the Nunn-McCurdy process, NASA and NOAA provided resources from core programs to allow the OMPS-Limb instrument to be re-manifested on NPP in April 2007, thus restoring both the nadir total ozone measurements and the limb profiling capabilities for NPP. This first-ever combination of total and vertically resolved ozone measurements will provide scientists unique insight into the dynamical and chemical processes that regulate atmospheric composition.

Both the IPO-developed VIIRS and CrIS instruments are presenting significant development challenges. The first CrIS flight unit suffered a structural failure during testing in October 2006, requiring structural design changes and delaying delivery of a flight unit for integration onto the NPP satellite until March 2008. Initial testing is indicating that the VIIRS measurements may be less accurate than those of the present NASA MODIS instruments. The NASA NPP Science Team is working closely with NOAA and IPO personnel to evaluate the impacts of these instrument performance shortfalls on NASA's Earth system science objectives. Although these analyses are in an early stage, it is likely that the present VIIRS flight model for NPP will lack the accuracy and precision to support NASA research related to ocean color and aerosols unless significant resources are applied to implement sensor changes.

The future operational NPOESS system was significantly restructured in June 2006 as a result of the Nunn-McCurdy recertification. The original series of two, 3-satellite constellations was downsized to two, 2-satellite constellations with measurements from the mid-morning orbit to be supplied by the European EUMETSAT MetOp missions. Furthermore, the Nunn-McCurdy process focused NPOESS on its core weather forecasting objectives, removing several important climate sensors and degrading the performance of certain other instruments. The recertified NPOESS does not include total solar irradiance and Earth radiation budget instruments, an altimeter to make accurate global measurements of sea level, and the OMPS-Limb capability to measure vertical profiles of tropospheric and stratospheric ozone. In addition, the Conically Scanning Microwave Imager/Sounder (CMIS) was replaced by a Microwave Imaging Sensor (MIS) whose detailed capabilities have not yet been defined. From the standpoint of addressing NASA science objectives, this change from CMIS to MIS may substantially reduce our ability to acquire all-weather sea-surface temperature measurements as well as information on surface wind direction and speed over the ice-free oceans.

The Decadal Survey, the U.S. Climate Change Science Program, and NASA's own planning in Earth Science all assume the presence of an operational system of environmental monitoring satellites that can make climate-quality measurements. Indeed, that is a major reason why NASA, along with NOAA and the Air Force, is a member of the NPOESS governing body. As the Decadal Survey committee was finalizing its notional mission set and sequence, the full impact of the removal of the climate sensors from the NPOESS program was just coming to light. Since last summer, NASA has been working closely with NOAA, OSTP, and the scientific research community to understand and rank the impacts of these programmatic perturbations and to develop realistic mitigation scenarios for the most important measurements. In addition to our agency-based technical evaluations and preliminary mitigation strategy designs, NASA and NOAA commissioned, supported, and participated in a National Research Council workshop held June 19–21, 2007, after several weeks of community planning (including participation by members of the original Decadal Survey committee). The workshop was chartered to examine the scientific and research-focused impacts of the programmatic changes to NPOESS and to consider various potential recovery scenarios. NASA and NOAA anticipate receiving the workshop report later this summer.

GOES-R

NASA has historically managed the development and launch of the Geostationary Operational Environmental Satellite (GOES) system under a reimbursable work agreement with and in support of NOAA. Two legacy GOES spacecraft are presently built and in ground storage. Work has begun on design and development for the next-generation GOES series known as "GOES-R." These spacecraft will fly an advanced imager capable of simultaneous focused high resolution measurement and full-field low resolution acquisition. The GOES-R instrument complement will also include a first-ever lightning sensor capable of operating from geostationary orbit, as well as a complement of space weather instrumentation. NASA will manage the spaceborne hardware portion of GOES-R for NOAA as a reimbursable project through a program office at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

QuikSCAT

Launched on June 19, 1999, QuikSCAT carries as its only science instrument an active radar scatterometer instrument that provides ocean surface vector wind data under nearly all-weather conditions. QuikSCAT's primary mission is scientific research, but from the start NASA and NOAA recognized the value of the ocean surface vector wind data for operational weather and marine hazard forecasting. Prior to launch, NASA and NOAA collaborated to assure that QuikSCAT data could be downlinked to Earth and processed sufficiently rapidly to be useful to NOAA for weather forecasting. The NASA–NOAA collaboration included both use of distributed ground telemetry stations, and development by NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California of specific computer algorithms and data formats to allow rapid processing by NOAA and efficient use of the QuikSCAT wind measurements in NOAA weather forecasting models at the National Weather Service (NWS) National Centers for Environmental Prediction and NWS Weather Forecast Offices having coastal responsibilities.

QuikSCAT has been on orbit for 8 years, 5 years beyond its original three-year baseline mission. Although some redundant subsystems have failed or have suffered degradation (in particular the transmitter which allows the satellite's measurements to be sent to the ground for processing), backup systems are working well, and the data remain of high quality. The satellite is clearly aging, but shows no indication of imminent failure.

NASA has neither a scientific mandate nor any near-term plan to replace QuikSCAT's active radar scatterometry measurements. The Decadal Survey identifies a sea surface wind vector scatterometry mission, the Extended Ocean Vector Winds Mission (XOVWM), as a mid-decadal priority for NOAA. NASA continues to work closely with NOAA to support an efficient transition of ocean surface vector wind measurements from research to operations. NOAA is evaluating a number of options for addressing its ocean vector wind requirements and has taken a number of steps including funding a JPL study of QuikSCAT replacement options. The results of this study are due in January 2008 and will help NOAA determine the best way to provide accurate, extensive, all-weather, surface wind speed and direction measurements over the global oceans.

Conclusion

In summary, NASA and NOAA have an ongoing and growing collaborative relationship. The two agencies have complementary programmatic expertise and objectives. Both NASA'S research to advance Earth system science and NOAA's prediction objectives require an operational satellite system that can reliably acquire accurate measurements. Both NOAA's prediction tasks and NASA's science investigations require the development and on-orbit demonstration of new measurement techniques to improve the scope and quality of measurements. Transitioning from research to operations is challenging, but the ongoing frequent communication between NOAA and NASA at various technical and management levels, and in a variety of fora, will result in effective solutions for the Nation.

I welcome your questions on NASA's Earth Science program and its relationship to NOAA.

Senator NELSON. Thank you, Dr. Freilich.

We want to hear GAO's point of view. Mr. Powner?

STATEMENT OF DAVID A. POWNER, DIRECTOR, INFORMATION TECHNOLOGY MANAGEMENT ISSUES, GAO

Mr. POWNER. Chairman Nelson, and members of the Committee, GAO has, for the past several years, monitored the NPOESS and GOES–R programs. As you mentioned, Mr. Chairman, these environmental satellite programs are essential to monitoring and having the continuity of critical weather data through nearly 2030, and they play a key role in hurricane forecasting. NPOESS is well into its acquisition cycle, and its life-cycle costs will now exceed $12 billion. GOES–R is early in its acquisition cycle, as the prime contracts are expected to be awarded next year.

Today's request, I will provide a brief status of each, highlight key challenges, and discuss recommendations, going forward.

First, NPOESS: Over the past several years, NPOESS has experienced significant cost overruns and delays due to sensor development problems, poor contractor performance and program management, and inadequate executive-level involvement that led to a June 2006 decision to restructure the program. This decision decreased the complexity of the program by reducing a number of key sensors, increased the estimated costs by $4 billion, and delayed the launches of the first satellites. Since then, the NPOESS program has made progress; however, we remain concerned about its remaining risks, the interagency management of this tri-agency program, and a premature rotation of the program's key executive.

Before expanding on each of these concerns, the NPOESS management team deserves credit for recently improving program oversight and holding NPOESS's contractors more accountable. Despite these efforts, the NPOESS program is still fraught with risks. Our latest report, issued last month, highlights the major technical risks with two critical sensors known as VIIRS and CrIS. Both sensors remain high risk. We also remain concerned about the interagency coordination and the commitment required to effectively manage this tri-agency program. The tri-agency management approach has, and continues to be, a contributing factor to NPOESS's problems.

We also remain concerned about DOD's plan to reassign the program executive officer this month. Having a seasoned PEO has streamlined executive decisionmaking and has resulted in more aggressive risk management for the program. The PEO has only been in this position for 20 months. Given that the program is still being restructured, the significant challenges, and the fact that a replacement has yet to be named, such a move adds unnecessary risk to an already risky program.

Mr. Chairman, despite some progress, NPOESS is far from being out of the woods. Moving forward, it is essential that the program aggressively manage its remaining developmental risks, especially those associated with its high-risk sensors, and quickly manage the transition and knowledge transfer associated with the risky decision to reassign the PEO. Failing to address these and other concerns will lead to additional cost increases and schedule delays.

Turning to GOES–R: As originally planned, this acquisition was to consist of four satellites that would each contain five sensors that are to significantly increase the amount and precision of environmental data. NOAA had three vendors working on preliminary designs, and plans to award prime contracts next summer. The first GOES–R satellite is expected to be launched in 2014.

Regarding costs, Mr. Chairman, last year the life-cycle cost was reported to be $6.2 billion for four satellites. During our review at that time, we learned that the costs could be in the $11–$12 billion range, double the original estimate. This led the agency to reconsider the program and re-scope it, reducing the complexity by reducing the number of satellites from four to two, and canceling a technically complex sensor, referred to as HES. Currently, the overall scope and cost of the program is in flux, as the number of satellites is being reconsidered, as are other requirements and capabilities.

Our review also showed that NOAA's management team is taking into consideration lessons learned from the recent NPOESS and GOES–R programs, but that even more attention to these past problems is needed.

Past problems experienced with these acquisitions include poor cost and schedule estimates, technical complexity that exceeds the contractor's and government's abilities to deliver, insufficient contractor oversight, and ineffective executive involvement.

NOAA has plans to address many of these past problems; however, additional actions are needed to better position NOAA for success, including establishing processes to ensure that an accurate independent cost estimate is developed, and having an independent review team assess the adequacy of key resources needed to oversee the contractor's performance.

In summary, Mr. Chairman, NOAA's attention to both NPOESS's challenges and incorporating lessons learned from past satellite acquisitions on GOES–R is commendable, but continued attention to these acquisition risks is essential to maintain continuity of our Nation's warning and forecasting operations.

This concludes my statement. I would be pleased to respond to questions.

[The prepared statement of Mr. Powner follows:]

PREPARED STATEMENT OF DAVID A. POWNER, DIRECTOR,
INFORMATION TECHNOLOGY MANAGEMENT ISSUES, GAO

Mr. Chairman and members of the Committee:

We appreciate the opportunity to participate in today's hearing to discuss our work on two major operational environmental satellite programs: the $12.5 billion National Polar-orbiting Operational Environmental Satellite System (NPOESS) program and the planned $7 billion Geostationary Operational Environmental Satellites-R (GOES-R) program.

Operational 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 oceans, and the environment. NPOESS—a tri-agency program managed by the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), the Department of Defense/U.S. Air Force, and the National Aeronautics and Space Administration (NASA)—is expected to be a state-of-the-art, environment monitoring satellite system that will replace two existing polar-orbiting environmental satellite systems. The GOES-R series, managed by NOAA with assistance from NASA, is to replace the current series of satellites which will likely begin to reach the end of their useful lives in approximately 2012. This new series is expected to mark the first major technological advance in GOES instrumentation since 1994. The NPOESS and GOES-R programs are considered critical to the United States' ability to maintain the continuity of data required for weather forecasting (including severe weather events such as hurricanes) and global climate monitoring through the years 2026 and 2028 respectively.

At your request, we are summarizing the results of our previous work on operational environmental satellite programs, including NPOESS and the GOES-R program.[1] In preparing this testimony, we relied on the work supporting our prior reports. Those reports contain detailed overviews of our scope and methodology. All of the work on which this testimony is based was performed in accordance with generally accepted government auditing standards.

Results in Brief

NOAA is involved in two major satellite acquisition programs, NPOESS and GOES-R, and both are costly, technically complex, and critically important to weather forecasting and climate monitoring. NPOESS was originally estimated to cost about $6.5 billion over the 24-year life of the program, with its first satellite launch planned for April 2009. Over the last few years, NPOESS experienced escalating costs, schedule delays, and technical difficulties. These factors led to a June 2006 decision to restructure the program thereby decreasing the program's complexity by reducing the number of sensors and satellites, increasing its estimated cost to $12.5 billion, and delaying the launches of the first two satellites to 2013 and 2016, respectively. Since that time, the program office has made progress in restructuring the satellite acquisition and establishing an effective management structure; however, important tasks remain to be done and significant risks remain. Specifically, key acquisition documents that were originally due in September 2006 are still not completed, the program office is not yet fully staffed, and the early July turnover of the program executive officer increases the program's risk. Additionally, technical risks remain in the development of key system sensors and the ground-based data processing system. In April 2007, we made recommendations to complete key acquisition documents, increase staffing at the program office, and delay reassignment of the program executive. Implementation of these recommendations should reduce risk on this critical acquisition.

The GOES-R acquisition, originally estimated to cost $6.2 billion and scheduled to have the first satellite ready for launch in 2012, is at a much earlier stage in its life cycle than NPOESS. In September 2006, we reported that NOAA had issued contracts for the preliminary design of the overall GOES-R system to three vendors and expected to award a contract to one of these vendors in August 2007 to develop the satellites. However, analyses of GOES-R cost—which in May 2006 was estimated to reach $11.4 billion—led the agency, in September 2006, to reduce the program's scope from four to two satellites and to discontinue one of the critical sensors. Program officials now report that they are reevaluating that decision and may further revise the scope and requirements of the program in coming months. We also reported that NOAA had taken steps to implement lessons learned from past satellite programs, but more remained to be done to ensure sound cost estimates and adequate system engineering capabilities. We made recommendations to the program to improve its capabilities for managing this program and agency officials agreed with these recommendations and initiated efforts to implement them. We currently have work under way to evaluate GOES-R risks and challenges.

Background

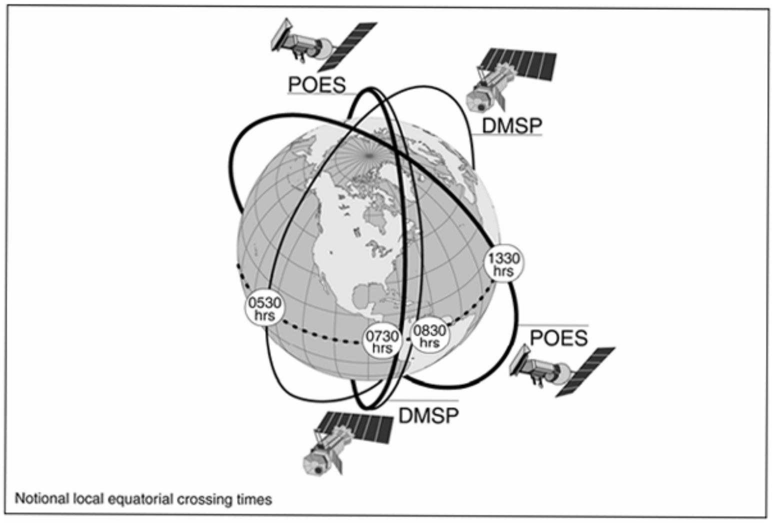
Since the 1960s, geostationary and polar-orbiting operational environmental satellites have been used by the United States to provide meteorological data for weather observation, research, and forecasting. NOAA's National Environmental Satellite Data and Information Service (NESDIS) is responsible for managing the existing civilian geostationary and polar-orbiting satellite systems as two separate programs, called the Geostationary Operational Environmental Satellites and the Polar Operational Environmental Satellites (POES), respectively. The Air Force is responsible for operating a second polar-orbiting environmental satellite system—the Defense Meteorological Satellite Program (DMSP).

Polar-orbiting environmental satellites obtain environmental data that are processed to provide graphical weather images and specialized weather products. These satellite data are also the predominant input to numerical weather prediction models, which are a primary tool for forecasting weather 3 or more days in advance—including forecasting the path and intensity of hurricanes. The weather products

[1] GAO, *Polar-orbiting Operational Environmental Satellites: Restructuring is Under Way, but Technical Challenges and Risks Remain,* GAO–07–498 (Washington, D.C.: April 27, 2007); *Polar-orbiting Operational Environmental Satellites: Restructuring is Under Way, but Challenges and Risks Remain,* GAO–07–910T (Washington, D.C.: June 7, 2007); *Geostationary Operational Environmental Satellites: Steps Remain in Incorporating Lessons Learned from Other Satellite Programs,* GAO–06–993 (Washington, D.C.: Sept. 6, 2006); and *Geostationary Operational Environmental Satellites: Additional Action Needed to Incorporate Lessons Learned from Other Satellite Programs,* GAO–06–1129T (Washington, D.C.: Sept. 29, 2006).

and models are used to predict the potential impact of severe weather so that communities and emergency managers can help prevent and mitigate their effects. Polar satellites also provide data used to monitor environmental phenomena, such as ozone depletion and drought conditions, as well as data sets that are used by researchers for a variety of studies such as climate monitoring. Figure 1 illustrates the current operational polar satellite configuration consisting of two POES and two DMSP satellites.

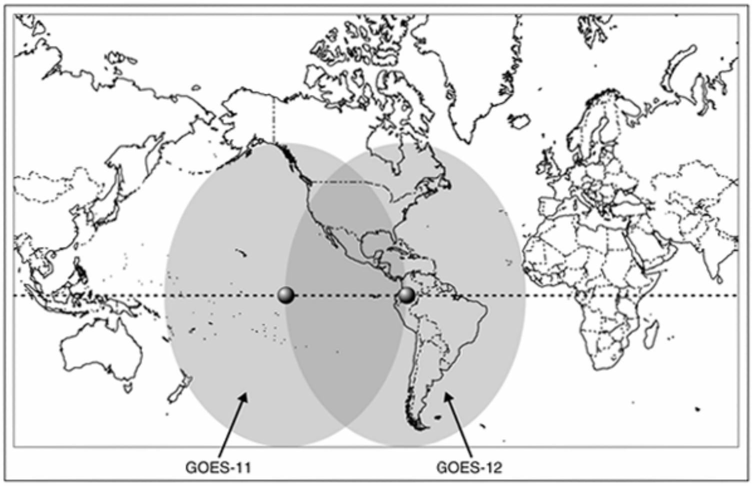
Figure 1: Configuration of Operational Polar Satellites



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

Unlike polar-orbiting satellites, which constantly circle the Earth in a relatively low polar orbit, geostationary satellites can maintain a constant view of the Rarth from a high orbit of about 22,300 miles in space. NOAA operates GOES as a two-satellite system that is primarily focused on the United States (see fig. 2). These satellites are uniquely positioned to provide timely environmental data to meteorologists and their audiences on the Earth's atmosphere, its surface, cloud cover, and the space environment. They also observe the development of hazardous weather, such as hurricanes and severe thunderstorms, and track their movement and intensity to reduce or avoid major losses of property and life. Furthermore, the satellites' ability to provide broad, continuously updated coverage of atmospheric conditions over land and oceans is important to NOAA's weather forecasting operations.

Figure 2: Approximate GOES Geographic Coverage



Sources: NOAA (data), MapArt (map).

Satellite Acquisition Programs Often Experience Technical Problems, Cost Overruns, and Schedule Delays

Satellite acquisition programs are often technically complex and risky undertakings, and as a result, they often experience technical problems, cost overruns, and schedule delays. We and others have reported on a historical pattern of repeated missteps in the procurement of major satellite systems, including NPOESS, the GOES I–M series, the Air Force's Space Based Infrared System High Program (SBIRS-High), and the Air Force's Advanced Extremely High Frequency Satellite System (AEHF).[2] Table 1 lists key problems experienced with these programs. While each of the programs faced multiple problems, all of them experienced insufficient maturity of technologies, overly aggressive schedules, insufficient subcontract management, and inadequate system engineering capabilities for overseeing contractors.

Table 1: Key Problems Experienced on Selected Major Space Systems

Problem	NPOESS	GOES I–M	SBIRS—High	AEHF
Insufficient technical readiness prior to critical decision points				
Inadequate preliminary studies prior to the decision to award a development contract	X	X	X	
Insufficient technical maturity prior to the decision to move to production	X	X	X	X

[2] GAO–07–498; GAO–06–993; GAO, *Defense Acquisitions: Space System Acquisition Risks and Keys to Addressing Them,* GAO–06–776R (Washington, D.C.: June 1, 2006); *Polar-orbiting Operational Environmental Satellites: Cost Increases Trigger Review and Place Program's Direction on Hold,* GAO–06–573T (Washington, D.C.: Mar. 30, 2006); *Polar-orbiting Operational Environmental Satellites: Technical Problems, Cost Increases, and Schedule Delays Trigger Need for Difficult Trade-off Decisions,* GAO–06–249T (Washington, D.C.: Nov. 16, 2005); *Polar-orbiting Environmental Satellites: Information on Program Cost and Schedule Changes,* GAO–04–1054 (Washington, D.C.: Sept. 30, 2004); *Defense Acquisitions: Despite Restructuring, SBIRS High Program Remains at Risk of Cost and Schedule Overruns,* GAO–04–48 (Washington, D.C.: Oct. 31, 2003); *Military Space Operations: Common Problems and Their Effects on Satellite and Related Acquisitions,* GAO–03–825R (Washington, D.C.: June 2, 2003); *Defense Acquisitions: Assessments of Major Weapon Programs,* GAO–03–476 (Washington, D.C.: May 15, 2003); *Weather Satellites: Action Needed to Resolve Status of the U.S. Geostationary Satellite Program,* GAO/NSIAD–91–252 (Washington, D.C.: July 24, 1991). Defense Science Board/Air Force Scientific Advisory Board Joint Task Force, *Report on the Acquisition of National Security Space Programs* (May 2003).

Table 1: Key Problems Experienced on Selected Major Space Systems—Continued

Problem	NPOESS	GOES I–M	SBIRS—High	AEHF
Unrealistic cost and schedule estimates				
Optimistic assumptions including:				
• savings from heritage systems	X	X	X	
• readiness of technology maturity	X	X	X	X
• constant and available industrial base			X	
• no weight growth	X		X	X
• no requirements growth				X
• savings from lot buys versus single-unit purchase			X	
• overly aggressive schedule	X	X	X	X
Poor program and contractor management				
Quality and subcontractor issues	X	X	X	X
Inadequate systems engineering capabilities	X	X	X	X
Inadequate earned value management capabilities	X		X	X
Insufficient management reserve	X			X
Ineffective contract award fee structure	X	X	X	
Poor senior executive level oversight				
Infrequent meetings	X			
Inability to make timely decisions	X			
Other				
Unstable funding stream	X		X	X
Unstable requirements			X	X

Source: GAO analysis of NOAA and DOD data.

NPOESS: Overview, Issues, and Prior GAO Recommendations

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

Within the program office, each agency has the lead on certain activities: NOAA has overall program management responsibility for the converged system and for 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. The NPOESS program office is overseen by an Executive Committee, which is made up of the Administrators of NOAA and NASA and the Under Secretary of the Air Force.

NPOESS is a major system acquisition that was originally estimated to cost about $6.5 billion over the 24-year life of the program from its inception in 1995 through 2018. The program was to provide satellite development, satellite launch and operation, and ground-based satellite data processing. When the NPOESS engineering, manufacturing, and development contract was awarded in August 2002, the estimated cost was $7 billion. Acquisition plans called for the procurement and launch of six satellites over the life of the program, as well as the integration of 13 instruments—consisting of 10 environmental sensors and 3 subsystems (see table 2).

[3] Presidential Decision Directive NSTC–2 (May 5, 1994).

Table 2: Expected NPOESS Instruments as of August 31, 2004 (critical sensors are in italic)

Instrument	Description
Advanced technology microwave sounder (ATMS)	Measures microwave energy released and scattered by the atmosphere and is to be used with infrared sounding data from NPOESS's cross-track infrared sounder to produce daily global atmospheric temperature, humidity, and pressure profiles.
Aerosol polarimetry sensor	Retrieves specific measurements of clouds and aerosols (liquid droplets or solid particles suspended in the atmosphere, such as sea spray, smog, and smoke).
Conical-scanned microwave imager/sounder (CMIS)	Collects 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.
Cross-track infrared sounder (CrIS)	Collects measurements of the earth's radiation to determine the vertical distribution of temperature, moisture, and pressure in the atmosphere.
Data collection system	Collects environmental data from platforms around the world and delivers them to users worldwide.
Earth radiation budget 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.
Ozone mapper/profiler suite (OMPS)	Collects data needed to measure the amount and distribution of ozone in the earth's atmosphere.
Radar altimeter	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.
Search and rescue satellite aided tracking system	Detects and locates aviators, mariners, and land-based users in distress.
Space environmental sensor suite	Collects data to identify, reduce, and predict the effects of space weather on technological systems, including satellites and radio links.
Survivability sensor	Monitors for attacks on the satellite and notifies other instruments in case of an attack.
Total solar irradiance sensor	Monitors and captures total and spectral solar irradiance data.
Visible/infrared imager radiometer suite (VIIRS)	Collects images and radiometric data used to provide information on the earth's clouds, atmosphere, ocean, and land surfaces.

Source: GAO, based on NPOESS program office data.

In addition, a demonstration satellite (called the NPOESS Preparatory Project or NPP) was planned to be launched several years before the first NPOESS satellite in order to reduce the risk associated with launching new sensor technologies and to ensure continuity of climate data with NASA's Earth Observing System satellites.

NPOESS Experienced Cost Increases, Schedule Delays, and Technical Problems Over Several Years

Over the last few years, NPOESS experienced continued cost increases and schedule delays, requiring difficult decisions to be made about the program's direction and capabilities. In 2003, we reported that changes in the NPOESS funding stream led the program to develop a new program cost and schedule baseline.[4] After this new baseline was completed in 2004, we reported that the program office increased the NPOESS cost estimate from about $7 billion to $8.1 billion, delaying key milestones, including the launch of the first satellite, and extending the life of the program until 2020.[5] In mid-November 2005, we reported that NPOESS continued to experience problems in the development of a key sensor, resulting in schedule delays and anticipated cost increases. This was due in part, to problems at multiple levels of management—including subcontractor, contractor, program office, and executive leadership. Recognizing that the budget for the program was no longer executable, the NPOESS Executive Committee planned to make a decision in December 2005 on the future direction of the program—what would be delivered, at what cost, and by when. This involved deciding among options involving increased costs, delayed schedules, and reduced functionality. We noted that continued oversight,

[4] GAO; *Polar-Orbiting Environmental Satellites: Project Risks Could Affect Weather Data Needed by Civilian and Military Users,* GAO–03–987T (Washington, D.C.: July 15, 2003).
[5] GAO–04–1054.

strong leadership, and timely decisionmaking were more critical than ever, and we urged the Committee to make a decision quickly so that the program could proceed.

However, we subsequently reported that, in late November 2005, NPOESS cost growth exceeded a legislatively mandated threshold that requires DOD to certify the program to Congress.[6] This placed any decision about the future direction of the program on hold until the certification took place in June 2006. In the meantime, the program office implemented an interim program plan for Fiscal Year 2006 to continue work on key sensors and other program elements using Fiscal Year 2006 funding.

Nunn-McCurdy Process Led To a Decision To Restructure the NPOESS Program

The Nunn-McCurdy law requires DOD to take specific actions when a major defense acquisition program exceeds certain cost increase thresholds.[7] The law requires the Secretary of Defense to notify Congress when a major defense acquisition is expected to overrun its project baseline by 15 percent or more and to certify the program to Congress when it is expected to overrun its baseline by 25 percent or more.[8] In late November 2005, NPOESS exceeded the 25 percent threshold, and DOD was required to certify the program. Certifying the program entailed providing a determination that (1) the program is essential to national security, (2) there are no alternatives to the program that will provide equal or greater military capability at less cost, (3) the new estimates of the program's cost are reasonable, and (4) the management structure for the program is adequate to manage and control costs. DOD established tri-agency teams—made up of DOD, NOAA, and NASA experts—to work on each of the four elements of the certification process.

In June 2006, DOD (with the agreement of both of its partner agencies) certified a restructured NPOESS program, estimated to cost $12.5 billion through 2026.[9] This decision approved a cost increase of $4 billion over the prior approved baseline cost and delayed the launch of NPP and the first two satellites by roughly 3 to 5 years. The new program also entailed establishing a stronger program management structure, reducing the number of satellites to be produced and launched from 6 to 4, and reducing the number of instruments on the satellites from 13 to 9—consisting of 7 environmental sensors and 2 subsystems. It also entailed using NPOESS satellites in the early morning and afternoon orbits and relying on European satellites for mid-morning orbit data.[10] Table 3 summarizes the major program changes made under the Nunn-McCurdy certification decision.

Table 3: Summary of Changes to the NPOESS Program

Key area	Program before the Nunn-McCurdy decision	Program after the Nunn-McCurdy decision
Life cycle range	1995–2020	1995–2026
Estimated life cycle cost	$8.4 billion	$12.5 billion
Launch schedule	NPP by October 2006 First NPOESS by November 2009 Second NPOESS by June 2011	NPP by January 2010 First NPOESS by January 2013 Second NPOESS by January 2016
Management structure	System Program Director reports to a tri-agency steering committee and the tri-agency Executive Committee Independent program reviews noted insufficient system engineering and cost analysis staff	System Program Director is responsible for day-to-day program management and reports to the Program Executive Officer Program Executive Officer oversees program and reports to the tri-agency Executive Committee
Number of satellites	6 (in addition to NPP)	4 (in addition to NPP)
Number of orbits	3 (early morning, midmorning, and afternoon)	2 (early morning and afternoon; will rely on European satellites for midmorning orbit data)

[6] GAO, *Polar-orbiting Operational Environmental Satellites: Cost Increases Trigger Review and Place Program's Direction on Hold,* GAO–06–573T (Washington, D.C.: Mar. 30, 2006).

[7] 10 U.S.C § 2433 is commonly referred to as Nunn-McCurdy.

[8] 10 U.S.C. § 2433(e)(2).

[9] DOD estimated that the acquisition portion of the certified program would cost $11.5 billion. The acquisition portion includes satellite development, production, and launch, but not operations and support costs after launch. When combined with an estimated $1 billion for operations and support after launch, this brings the program life cycle cost to $12.5 billion.

[10] The European Organization for the Exploitation of Meteorological Satellites' MetOp program is a series of three polar-orbiting satellites dedicated to operational meteorology. MetOp satellites are planned to be launched sequentially over 14 years.

Table 3: Summary of Changes to the NPOESS Program—Continued

Key area	Program before the Nunn-McCurdy decision	Program after the Nunn-McCurdy decision
Number and complement of instruments	13 instruments (10 sensors and 3 subsystems)	9 instruments (7 sensors and 2 subsystems); 4 of the sensors are to provide fewer capabilities
Number of EDRs	55	39 (6 are to be degraded products)

Source: GAO analysis of NPOESS program office data.

The Nunn-McCurdy certification decision established new milestones for the delivery of key program elements, including launching NPP by January 2010,[11] launching the first NPOESS satellite (called C1) by January 2013, and launching the second NPOESS satellite (called C2) by January 2016. These revised milestones deviated from prior plans to have the first NPOESS satellite available to back up the final POES satellite should anything go wrong during that launch.

Delaying the launch of the first NPOESS satellite means that if the final POES satellite fails on launch, satellite data users would need to rely on the existing constellation of environmental satellites until NPP data becomes available—almost 2 years later. Although NPP was not intended to be an operational asset, NASA agreed to move it to a different orbit so that its data would be available in the event of a premature failure of the final POES satellite. However, NPP will not provide all of the operational capability planned for the NPOESS spacecraft. If the health of the existing constellation of satellites diminishes—or if NPP data is not available, timely, and reliable—then there could be a gap in environmental satellite data.

In order to reduce program complexity, the Nunn-McCurdy certification decision decreased the number of NPOESS sensors from 13 to 9 and reduced the functionality of 4 sensors. Specifically, of the 13 original sensors, 5 sensors remain unchanged, 3 were replaced with less capable sensors, 1 was modified to provide less functionality, and 4 were canceled. Table 4 shows the changes to NPOESS sensors, including the 4 identified as critical sensors.

Table 4: Changes to NPOESS Instruments (critical sensors are in italic)

Instrument	Status of instrument after the Nunn-McCurdy decision	Change description
ATMS	Unchanged	Sensor is to be included on NPP and on the first and third NPOESS satellites.
Aerosol polarimetry sensor	Cancelled	Sensor was cancelled, but could be reintegrated on future NPOESS satellites should another party choose to fund it.[a]
CMIS	Replaced	CMIS sensor was cancelled, and the program office is to procure a less complex *Microwave imager/sounder* for inclusion on the second, third, and fourth NPOESS satellites.
CrIS	Unchanged	Sensor is to be included on NPP and on the first and third NPOESS satellites.
Data collection system	Unchanged	Subsystem is to be included on all four NPOESS satellites.
Earth radiation budget sensor	Replaced	Sensor was cancelled, and is to be replaced on the first NPOESS satellite (and no others) by an existing sensor with fewer capabilities called the *Clouds and the Earth's Radiant Energy System.*
OMPS	Modified	One part of the sensor, called OMPS (nadir), is to be included on NPP and on the first and third NPOESS satellites; the remaining part, called OMPS (limb), was cancelled on the NPOESS satellites, but will be included on NPP a Radar altimeter Cancelled Sensor was cancelled, but could be reintegrated on future NPOESS satellites should another party choose to fund it.[a]
Search and rescue satellite aided tracking system	Unchanged	Subsystem is to be included on all four NPOESS satellites.
Space environmental sensor suite	Replaced	Sensor is to be replaced *by a less capable, less expensive, legacy sensor called the Space* Environment Monitor on the first and third NPOESS satellites.

[11] According to program officials, although the Nunn-McCurdy certification decision specifies NPP is to launch by January 2010, NASA plans to launch it by September 2009 to reduce the possibility of a climate data continuity gap.

Table 4: Changes to NPOESS Instruments (critical sensors are in italic)—Continued

Instrument	Status of instrument after the Nunn-McCurdy decision	Change description
Survivability sensor	Cancelled	Subsystem contract was cancelled, but could be re-integrated on future NPOESS satellites should another party choose to fund it.[a]
Total solar irradiance sensor	Cancelled	Sensor contract was cancelled, but could be reintegrated on future NPOESS satellites should another party choose to fund it.[a]
VIIRS	Unchanged	Sensor is to be included on NPP and on all four NPOESS satellites.

Source: GAO analysis of NPOESS program office data.

[a] Although direct program funding for these instruments was eliminated, the instruments could be reintegrated on NPOESS satellites should other parties choose to fund them. The Nunn-McCurdy decision requires the program office to allow sufficient space on the spacecraft for these instruments and to provide the funding needed to integrate them.

The changes in NPOESS sensors affected the number and quality of the resulting weather and environmental products, called environmental data records or EDRs. In selecting sensors for the restructured program, the agencies placed the highest priority on continuing current operational weather capabilities and a lower priority on obtaining selected environmental and climate measuring capabilities. As a result, the revised NPOESS system has significantly less capability for providing global climate measures than was originally planned. Specifically, the number of EDRs was decreased from 55 to 39, of which 6 are of a reduced quality. The 39 EDRs that remain include cloud base height, land surface temperature, precipitation type and rate, and sea surface winds. The 16 EDRs that were removed include cloud particle size and distribution, sea surface height, net solar radiation at the top of the atmosphere, and products to depict the electric fields in the space environment. The 6 EDRs that are of a reduced quality include ozone profile, soil moisture, and multiple products depicting energy in the space environment.

NPOESS Acquisition Restructuring Is Well Under Way, but Key Steps Remain To Be Completed

Since the June 2006 decision to revise the scope, cost, and schedule of the NPOESS program, the program office has made progress in restructuring the satellite acquisition; however, important tasks remain to be done. Restructuring a major acquisition program like NPOESS is a process that involves identifying time-critical and high-priority work and keeping this work moving forward, while reassessing development priorities, interdependencies, deliverables, risks, and costs. It also involves revising important acquisition documents including the Memorandum of Agreement on the roles and responsibilities of the three agencies, the acquisition strategy, the system engineering plan, the test and evaluation master plan, the integrated master schedule defining what needs to happen by when, and the acquisition program baseline. Specifically, the Nunn-McCurdy certification decision required the Secretaries of Defense and Commerce and the Administrator of NASA to sign a revised Memorandum of Agreement by August 6, 2006. It also required that the program office, Program Executive Officer, and the Executive Committee revise and approve key acquisition documents including the acquisition strategy and system engineering plan by September 1, 2006, in order to proceed with the restructuring. Once these are completed, the program office can proceed to negotiate with its prime contractor on a new program baseline defining what will be delivered, by when, and at what cost.

The NPOESS program office has made progress in restructuring the acquisition. Specifically, the program office has established interim program plans guiding the contractor's work activities in 2006 and 2007 and has made progress in implementing these plans. The program office and contractor also developed an integrated master schedule for the remainder of the program—beyond Fiscal Year 2007. This integrated master schedule details the steps leading up to launching NPP by September 2009, launching the first NPOESS satellite in January 2013, and launching the second NPOESS satellite in January 2016. Near-term steps include completing and testing the VIIRS, CrIS, and OMPS sensors; integrating these sensors with the NPP spacecraft and completing integration testing; completing the data processing system and integrating it with the command, control, and communications segment; and performing advanced acceptance testing of the overall system of systems for NPP.

However, key steps remain for the acquisition restructuring to be completed. Although the program office made progress in revising key acquisition documents, including the system engineering plan, the test and evaluation master plan, and the acquisition strategy plan, it has not yet obtained the approval of the Secretaries of Commerce and Defense and the Administrator of NASA on the Memorandum of Agreement among the three agencies, nor has it obtained the approval of the NPOESS Executive Committee on the other key acquisition documents. As of June 2007, these approvals are over 9 months past due. Agency officials noted that the September 1, 2006, due date for the key acquisition documents was not realistic given the complexity of coordinating documents among three different agencies.

Finalizing these documents is critical to ensuring interagency agreement and will allow the program office to move forward in completing other activities related to restructuring the program. These other activities include completing an integrated baseline review with the contractor to reach agreement on the schedule and work activities, and finalizing changes to the NPOESS development and production contract. Program costs are also likely to be adjusted during upcoming negotiations on contract changes—an event that the Program Director expects to occur in July 2007. Completion of these activities will allow the program office to lock down a new acquisition baseline cost and schedule. Until key acquisition documents are finalized and approved, the program faces increased risk that it will not be able to complete important restructuring activities in time to move forward in Fiscal Year 2008 with a new program baseline in place. This places the NPOESS program at risk of continued delays and future cost increases.

Progress Has Been Made in Establishing an Effective NPOESS Management Structure, but Executive Turnover Increases Risks and Staffing Problems Remain

The NPOESS program has made progress in establishing an effective management structure, but—almost a year after this structure was endorsed during the Nunn-McCurdy certification process—the Integrated Program Office still faces staffing problems. Over the past few years, we and others have raised concerns about management problems at all levels of the NPOESS program, including subcontractor and contractor management, program office management, and executive-level management.[12] Two independent review teams also noted a shortage of skilled program staff, including budget analysts and system engineers. Since that time, the NPOESS program has made progress in establishing an effective management structure—including establishing a new organizational framework with increased oversight by program executives, instituting more frequent subcontractor, contractor, and program reviews, and effectively managing risks and performance. However, DOD's plans for reassigning the Program Executive Officer in the summer of 2007 increase the program's risks. Additionally, the program lacks a staffing process that clearly identifies staffing needs, gaps, and plans for filling those gaps. As a result, the program office has experienced delays in getting core management activities under way and lacks the staff it needs to execute day-to-day management activities.

NPOESS Program Has Made Progress in Establishing an Effective Management Structure and Increasing Oversight Activities, but Executive Turnover Will Increase Program Risks

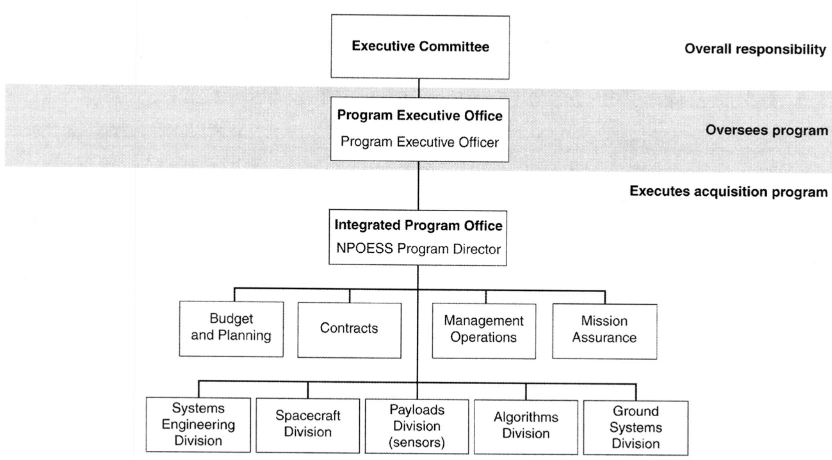
The NPOESS program has made progress in establishing an effective management structure and increasing the frequency and intensity of its oversight activities. Over the past few years, we and others have raised concerns about management problems at all levels of management on the NPOESS program, including subcontractor and contractor management, program office management, and executive-level management. In response to recommendations made by two different independent review teams, the program office began exploring options in late 2005 and early 2006 for revising its management structure.

In November 2005, the Executive Committee established and filled a Program Executive Officer position, senior to the NPOESS Program Director, to streamline decisionmaking and to provide oversight to the program. This Program Executive Officer reports directly to the Executive Committee. Subsequently, the Program Executive Officer and the Program Director proposed a revised organizational framework

[12] GAO–06–249T; U.S. Department of Commerce, Office of the Inspector General, *Poor Management Oversight and Ineffective Incentives Leave NPOESS Program Well Over Budget and Behind Schedule,* OIG–17794–6–0001/2006 (Washington, D.C.: May 2006). In addition, two independent teams reviewed the NPOESS program in 2005: A NASA-led Independent Review Team investigated problems with the VIIRS sensor and the impact on NPP, and a DOD-led Independent Program Assessment Team assessed the broader NPOESS program. The teams briefed the NPOESS Executive Committee on their findings in August 2005 and November 2005, respectively.

that realigned division managers within the Integrated Program Office responsible for overseeing key elements of the acquisition and increased staffing in key areas. In June 2006, the Nunn-McCurdy certification decision approved this new management structure and the Integrated Program Office implemented it. Figure 3 provides an overview of the relationships among the Integrated Program Office, the Program Executive Office, and the Executive Committee, as well as key divisions within the program office.

Figure 3: Overview of New NPOESS Management Structure



Source: NOAA.

Operating under this new management structure, the program office implemented more rigorous and frequent subcontractor, contractor, and program reviews, improved visibility into risk management and mitigation activities, and institutionalized the use of earned value management techniques to monitor contractor performance. In addition to these program office activities, the Program Executive Officer implemented monthly program reviews and increased the frequency of contacts with the Executive Committee. The Program Executive Officer briefs the Executive Committee in monthly letters, apprising committee members of the program's status, progress, risks, and earned value, and the Executive Committee now meets on a quarterly basis—whereas in the recent past, we reported that the Executive Committee had met only five times in 2 years.[13]

Although the NPOESS program has made progress in establishing an effective management structure, this progress is currently at risk. We recently reported that DOD space acquisitions are at increased risk due in part to frequent turnover in leadership positions, and we suggested that addressing this will require DOD to consider matching officials' tenure with the development or delivery of a product.[14] In March 2007, NPOESS program officials stated that DOD is planning to reassign the recently appointed Program Executive Officer in the summer of 2007 as part of this executive's natural career progression. As of June 2007, the Program Executive Officer has held this position for 19 months. Given that the program is currently still being restructured, and that there are significant challenges in being able to meet critical deadlines to ensure satellite data continuity, such a move adds unnecessary risk to an already risky program.

NPOESS Program Has Filled Key Vacancies but Lacks a Programwide Staffing Process

The NPOESS program office has filled key vacancies but lacks a staffing process that identifies programwide staffing requirements and plans for filling those needed positions. Sound human capital management calls for establishing a process or plan for determining staffing requirements, identifying any gaps in staffing, and planning to fill critical staffing gaps. Program office staffing is especially important for

[13] GAO–06–249T.
[14] GAO, *Space Acquisitions: Improvements Needed in Space Acquisitions and Keys to Achieving Them,* GAO–06–626T (Washington, D.C.: Apr. 6, 2006).

NPOESS, given the acknowledgment by multiple independent review teams that staffing shortfalls contributed to past problems. Specifically, these review teams noted shortages in the number of system engineers needed to provide adequate oversight of subcontractor and contractor engineering activities and in the number of budget and cost analysts needed to assess contractor cost and earned value reports. To rectify this situation, the June 2006 certification decision directed the Program Director to take immediate actions to fill vacant positions at the program office with the approval of the Program Executive Officer.

Since the June 2006 decision to revise NPOESS management structure, the program office has filled multiple critical positions, including a budget officer, a chief system engineer, an algorithm division chief, and a contracts director. In addition, on an ad hoc basis, individual division managers have assessed their needs and initiated plans to hire staff for key positions. However, the program office lacks a programwide process for identifying and filling all needed positions. As a result, division managers often wait months for critical positions to be filled. For example, in February 2006, the NPOESS program estimated that it needed to hire up to 10 new budget analysts. As of September 2006, none of these positions had been filled. As of April 2007, program officials estimated that they still needed to fill 5 budget analyst positions, 5 systems engineering positions, and 10 technical manager positions. The majority of the vacancies—4 of the 5 budget positions, 4 of the 5 systems engineering positions, and 8 of the 10 technical manager positions—are to be provided by NOAA. NOAA officials noted that each of these positions is in some stage of being filled—that is, recruitment packages are being developed or reviewed, vacancies are being advertised, or candidates are being interviewed, selected, and approved.

The program office attributes its staffing delays to not having the right personnel in place to facilitate this process, and it did not even begin to develop a staffing process until November 2006. Program officials noted that the tri-agency nature of the program adds unusual layers of complexity to the hiring and administrative functions because each agency has its own hiring and performance management rules. In November 2006, the program office brought in an administrative officer who took the lead in pulling together the division managers' individual assessments of needed staff and has been working with the division managers to refine this list. This new administrative officer plans to train division managers in how to assess their needs and to hire needed staff, and to develop a process by which evolving needs are identified and positions are filled. However, there is as yet no date set for establishing this basic programwide staffing process. As a result of the lack of a programwide staffing process, there has been an extended delay in determining what staff is needed and in bringing those staff on board; this has resulted in delays in performing core activities, such as establishing the program office's cost estimate and bringing in needed contracting expertise. Additionally, until a programwide staffing process is in place, the program office risks not having the staff it needs to execute day-to-day management activities.

In commenting on a draft of our report, Commerce stated that NOAA implemented an accelerated hiring model. More recently, the NPOESS program office reported that several critical positions were filled in April and May 2007. However, we have not yet evaluated NOAA's accelerated hiring model and, as of June 2007, about 10 key positions remained to be filled.

Major Program Segments Are Under Development, but Significant Risks Remain

Major segments of the NPOESS program—the space segment and ground systems segment—are under development; however, significant problems have occurred and risks remain. The program office is aware of these risks and is working to mitigate them, but continued problems could affect the program's overall cost and schedule. Given the tight time-frames for completing key sensors, integrating them on the NPP spacecraft, and developing, testing, and deploying the ground-based data processing systems, it will be important for the NPOESS Integrated Program Office, the Program Executive Office, and the Executive Committee to continue to provide close oversight of milestones and risks.

Space Segment—Progress Made, but Key Sensors Continue To Face Major Risks

The space segment includes the sensors and the spacecraft. Four sensors are of critical importance—VIIRS, CrIS, OMPS, and ATMS—because they are to be launched on the NPP satellite in September 2009. Initiating work on another sensor, the Microwave imager/sounder, is also important because this new sensor—replacing the canceled CMIS sensor—will need to be developed in time for the second NPOESS satellite launch. Over the past year, the program made progress on each of the sensors and the spacecraft. However, two sensors, VIIRS and CrIS, have experienced major problems. The status of each of the components of the space segment is described in table 5.

Table 5: Status of Selected Components of the Space Segment, as of April 2007

Space segment component	Risk level	Status
VIIRS	High	VIIRS development has continued in 2006 and in early 2007. In December 2006, the contractor completed environmental tests of VIIRS's engineering design unit (a prototype) and identified three problems.a While these problems were being studied, the program office approved the delivery of the engineering unit to the subcontractor responsible for integration and testing on NPP. In late February 2007, program officials determined that the contractor was able to mitigate all but one of the problems, and they approved the flight unit to proceed to system level integration with a goal of resolving the final problem before a technical readiness review milestone. VIIRS flight unit is scheduled to be delivered to NPP by July 2008.
CrIS	High	Development of CrIS was put on hold in October 2006 when the flight unit designated to go on NPP experienced a major structural failure during its vibration testing. As of March 2007, a failure review board established by the contractors and the NPOESS program office identified causes for failure and has planned an approach to completing flight unit development and delivery for NPP. The review board has also initiated inspections of all sensor modules and subsystems for damage. The program office expects to restart acceptance testing in July 2007, and the CrIS flight unit is expected to be delivered to NPP by February 2008.
OMPS	Moderate	As part of the Nunn-McCurdy certification in June 2006, one element of the OMPS sensor, called OMPS (limb), was removed from the program. In February 2007, program officials agreed to reintegrate OMPS (limb) on NPP if NOAA and NASA would fund it. This funding was approved in early April 2007. OMPS is currently on schedule for delivery to NPP by May 2008; however, there are concerns that the OMPS flight unit delivery will be so late in the integration testing process that there could be an insufficient schedule margin should a problem arise.
ATMS	Low	The ATMS flight unit for NPP was developed by a NASA contractor and delivered to the program in October 2005. NASA integrated the flight unit on the spacecraft and is awaiting delivery of the other sensors in order to complete integration testing.
Microwave imager/ sounder	Not yet rated	A new microwave imager/sounder sensor is being planned to replace the cancelled CMIS sensor. It is planned to be ready for the launch on the second NPOESS satellite. In October 2006, the program office issued a request for information seeking industry ideas for the design of the new sensor. The program office anticipates awarding a contract to develop the sensor by October 2008.
Spacecraft	Low	The development of the spacecrafts for NPP and NPOESS are on track. The NPP spacecraft was completed in June 2005. Integration testing will be conducted once the NPP sensors are delivered. Early issues with the NPOESS spacecraft (including issues with antennas and a data storage unit) have been resolved; however, risks remain that could delay the completion of the spacecraft. A key risk involves delays in the delivery of the solar array, which may arrive too late to be included in some key testing. Other risks associated with the electrical power subsystem are taking longer than anticipated to resolve.

Source: GAO analysis of NPOESS Integrated Program Office data.

[a] The three problems are (1) band-to-band co-registration, an issue in which band registration shifts with different temperatures; (2) cross-talk, which involves information from sensor cells leaking into other cells; and (3) line-spread function issues, in which the instrument's focus changes with changes in temperature.

Managing the risks associated with the development of VIIRS and CrIS is of particular importance because these components are to be demonstrated on the NPP satellite, currently scheduled for launch in September 2009. Any delay in the NPP launch date could affect the overall NPOESS program, because the success of the program depends on the lessons learned in data processing and system integration from the NPP satellite. Additionally, continued sensor problems could lead to higher final program costs.

Ground Segment—Progress Has Been Made, but Work Remains

Development of the ground segment—which includes the interface data processing system, the ground stations that are to receive satellite data, and the ground-based command, control, and communications system—is under way and on track. However, important work pertaining to developing the algorithms that translate satellite data into weather products within the integrated data processing segment remains to be completed. Table 6 describes each of the components of the ground segment and identifies the status of each.

Table 6: Status of Ground Segment Components, as of April 2007

Ground segment component/description	Risk level	Status
Interface Data Processing System (IDPS): 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. IDPS will be deployed at the four weather data processing centers.	Moderate	IDPS is being developed in a series of builds. Currently, IDPS build 1.4 has been delivered for testing and recently passed two key data transfer tests. Contractors are currently working to develop IDPS build 1.5, which is expected to be the build that will be used with NPP. However, work remains in three areas: system latency, algorithm performance, and calibration and validation planning. Latency—IDPS must process volumes of data within 65 minutes to meet NPP requirements. The contractor has made progress in reducing the latency of the system's data handling from 93 minutes to 73 minutes and is working to reduce it by 8 minutes more by resolving data management issues, increasing the number of processors, and increasing algorithm efficiency. Algorithm performance—IDPS algorithms are the mathematical functions coded into the system software that transform raw data into data products, including sensor data records and environmental data records. IDPS build 1.4 contains provisional algorithms, which are being refined as the sensors complete various stages of testing. Because some sensors are delayed, full characterization of those sensors in order to refine the algorithms has also been delayed and may not be completed in time for the delivery of IDPS build 1.5 in early 2009. If this occurs, agency officials plan to improve the algorithms in build 1.5 during a planned maintenance upgrade prior to NPP launch. Calibration/validation—Calibration/validation is the process for tweaking algorithms to provide more accurate observations. The contractor has documented a detailed schedule for calibration and validation during IDPS development and is developing a postlaunch task list to drive prelaunch preparation efforts. However, much work and uncertainty continue to exist in the calibration and validation area. A program official noted that, while teams can do a lot of preparation work, including building the infrastructure to allow sensor testing and having a good understanding of the satellite, sensors, and available data for calibration, many issues need to take place after launch.
Ground stations for receiving satellite data: 15 unmanned ground stations around the world (called SafetyNet™) are to receive satellite data and send these to the four data processing centers.	Low	NOAA is working with domestic and foreign authorities to gain approval to operate ground stations to receive satellite data. According to agency officials, the full complement of ground stations will not be in place in time for the C1 launch: however, the ground stations will be phased in by the launch of C2. To date, the program office has reached agreement with 4 of 15 ground station sites.

Source: GAO analysis of NPOESS program office data.

Managing the risks associated with the development of the IDPS system is of particular importance because this system will be needed to process NPP data.

Implementation of GAO Recommendations Should Reduce Risk

Because of the importance of effectively managing the NPOESS program to ensure that there are no gaps in the continuity of critical weather and environmental observations, in our April 2007 report,[15] we made recommendations to the Secretaries of Defense and Commerce and to the Administrator of NASA to ensure that the responsible executives within their respective organizations approve key acquisition documents, including the Memorandum of Agreement among the three agencies, the system engineering plan, the test and evaluation master plan, and the acquisition strategy, as quickly as possible but no later than April 30, 2007. We also recommended that the Secretary of Defense direct the Air Force to delay reassigning the recently appointed Program Executive Officer until all sensors have been delivered to the NPOESS Preparatory Program; these deliveries are currently scheduled to occur by July 2008. We also made two additional recommendations to the Secretary of Commerce to (1) develop and implement a written process for identifying and addressing human capital needs and for streamlining how the program handles the three different agencies' administrative procedures and (2) establish a plan for immediately filling needed positions.

In written comments, all three agencies agreed that it was important to finalize key acquisition documents in a timely manner, and DOD proposed extending the due dates for the documents to July 2, 2007. DOD subsequently extended the due dates to September and October 2007 and March 2008 in the case of the test and evaluation master plan. Because the NPOESS program office intends to complete

[15] GAO–07–498.

contract negotiations in July 2007, we remain concerned that any further delays in approving the documents could delay contract negotiations and thus increase the risk to the program.

In addition, the Department of Commerce agreed with our recommendation to develop and implement a written process for identifying and addressing human capital needs and to streamline how the program handles the three different agencies' administrative procedures. The Department also agreed with our recommendation to plan to immediately fill open positions at the NPOESS program office. Commerce noted that NOAA identified the skill sets needed for the program and has implemented an accelerated hiring model and schedule to fill all NOAA positions in the NPOESS program. Commerce also noted that NOAA has made NPOESS hiring a high priority and has documented a strategy—including milestones—to ensure that all NOAA positions are filled by June 2007.

DOD did not concur with our recommendation to delay reassigning the Program Executive Officer, noting that the NPOESS System Program Director responsible for executing the acquisition program would remain in place for 4 years. The Department of Commerce also noted that the Program Executive Officer position is planned to rotate between the Air Force and NOAA. Commerce also stated that a selection would be made before the departure of the current Program Executive Officer to provide an overlap period to allow for knowledge transfer and ensure continuity. However, over the last few years, we and others (including an independent review team and the Commerce Inspector General) have reported that ineffective executive-level oversight helped foster the NPOESS program's cost and schedule overruns. We remain concerned that reassigning the Program Executive at a time when NPOESS is still facing critical cost, schedule, and technical challenges will place the program at further risk.

In addition, while it is important that the System Program Director remain in place to ensure continuity in executing the acquisition, this position does not ensure continuity in the functions of the Program Executive Officer. The current Program Executive Officer is experienced in providing oversight of the progress, issues, and challenges facing NPOESS and coordinating with Executive Committee members as well as the Defense acquisition authorities. Additionally, while the Program Executive Officer position is planned to rotate between agencies, the Memorandum of Agreement documenting this arrangement is still in draft and should be flexible enough to allow the current Program Executive Officer to remain until critical risks have been addressed.

Further, while Commerce plans to allow a period of overlap between the selection of a new Program Executive Officer and the departure of the current one, time is running out. The current Program Executive Officer is expected to depart in early July 2007, and as of early July 2007, a successor has not yet been named. NPOESS is an extremely complex acquisition, involving three agencies, multiple contractors, and advanced technologies. There is not sufficient time to transfer knowledge and develop the sound professional working relationships that the new Program Executive Officer will need to succeed in that role. Thus, we remain convinced that given NPOESS current challenges, reassigning the current Program Executive Officer at this time is not appropriate.

GOES-R: Overview, Issues, and Prior GAO Recommendations

To provide continuous satellite coverage, NOAA acquires several satellites at a time as part of a series and launches new satellites every few years (see table 7). To date, NOAA has procured three series of GOES satellites and is planning to acquire a fourth series, called GOES-R.

Table 7: Summary of the Procurement History of GOES

Series name	Procurement duration[a]	Satellites
Original GOES[b]	1970–1987	1, 2, 3, 4, 5, 6, 7
GOES I–M	1985–2001	8, 9, 10, 11, 12
GOES–N	1998–2011	13, O, P, Q[c]
GOES–R	2007–2020	R, S, T, U[d]

Source: GAO analysis of NOAA data.

[a] Duration includes time from contract award to final satellite launch.

[b] The procurement of these satellites consisted of four separate contracts for (1) two early prototype satellites and GOES–1, (2) GOES–2 and –3, (3) GOES–4 through –6, and (4) GOES–G (failed on launch) and GOES–7.

[c] NOAA decided not to exercise the option for this satellite.

[d] NOAA recently decided to drop satellites T and U from this series, but is now reconsidering that decision.

Original GOES Satellites

In 1970, NOAA initiated its original GOES program based on experimental geostationary satellites developed by NASA. While these satellites operated effectively for many years, they had technical limitations. For example, this series of satellites was "spin-stabilized," meaning that the satellites slowly spun while in orbit to maintain a stable position with respect to the Earth. As a result, the satellite viewed the Earth only about 5 percent of the time and had to collect data very slowly, capturing one narrow band of data each time its field-of-view swung past the Earth. A complete set of sounding data took 2 to 3 hours to collect.

GOES I–M Series

In 1985, NOAA and NASA began to procure a new generation of GOES, called the GOES I-M series, based on a set of requirements developed by NOAA's National Weather Service, NESDIS, and NASA, among others. GOES I–M consisted of five satellites, GOES–8 through GOES–12, and was a significant improvement in technology from the original GOES satellites. For example, GOES I–M was "body-stabilized," meaning that the satellite held a fixed position in orbit relative to the Earth, thereby allowing for continuous meteorological observations. Instead of maintaining stability by spinning, the satellite would preserve its fixed position by continuously making small adjustments in the rotation of internal momentum wheels or by firing small thrusters to compensate for drift. These and other enhancements meant that the GOES I–M satellites would be able to collect significantly better quality data more quickly than the older series of satellites.

GOES–N Series

In 1998, NOAA began the procurement of satellites to follow GOES I–M, called the GOES-N series. This series used existing technologies for the instruments and added system upgrades, including an improved power subsystem and enhanced satellite pointing accuracy. Furthermore, the GOES–N satellites were designed to operate longer than its predecessors. This series originally consisted of four satellites, GOES–N through GOES–Q. However, the option for the GOES–Q satellite was canceled based on NOAA's assessment that it would not need the final satellite to continue weather coverage. In particular, the agency found that the GOES satellites already in operation were lasting longer than expected and that the first satellite in the next series could be available to back up the last of the GOES–N satellites. As noted earlier, the first GOES–N series satellite—GOES–13—was launched in May 2006. The GOES–O and GOES–P satellites are currently in production and are expected to be launched in July 2008 and July 2011, respectively.

Planned GOES-R Series

NOAA is currently planning to procure the next series of GOES satellites, called the GOES-R series. NOAA is planning for the GOES-R program to improve on the technology of prior GOES series, both in terms of system and instrument improvements. The system improvements are expected to fulfill more demanding user requirements and to provide more rapid information updates. Table 8 highlights key system-related improvements that GOES-R is expected to make to the geostationary satellite program.

Table 8: Summary of Key GOES–R System Improvements

Key feature	GOES–N (current)	GOES–R
Total products	41	~152
Downlink rate of raw data collected by instruments (from satellite to ground stations)	2.6 Mbps	132 Mbps
Broadcast rate of processed GOES data (from satellite to users)	2.1 Mbps	17–24 Mbps
Raw data storage (the length of time that raw data will be stored at ground stations)	0 days	30 days

Source: GAO analysis of NOAA data.

The instruments on the GOES-R series are expected to increase the clarity and precision of the observed environmental data. Originally, NOAA planned to acquire 5 different instruments. The program office considered two of the instruments—the Advanced Baseline Imager and the Hyperspectral Environmental Suite—to be the most critical because they would provide data for key weather products. Table 9 summarizes the originally planned instruments and their expected capabilities.

Table 9: Expected GOES-R Series Instruments, as of June 2006

Planned instrument	Description
Advanced Baseline Imager	Expected to provide variable area imagery and radiometric information of the earth's surface, atmosphere, and cloud cover. Key features include • monitoring and tracking severe weather, • providing images of clouds to support forecasts, and • providing higher resolution, faster coverage, and broader coverage simultaneously.
Hyperspectral Environmental Suite	Expected to provide information about the earth's surface to aid in the prediction of weather and climate monitoring. Key features include • providing atmospheric moisture and temperature profiles to support forecasts and climate monitoring, • monitoring coastal regions for ecosystem health, water quality, coastal erosion, and harmful algal blooms, and • providing higher resolution and faster coverage.
Space Environmental In-Situ Suite	Expected to provide information on space weather to aid in the prediction of particle precipitation, which causes disturbance and disruption of radio communications and navigation systems. Key features include • measuring magnetic fields and charged particles, • providing improved heavy ion detection, adding low energy electrons andprotons, and • enabling early warnings for satellite and power grid operation, telecom services, astronauts, and airlines.
Solar Imaging Suite	Expected to provide coverage of the entire dynamic range of solar X-ray features, from coronal holes to X-class flares, as well as estimate the measure of temperature and emissions. Key features include • providing images of the sun and measuring solar output to monitor solar storms and • providing improved imager capability.
Geostationary Lightning Mapper	Expected to continuously monitor lightning activity over the United States and provide a more complete dataset than previously possible. Key features include • detecting lightning strikes as an indicator of severe storms and • providing a new capability to GOES that only previously existed on polar satellites.

Source: GAO analysis of NOAA data.

After our report was issued, NOAA officials told us that the agency decided to cancel its plans for the development of the Hyperspectral Environmental Suite, but expected to explore options to ensure the continuity of data provided by the current GOES series. Additionally, NOAA reduced the number of satellites in the GOES-R series from four to two satellites.

The GOES-R Series Procurement Activities Are Under Way, but System Requirements and Cost Estimates May Change

NOAA is nearing the end of the preliminary design phase of its GOES-R system, which was initially estimated to cost $6.2 billion and scheduled to have the first satellite ready for launch in 2012. At the time of our most recent review in September 2006,[16] NOAA had issued contracts for the preliminary design of the overall GOES-R system to three vendors and expected to award a contract to one of these vendors in August 2007 to develop the satellites. In addition, to reduce the risks associated with developing new instruments, NOAA issued contracts for the early development of two instruments and for the preliminary designs of three other instruments.

However, analyses of the GOES-R program cost—which in May 2006 the program office estimated could reach $11.4 billion—led the agency to consider reducing the scope of requirements for the satellite series. In September 2006, NOAA officials reported that the agency had made a decision to reduce the scope and complexity of the GOES-R program by reducing the number of satellites from 4 to 2 and canceling a technically complex instrument—called the Hyperspectral Environmental Suite. As of July 2007, agency officials reported that they are considering further changes to the scope of the program, which are likely to affect the overall program cost. We have work under way to evaluate these changes.

Steps Taken To Reduce GOES–R Risk, More Work Remains

NOAA has taken steps to implement lessons learned from past satellite programs, but more remains to be done. As outlined previously, key lessons from these programs include the need to (1) establish realistic cost and schedule estimates, (2) en-

[16] GAO–06–993.

sure sufficient technical readiness of the system's components prior to key decisions, (3) provide sufficient management at government and contractor levels, and (4) perform adequate senior executive oversight to ensure mission success. NOAA established plans to address these lessons by conducting independent cost estimates, performing preliminary studies of key technologies, placing resident government offices at key contractor locations, and establishing a senior executive oversight committee. However, many steps remain to fully address these lessons. Specifically, at the time of our review, NOAA had not yet developed a process to evaluate and reconcile the independent and government cost estimates. In addition, NOAA had not yet determined how it will ensure that a sufficient level of technical maturity will be achieved in time for an upcoming decision milestone, nor had it determined the appropriate level of resources it needs to adequately track and oversee the program using earned value management.[17] Until it completes these activities, NOAA faces an increased risk that the GOES–R program will repeat the increased cost, schedule delays, and performance shortfalls that have plagued past procurements.

Implementation of GAO Recommendations Should Reduce GOES-R Acquisition Risk

To improve NOAA's ability to effectively manage the GOES-R procurement, in our September 2006 report,[18] we made recommendations to the Secretary of Commerce to direct its NOAA Program Management Council to establish a process for objectively evaluating and reconciling the government and independent life cycle cost estimates once the program requirements are finalized; to establish a team of system engineering experts to perform a comprehensive review of the Advanced Baseline Imager instrument to determine the level of technical maturity achieved on the instrument before moving the instrument into production; and to seek assistance in determining the appropriate levels of resources needed at the program office to adequately track and oversee the contractor's earned value management data. In written comments at that time, the Department of Commerce agreed with our recommendations and provided information on its plans to implement our recommendations.

In summary, both the NPOESS and GOES-R programs are critical to developing weather forecasts, issuing severe weather warnings for events such as hurricanes, and maintaining continuity in environmental and climate monitoring. Over the last several years, the NPOESS program experienced cost, schedule, and technical problems, but has now been restructured and is making progress. Still, technical and programmatic risks remain. The GOES-R program has incorporated lessons from other satellite acquisitions, but still faces challenges in establishing the management capabilities it needs and in determining the scope of the program. We have work under way to evaluate the progress and risks of both NPOESS and GOES-R in order to assist with Congressional oversight of these critical programs.

Mr. Chairman, this concludes my statement. I would be happy to answer any questions that you or members of the Committee may have at this time.

Senator NELSON. Thanks, Mr. Powner. And we'll have a number of questions to follow up on your observations of the system, as well as the management.

Dr. Holland, let's hear your perspective from the National Center for Atmospheric Research.

STATEMENT OF GREG J. HOLLAND, PH.D., DIRECTOR, MESOSCALE AND MICROSCALE METEOROLOGY DIVISION, EARTH SYSTEMS LABORATORY, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Dr. HOLLAND. Thank you, Mr. Chairman. And, in particular, thank you for the opportunity to address the Committee on the importance of hurricane observations. And I'm going to focus on the hurricane observations, and I'm going to take those as part of the complete forecast process, because I think it is important that we do that.

[17] Earned value management is a method that compares the value of work accomplished during a given period with that of the work expected in that period.
[18] GAO–06–993.

As you've correctly noted, we came out of a period of low hurricane activity in the 1970s and 1980s, into an enhanced period starting in 1995. And looking back on that period, it is now—it seems inevitable that 2004 and 2005 would eventually happen. I think that what it has done is brought us to a position where there is genuinely a crisis of hurricane proportions in regard to the total observing and forecasting process for the country.

And I might add, also, that this affects all of the country. New York—let me take New Orleans, for a start. That was an extremely bad disaster, but it pales in significance of what could happen with New York if a Category or0hurricane came through and generated the storm surge that would flood the subways and the underground communications and electronics systems. You could actually have the situation where the entire city was essentially uninhabitable for weeks, or perhaps months, without there being any real visible sign of damage above the ground.

We have—for every dollar that gets spent in coastal regions to improve—to repair hurricane damage, there are bridges and other facilities in another part of the country that did not get built. And our port facilities are all—almost all located in hurricane-impacted areas. So, it's a problem that really does affect the country from Puerto Rico to Guam and from Florida to Alaska.

It's also a problem that is projected to continue for some period. There is no evidence that the problem is going to go away in the next decade or two, and is, therefore, something that we will see an increasing need to address.

So, my testimony addresses the entire process, from the observing through to the response.

The observing part has been taken up here, and I congratulate and thank the Committee for taking their valuable time to address the hurricane—the satellite observing process, in general—but it only—also includes how we actually put those data into the numerical models and into the analysis system. It includes the actual models that are actually used for the forecasting. It includes the research that is underpinning all of the work that is happening. It includes the communications of the result to the general public. And it also includes us doing the work that allows us to make projections out into the future which are both rational and as accurate as possible, so that our children, and our children's children, will not have to live with some of the mistakes that we're seeing from our parents today.

So, in specific reference to satellites, I have referred to three or four different satellites in there, but I want to start by saying that it's often easy to focus on a satellite and focus on, say, the North Atlantic or a particular hurricane and say, "What observations have we got on that hurricane?" But I put it to you that the real advantage of the satellite system is not the observations taken in the vicinity of the hurricane, they are the global observations for which the satellites stand alone and shine, that are absolutely essential to the forecast process. If an error is made in the analysis in China, and, 7 days later, a tropical cyclone is coming into Florida, the errors from that analysis can propagate through the entire system so that there is actually an error in the track of the tropical cyclone coming into Florida simply because there were bad data in

China. And that is just simply a fact of life of the way in which meteorology works.

So, I've referred to various instruments in there. I'll leave it to you and your colleagues to read the details. But I do want to go, in my last few minutes, to emphasize the need for a integrated approach to this problem.

After the disastrous 2005 hurricane season, there was—several peak scientific bodies got together, of which, somehow, I was on some, and these included the Hurricane Intensity Research Working Group, reporting to the NOAA Science Board, the large group of people that reported to the National Science Board on the hurricane problem, an AGU meeting of experts, and a ad hoc grouping of general experts in tropical cyclones across the whole board, that got together and looked at the problem. They all came to the same conclusions, and these conclusions are embodied in the National Hurricane Research Initiative Act of 2007 which is before this Committee. And I thank Senator Nelson and your colleagues for having brought it to the Committee.

I urge that you not just address the observing problem, that you take the entire problem and give priority attention to this important Act.

[The prepared statement of Dr. Holland follows:]

PREPARED STATEMENT OF GREG J. HOLLAND, PH.D.,* DIRECTOR, MESOSCALE AND MICROSCALE METEOROLOGY DIVISION, EARTH SYSTEMS LABORATORY NATIONAL CENTER FOR ATMOSPHERIC RESEARCH **

Introduction

I thank Chairman Inouye, Vice Chairman Stevens, and the other members of the Committee for the opportunity to speak with you today on the importance of observations in reducing the impacts of hurricanes. My name is Greg J. Holland and I am Director of the Mesoscale and Microscale Meteorology Division in the Earth Sun Systems Laboratory at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado. I commenced my career as a weather forecaster and my personal research has centered on severe weather, especially hurricanes, and has covered all aspects: basic theory; conduct of major field programs; development of new observing systems; computer modeling and direct operational applications. I have authored or co-authored more than 110 peer-reviewed scientific journal articles and book chapters. I have given several hundred invited talks worldwide, as well as many contributed presentations at national and international conferences on hurricanes and related events. I have convened several national and international workshops, and I have served on several national and international science-planning efforts, including Chairmanship of the World Meteorological Organization's Tropical Meteorology Research Program. Currently, I am serving on the National Research Council Study Committee: New Orleans Hurricane Protection and I am a Lead author on the U.S. Climate Change Science Program (CCSP) *Draft Synthesis and Assessment Product 3.3: Weather and Climate Extremes in a Changing Climate*.

The work in my division at NCAR (*www.mmm.ucar.edu/index.php*) includes research on the modeling and prediction of hurricanes. We developed and are continuously improving the Advanced Weather Research and Forecasting (WRF) Model, which is in widespread use for both research and operations in over 70 countries. Our scientists have lead the development of innovative observing systems extending from specialized field instruments to the Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) satellite system, an innovative and inexpensive system to obtain very accurate vertical profiles of temperature and water vapor in the global atmosphere for use in weather forecasting. And we are currently collaborating with the climate community on bringing the best of weather and cli-

* Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author and do not necessarily reflect those of the National Science Foundation.

** The National Center for Atmospheric Research (NCAR) is sponsored by the National Science Foundation.

mate models together into a system capable of analysis and prediction across all time and space scales.

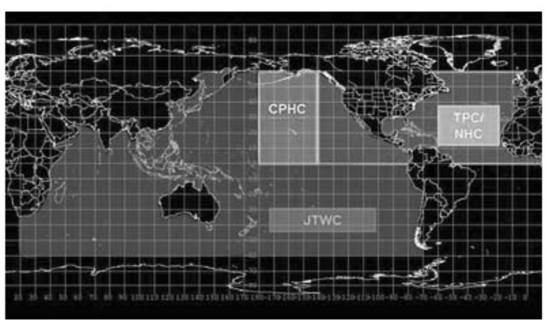
In this testimony I address observing systems as a component of a complex hurricane forecasting and warning process. The forecast process is a delicately balanced chain, starting with the observations of many types, moving through analysis and data assimilation, computer modeling, preparation of forecasts and warnings, and dissemination to the public. It is sometimes unfortunate that debate tends toward defense of one observing instrument over another, when in reality it should be on maintaining the best possible integrated process. All parts of the complex forecast chain are critical to the outcome, which must be focused very clearly on providing the best possible forecasts and warnings to the American public.

The U.S. has never been more vulnerable to hurricanes and the scientific community is of the strong and considered view that this vulnerability will not decrease in the medium term. A warming climate also may well create more and more intense hurricanes, although this is not certain. Accurate forecasts and warnings of hurricanes are therefore a national priority. *I urge that the Committee give the highest priority to the passage of the National Hurricane Research Initiative (NHRI) Act of 2007, as this presents an excellent, well-considered plan for improving hurricane forecasting through the entire chain from observations to warnings and reducing the impacts of these dangerous storms.*

Background Considerations

U.S. Hurricane Responsibility Regions

As shown in the accompanying figure from the Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead (ISRP), U.S. facilities have responsibility for forecasting in all parts of the globe affected by hurricanes. The NOAA Tropical Prediction Center/National Hurricane Center (NHC) has sole responsibility for the North Atlantic and eastern North Pacific Basins. The NOAA Central Pacific Hurricane Center (CPHC) has similar responsibilities for the central North Pacific region. The remainder of the hurricane globe is routinely monitored and warned by the DOD Joint Typhoon Warning Center (JTWC). While this is done primarily for DOD interests, JTWC forecasts are also included in the suite of advices used by other domestic forecast services, and by commercial services for both mobile and fixed assets around the world. Thus the United States has global responsibilities for forecasting hurricanes.



This global responsibility has important implications for our observational priorities in support of hurricane forecasting. Satellite observations are the foundation for our present global observing system. Certain regions, such as the eastern Pacific and North Atlantic have the additional very substantial advantage of aircraft reconnaissance. As you are well aware, the U.S. satellite system, as described by the recent National Research Council Report *Earth Science Applications from Space: National Imperatives for the Next Decade and Beyond,* "is at risk of collapse." Since accurate forecasts of hurricanes beyond a day or so depend upon global observations, this degradation of the satellite system has significant implications for the accuracy of future hurricane forecasts, at a time when the U.S. has never been so vulnerable.

Forecast System Requirements

Hurricane observing and forecast requirements are defined by the major offshore, coastal and inland impacts:

- Offshore, hurricanes impact high-seas shipping and oil and gas rigs through high winds, waves and ocean currents, including those in the deep ocean. The forecast requirements therefore focus on the future track, the intensity, the overall wind structure, and the oceanic response to its passage.
- On approaching a coast, the scale of hurricanes impacts rise sharply and now include communities and commercial facilities, local ecosystems, and port facilities. In addition to the high winds, waves and ocean currents undergo complex interactions in a variable coastline to generate storm surges that can exceed 30 ft, be accompanied by large waves and remove substantial barrier islands. Flooding and potential for landslip add to the concerns. Forecasts therefore now also must include details of the rain structure, including that occurring in outer rainbands and the amplifying effect of orography.
- As a hurricane proceeds inland its high winds diminish rapidly, but this does not completely remove the danger. Now the impacts largely arise from heavy rain and flooding, with high-winds associated with squalls and tornadoes also bringing the potential for local devastation.

The forecast lead times vary according to the time taken to effectively respond to the approaching threat. Most coastal communities require 48 hours notice of the onset of high winds (which can be many hours before the arrival of the hurricane core), some require 72 hours. Major port and offshore facilities can require up to 4–5 days to prepare for a hurricane passage. For this reason, NHC forecasts were extended to 5 days in 2001. Accurate forecasts at this extended time period are dependent on the global observing system, which again emphasizes the importance of maintaining and improving satellite observing systems.

These long lead times place great stress on the forecast system to anticipate sudden or sharp changes in hurricane characteristics, especially near vulnerable communities and facilities. The former Director of the Hurricane Center Max Mayfield was quite clear in stating that the nightmare scenario was un-forecast rapid intensification or decay on approaching the coast. Rapid intensification leaves communities poorly prepared for a major catastrophe, whereas rapid decay can lead to a false sense of security and lack of adequate response the next time a threat is forecast.

Data Usage

Both the global and local data that are collected are used in two major ways. A subset is passed directly to the relevant hurricane warning center, where they are used to analyze current details of the storm, such as its intensity, size, current track, etc. The warning center also produces local statistical forecasts of parameters such as track and intensity. The full data set is fed into the computer forecasting system where the relevant data are assimilated into the suite of models that produce both short and extended range hurricane forecasts.

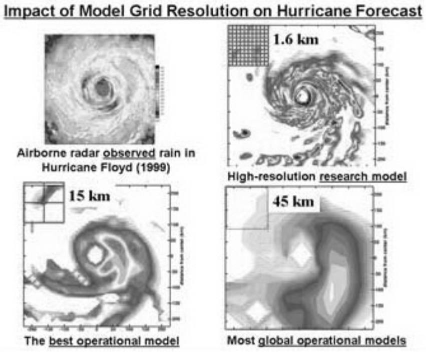
Thus, the observing system is one component of a complex forecasting and warning process. This entire process must be taken into account when considering changes to the observing system, as changes at one end often require changes throughout the process to be fully effective. This system also best operates in a dynamic fashion, one where mobile resources (such as aircraft) can be redeployed on the fly to cover deficiencies or uncertainties that appear in the forecast model calculations.

Current Deficiencies in the Forecast System

There is no doubt that the quality of the forecast can never be better than the observations that are used to develop it. However, before focusing on the observations several deficiencies in the rest of the forecast system require consideration. Hurricane track forecasts and warnings have been improving rapidly over the past 25 years due to (1) improved global observations from satellites, especially satellite atmospheric temperature and water vapor sounders, (2) improved computer models, (3) improved methods of assimilating the many observations into the models, and (4) improved understanding of physical processes for inclusion in the models. These improvements have undoubtedly saved hundreds of thousands of lives and billions of dollars of property. However, our experience here shows that all four components need additional attention and support in order for us to arrive at the desired outcome of increasing the accuracy of forecasts and warnings. Forecasts of hurricane intensity have shown less improvement, but there are good scientific reasons for hope.

Our current approaches to assimilating the data into the forecast models are not up to international standards, especially for intensity and structure forecasts. Important data, such as land-based and aircraft radar, are not used. The assimilation occurs by collecting all data over a time period into a single snapshot rather than being incorporated at the time they are collected. This deficiency is well-recognized and is being addressed in NCAR and the Joint Center for Satellite Data Assimilation. But the national investments do not match the importance of this effort. Assimilation research and application is relatively inexpensive compared to the cost of new observing systems, and it is important that adequate and stable funding be maintained for this work. *A good working model should be that* ~15 percent of all observing system budgets be devoted to ensuring the data are optimally used in the forecast models by both observing system sampling strategies and improved data assimilation.

Impact of Model Grid Resolution on Hurricane Forecast



Current operational forecast models and the computing facilities that they run on are simply not adequate for intensity and hurricane wind and rain structure forecasting, as emphasized by the report of the recent NOAA Science Board Hurricane Intensity Research Working Group (HIRWG). Research results and experimental forecast trials over the past few years have clearly demonstrated this. An example is shown in the accompanying figure (from S. Chen University of Miami). In the top left is a radar observation for Hurricane Floyd (1999). The other panels (in clockwise order) are forecast precipitation patterns obtained from a high-definition (1.6 km) research model, from the typical resolution used by current hurricane models (15 km), and from current global operational models (45 km). The top right-hand corner of each panel shows the scale of the model grids relative to the hurricane. Clearly the lower resolution models are incapable of predicting critical details in the hurricane core region. The required computer power increases by 5–10 times for each halving of the grid resolution, so this requires a substantial investment in computing. But there are clever ways of reducing this. Moving to fine definition also requires an investment in applied research to further develop the manner in which air-sea interactions and the internal workings of clouds are incorporated. *Clearly, investing in improved computer models and hardware is an investment that has to be made if we are to make substantive progress on predicting hurricane intensity and structure.*

The Observing System

A full analysis of the observing system is beyond this brief testimony, so I will concentrate on several areas of greatest need and potential return for the investment for both research and operational requirements. I will also mention promising new observing systems that are in need of research investigations for potential future use. This analysis assumes that the current suite of operational systems will be retained. In particular the geostationary satellite coverage and the aircraft reconnaissance programs are essential for maintaining the quality of analysis and short-term forecasting of hurricanes, whereas the entire satellite program including polar orbiters contributes substantially to the longer-term forecasts that are critical to planning and response.

In my opinion, the areas of greatest need and potential return are for satellite observations of:

- The full structure of the surrounding atmosphere, including winds, moisture and temperature;
- The available ocean energy for hurricane development, including the manner in which hurricanes extract this energy from the ocean;

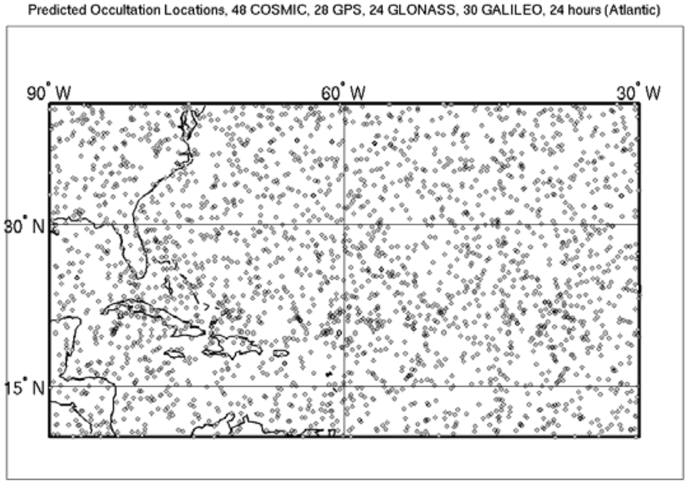
- The surface wind structure and particularly the extent of destructive winds in hurricanes.

Full Structure of the Surrounding Atmosphere

Forecasts of hurricanes beyond about a day relay heavily on numerical models of the atmosphere. These models in turn are dependent upon accurate measurements of atmospheric temperatures, winds, pressure and water vapor, not only in the immediate vicinity of the hurricane, but over the much larger environment of the storms, which extends thousands of miles in all direction from the hurricane center. The only feasible way of obtaining these global observations is from satellites, although weather balloons, aircraft and surface-based observations make significant contributions. The U.S. has been the world leader in providing the satellites in both geostationary and polar orbits that contribute the vital data needed by the forecast models.

However, as has been documented by the NRC Decadal Survey and other reports and testimonies, the U.S. satellite system is in serious trouble—-problems that threaten the number and quality of atmospheric and ocean data needed by the forecast models. For example, the future planned polar-orbiting NPOESS system has been reduced from six satellites to four and from three orbits to two. The NPOESS atmospheric sounding system has been degraded, and the ocean altimeter removed. In addition to this degradation of the NPOESS sounding capability, the planned Hyperspectral Environmental Sensor (HES) has been removed from the next geostationary satellite, GOES-R. Thus the Decadal Survey recommended that NOAA develop a strategy to restore the planned capability to make high temporal and vertical-resolution soundings from geosynchronous orbit.

Currently, atmospheric wind observations from satellite are obtained by measuring the movement of clouds and water vapor elements. These have been a considerable boon to forecasting in general, but they lack vertical detail and are not obtainable in areas where high cloud obscures the lower levels. *I support the NRC Decadal Survey recommendation that NASA launch and test a lidar wind observing system from space to test the ability to provide comprehensive wind observations for the globe—such wind measurements would be expected to have a significant positive effect on hurricane forecasts.*

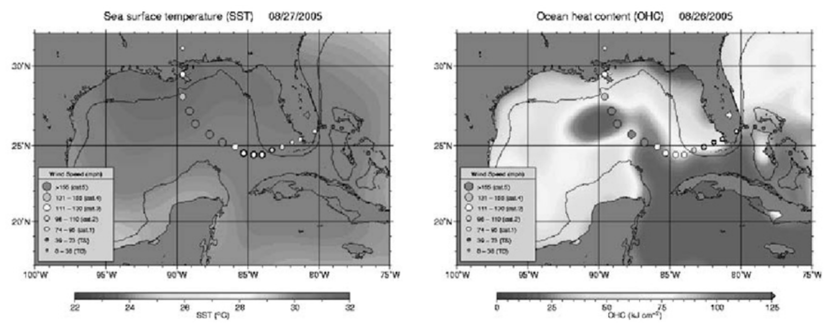


There is a new, exciting technique to make atmospheric soundings of temperature and water vapor from space at a relatively low cost of approximately $3 per sounding. The new technique called radio occultation, or RO, uses the global GPS satellite signals to obtain highly accurate vertical profiles of temperature and water vapor in both cloudy and clear regions, at a very low price compared to other observing systems. In an ongoing proof-of-operational-concept mission, COSMIC, RO data have been shown to have a positive impact on hurricane forecasting. The potential sounding coverage of a full system over the North Atlantic hurricane basin is shown in the accompanying figure. For these, and a number of other reasons, the recent NRC

Decadal Survey has recommended that NOAA implement an operational constellation of RO satellites beginning toward the end of the present research COSMIC mission, in 2010 or 2011. RO data are also very useful climate benchmark data and contribute to space weather. *As recommended by the NRC Decadal Study, NOAA should begin planning for this operational constellation immediately, while ensuring that the COSMIC mission is continued for as long as the satellites are producing good data.*

Ocean Energy

The available ocean energy dictates how intense a hurricane can become. As hurricanes move across changes in this ocean energy they can rapidly intensify or decay and this can be poorly forecast if we have not adequately observed such changes. The observing system must be able to include subsurface conditions, as hurricanes extract energy from below the ocean surface and can mix cold-subsurface water up to the surface. A good example was provided by Hurricane Katrina, as shown in the accompanying figure (from ISRP). A deep warm pool of water associated with the Gulf Stream Loop Current (right panel) was completely hidden below generally uniform sea surface temperatures (left panel). Katrina developed rapidly on moving over this deep warm pool then weakened substantially as it moved toward the coast.

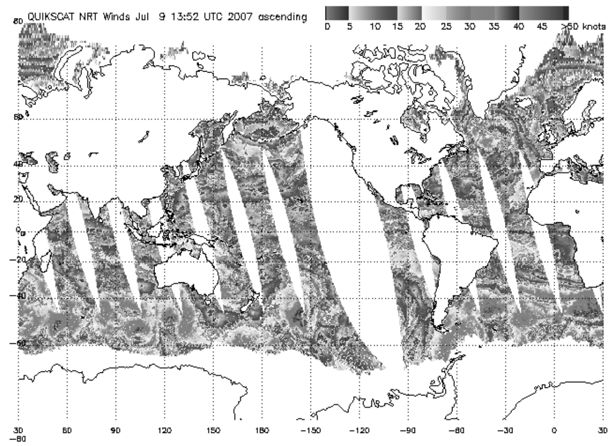


Oceanic instruments previously deployed to drift over long periods or expendable bathythermographs targeted to the expected hurricane track by hurricane aircraft provide one important means of observing this structure. But these can only be applied locally and in special circumstances and aircraft reconnaissance is only available routinely in the North Atlantic and eastern North Pacific, with special missions to the Central Pacific. A much more robust and generally applicable approach is to utilize satellite radar altimetry observations. Because the warm water expands the subsurface warm pools appear as local bulges in the sea surface. Observations of these bulges can be used in ocean models to provide a definition of the subsurface structure that is sufficient for hurricane forecasting.

The loss of the NPOESS altimeter in recent cutbacks is a serious step backward for observing such an important oceanic feature. Satellite altimeter measurements are a cost-effective method obtaining critical information on the upper-ocean energy storage and location of ocean currents.

Surface Wind Structure

Surface wind observations from conventional data, such as surface ships, are patchy and often missing from the vicinity of hurricanes, due to the ships staying well clear. Such surface wind data are important for several reasons: (1) Locating and identifying the initial wind swirl that indicates the development of a new hurricane; (2) Correctly identifying the extent of destructive winds, which is used to warn shipping and emergency managers of the timing of arrival of, for example, gale force winds (these winds may occur many hours before the destructive core to substantially disrupt preparations and evacuations); and (3) assimilating of the correct cyclone surface structure in forecast models impacts the forecasts of track and structure over the full forecast cycle. The only way to obtain such information over the global oceans is via satellite scatterometer observations and the Sea Winds instrument on QuickSCAT has demonstrated real skill in improving hurricane track forecasts as summarized by the IRSP. It is notable that this improvement occurs mostly 2–3 days into the forecast, which clearly indicates the importance of the global nature of the QuickSCAT observations.



Hurricane Reconnaissance

The requirements of an observing system are varied. I have already indicated the importance of global coverage by satellites, especially for the longer-range hurricane forecasts. But these global systems do not provide the depth of detail, spatial density and time resolution required in severe weather systems, such as tropical cyclones. Indeed, it would be a waste of resources to provide such coverage globally, as in many cases it is simply not needed. These data are best provided by adaptive and mobile observing systems that can go to the system of interest and take the required observations.

The U.S.A. has been fortunate to have had routine aircraft reconnaissance in the North Atlantic since soon after WWII. This reconnaissance program has produced a comprehensive long-period record of hurricane structure and intensity that enables current research into the impacts of climate variability and climate change on future risk. It has also ensured the best possible forecast and warning service at a cost that is a fraction of the direct savings. The reconnaissance system has been steadily upgraded, with addition of new platforms and instrumentation. Of particular importance are: the Doppler radar capacity, and particularly coordinated flight plans that enable dual Doppler observations of the total wind structure; GPS dropsondes that provide detailed vertical structure, especially in the poorly observed near ocean layer; and the stepped-frequency microwave radiometer (SFMR), which provides excellent details of the core region surface winds. The addition of the G4 to the aircraft suite, together with GPS dropsondes has provided near environmental information that has demonstrably improved forecast performance. *I recommend in the strongest possible terms that this aircraft reconnaissance strategy be retained and further upgraded.* Initially upgrades should concentrate not on new instrumentation, but on more effective utilization of the data that are currently collected, through effective assimilation into computer models, and on the design of new sampling strategies best suited to support the evolving forecast requirement.

In recent times, adaptive approaches have evolved in research mode to a stage where the computer models are used to define where the best data can be obtained, and the aircraft are directed to obtain these data. An excellent recent example of the effectiveness of this approach in a research field experiment can be seen in the recent NSF-sponsored Hurricane Rainband Experiment (RAINEX).

The aircraft reconnaissance system is now 60 years old and based entirely on manned aircraft. Recent developments with Unmanned Aerial Vehicles (UAVs) and Autonomous Underwater Vehicles (AUVs) have raised the potential for substantial supplementation to the manned aircraft approach. Advantages offered by UAVs is the very long endurance and the capacity to take observations in areas that are too dangerous for manned aircraft and not able to be observed by remote sensing. An example is the near surface atmospheric layer. This is where the hurricane gathers its energy and is the layer that directly impacts coastal and offshore structures through high winds, waves and storm surge. Yet this is also the most under-observed part of the hurricane. There is similar capacity and need for AUVs to be targeted to areas of prime interest for oceanic observations. Such capacity would complement very nicely the operational satellites and drifting or specially deployed buoys. I do caution that care needs to be taken here as some UAV systems cost substantially more than equivalent manned aircraft and this additional cost would need to be justified in terms of the expected forecast improvements.

I fully support the recommendations of an Interagency workshop on UASs, sponsored by NOAA, NASA, and the DOE and held in Las Vegas, Nevada, in February 2006, that an initial demonstration should be conducted for low-level observations, by a UAV in a hurricane. The objective of the demonstration should be to obtain detailed observations of the near-surface tropical cyclone boundary layer environment and to provide information on key questions of whether such observations could: supply data that will improve tropical cyclone intensity forecasts; help improve our understanding of the rarely observed tropical cyclone boundary layer environment; and provide information that successfully fills gaps in the current observing system.

Conclusion

The Nation has entered a difficult and dangerous period of vulnerability to hurricane impacts arising from a combination of sustained enhanced hurricane activity and increasing development in coastal regions. We must respond and I thank the Committee for taking your valuable time to consider an important part of this required response. Satellites are a mainstay of the hurricane forecast process. But this process extends well beyond the taking of observations and other areas are also in need of serious consideration. In my testimony I considered observing systems within the overall hurricane forecasting and warning process. I have identified several areas that should be given priority attention:

- *Data Assimilation and Sampling Strategies:* Every new instrument should be matched with an appropriate level of support for ensuring the data enter the forecast process in an optimal manner. A good working model should be that ~15 percent of all observing system budgets be devoted to both observing system sampling strategies and improved data assimilation;
- *Computer Modeling Capacity:* Without sufficient resources to improve the resolution of hurricane forecast models and their capacity to handle cloud-scale and air-sea interaction processes, our capacity to advance the forecasting of intensity and structure will be severely limited;
- *Satellite Observing Systems:* I have identified three specific priority areas:
    - Lidar measurements of the complete structure of atmospheric winds;
    - Use of GPS Radio Occultation to provide comprehensive atmospheric temperature and moisture observations;
    - Radar altimetry to provide information on the ocean heat energy storage that is available for hurricane intensification;
    - Scatterometer observations of the surface winds to improve location and structure information on hurricanes and to improve longer range forecasts.
- *Aircraft Reconnaissance:* I have stressed the importance of this to the national warning service and have noted several instruments that have been of immense worth in improving forecasts. I also have noted the promising potential of new approaches using UAVs and AUVs to monitor hitherto unobservable components of the hurricane.

Of greatest priority in my view is for there to be a coordinated, well-funded research and system development approach focused on reducing the impacts of hurricanes on vulnerable communities. The review committees that were formed after the disastrous 2005 hurricane season have gathered views and information widely and across all components of the research, operational, engineering, social science and emergency management community. While there are differences of detail, these groups have been unanimous in their call for urgent action and in the general thrust of the actions that are required. These are embodied in the National Hurricane Research Initiative Act of 2007 that is before you for consideration. History has shown that a full partnership between academia and operations with adequate funding will result in substantial forecast advances, including identification of critical observing needs. I urge you to give this urgent and serious attention.

Thank you for the opportunity to address the Committee on the importance of hurricane observations as part of a complete forecast and warning process—a topic that is has taken on increasing urgency as the impact of hurricanes on our vulnerable communities is rising.

Senator NELSON. Thank you, Dr. Holland.

Dr. Busalacchi, who is representing University of Maryland, where he is the director of the Earth System Science Interdisciplinary Center, we want to hear your perspective.

STATEMENT OF ANTONIO J. BUSALACCHI, JR, PH.D., CHAIRMAN, CLIMATE RESEARCH COMMITTEE; CHAIRMAN, COMMITTEE ON EARTH SCIENCE AND APPLICATION: ENSURING THE CLIMATE MEASUREMENTS FROM NPOES AND GOES–R, NATIONAL RESEARCH COUNCIL; AND DIRECTOR, EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER (ESSIC), UNIVERSITY OF MARYLAND

Dr. BUSALACCHI. Thank you, Mr. Chairman, members of the Committee for this opportunity to testify.

In addition, I'm a Professor of Atmospheric and Oceanic Science in the University of Maryland, and past graduate of Florida State University. I also serve as Chair of the National Academies' Climate Research Committee and of the Academies' Panel on Options to Ensure the Climate Record from the NPOESS and GOES–R Spacecraft. This latter study is in response to a NASA–NOAA request to the National Research Council for a follow-on report to the Decadal Survey in Earth Science that focuses on recovery of lost measurement capabilities, especially those related to climate research which occurred as a result of changes to the NPOESS and GOES–R satellite programs.

Three weeks ago, our NRC panel convened a 3-day workshop titled "Options to Ensure the Climate Record from the NPOESS and GOES–R Spacecraft." This workshop attracted some 100 scientists and engineers from academia, government, and industry. The workshop gave participants a chance to review and comment on the NASA–NOAA assessments of the climate impacts associated with the instrument cancellations and de-scopes to NPOESS which occurred following the June 2006 Nunn-McCurdy review, as well as offer input on a variety of suggested mitigation strategies. A report of the workshop will be available later this summer. A final report, with findings and recommendations, will be issued in January.

As the study is still underway, my remarks this morning will be of my own.

The climate community has three basic observational needs. One, sustain continuous and often overlapping measurements of certain key climate parameters critical to monitoring long-term climate trends and to validate climate models. Two, observations to initialize and force global climate prediction models. And, three, new or improved measurements of additional key parameters to advance climate science and reduce uncertainty in our understanding of the climate system.

It is the first and second category of needs which are now threatened by the current NPOESS program, though the third category—indeed, all of Earth science—is implicitly threatened by the cost overruns of NPOESS.

Access to uninterrupted space-based global observations of the atmosphere, oceans, and land surface has enabled breakthroughs in predicting natural climate variability beyond the day-to-day weather time-scale. Today's coupled climate models, initialized by global satellite observations, now routinely issue short-term climate forecasts from seasons out to a year in advance, with the realistic prospect of extension to years and decades.

To discriminate between natural climate variability and anthropogenic climate change requires instrument accuracy and stability greater than that which is normally required—to support weather prediction. Interruptions to the continuity of these climate data records without such accuracy and stability can induce uncertainty that may be as large or larger than the climate signal being monitored.

The present certified NPOESS program will mean a loss or discontinuity of critical climate data records, of total solar irradiance, the Earth's radiation budget, ocean surface topography—that is, sea level—stratospheric ozone, atmospheric aerosol properties, and precise ocean wind speed and direction. These observations are essential to our ability to monitor and predict climate variability and change, and will have a significant impact on the goals of a U.S. climate change research program.

Given the present NPOESS program, our climate monitoring capabilities are neither adequate to meet the needs of the climate research community nor the needs of decisionmakers. The NPOESS de-scopes highlight what has, for too long, been the precarious and loosely coordinated series of climate observations in which the long-term generation and support of climate data records are left out of key agencies' long-term planning.

The Nunn-McCurdy certification of NPOESS has exposed the fact that we do not have an agreed-upon national strategy for long-term, continuous, and stable observations of the Earth system. As the recent NRC Decadal Survey Committee pointed out, sustained measurements with both research and operational applications do not fall clearly into one agency's charter. This results in a metaphorical relay race between NASA and NOAA, where no runner is waiting to be passed the baton.

As it pertains to climate monitoring, then, the relative roles and responsibilities of NASA and NOAA remain uncertain. As a direct consequence, we are faced with a likely gap in critical long-term climate records and a diminished capability to understand and predict climate and related changes on our planet for generations to come.

As we seek to mitigate this situation, applying a Band-Aid, if you will, I urge members of this Committee to carefully consider how we might avoid having a similar hearing in the not-too-distant future.

Right now, we are in a reactive mode with respect to what can only be referred to as the NPOESS debacle. Our Nation needs a deliberate, forward-looking, and cost-effective strategy for satellite-based environmental monitoring. The Nation requires a coherent strategy for Earth observations which provides for operational climate monitoring and prediction, scientific advances, and the continuation of long-term measurements. Our Nation deserves such a strategy.

Thank you for the opportunity to appear before you today, and, at the appropriate time, I will be prepared to take any questions.

[The prepared statement of Dr. Busalacchi follows:]

PREPARED STATEMENT OF ANTONIO J. BUSALACCHI, JR., PH.D., CHAIRMAN, CLIMATE RESEARCH COMMITTEE; CHAIRMAN, COMMITTEE ON EARTH SCIENCE AND APPLICATION: ENSURING THE CLIMATE MEASUREMENTS FROM NPOES AND GOES–R, NATIONAL RESEARCH COUNCIL; AND DIRECTOR, EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER (ESSIC), UNIVERSITY OF MARYLAND

Mr. Chairman, Mr. Vice Chairman, and members of the Committee, thank you very much for this opportunity to testify. I am Dr. Tony Busalacchi, Director of the Earth System Science Interdisciplinary Center and Professor of Atmospheric and Oceanic Science at the University of Maryland. I also serve as the Chair of The National Academies' Climate Research Committee and of the Academies' "Panel on Options to Ensure the Climate Record from the NPOESS and GOES-R Spacecraft." This latter study is in response to a NASA and NOAA request to the National Research Council (NRC) for a follow-on report to the Decadal Survey in Earth Science that focuses on recovery of lost measurement capabilities, especially those related to climate research, which occurred as a result of changes to the NPOESS and GOES-R satellite programs.

On June 19, 2007, our NRC Panel convened a three-day workshop, "Options to Ensure the Climate Record from the NPOESS and GOES-R Spacecraft." The workshop attracted some 100 scientists and engineers from academia, government, and industry. The workshop gave the climate community a chance to review and comment on the NASA/NOAA assessments of the climate impacts associated with Nunn-McCurdy descopes of NPOESS, as well as offer input on a variety of suggested mitigation scenarios. A report of the workshop will be available later this summer. Presentations from the workshop are available for download at: (*http://www7.nationalacademies.org/ssb/SSB_NPOESS2007_Presentations.html*). A final report, with findings and recommendations, will be issued in January. As this study is still underway, the views I express today are my own.

As requested, I will use my time this morning to summarize my views on the status and direction of the Nation's current and planned constellation of weather and environmental satellites. In particular, I will focus on your request for information on the "budgetary, management, and schedule risks of these [weather and environmental] satellite systems, as well as the potential lost capabilities in climate monitoring, modeling, and forecasting that are possible under the current program."

This hearing takes place against the backdrop of significant developments in NOAA weather and environmental monitoring programs and NASA's Earth Science Program:

- In June 2006, the next-generation National Polar-orbiting Operational Environmental Satellite System (NPOESS) completed its "Nunn-McCurdy" certification.[1] As a result, the planned acquisition of six spacecraft was reduced to four, the launch of the first spacecraft was delayed until 2013, and several sensors were canceled or descoped in capability as the program was re-focused on "core" requirements related to the acquisition of data to support numerical weather prediction. "Secondary" sensors that would provide crucial continuity to some long-term climate records and other sensors that would have provided new data are not funded in the new NPOESS program.
- Costs for NOAA's next generation of geostationary weather satellites, GOES-R, have risen dramatically and late last year NOAA canceled plans to incorporate a key instrument on the spacecraft—HES (Hyperspectral Environmental Suite). HES was to provide GOES-R spacecraft with significantly advanced three-dimensional vertical profiles of atmospheric temperature and humidity, and coastal waters imagery to help scientists monitor events like harmful algal blooms or to assist in fisheries management.
- The 2005 National Research Council report, *Earth Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation*[2] described the national system of environmental satellites as "at risk of collapse." That judg-

[1] NPOESS was created by Presidential Decision Directive/National Science and Technology Council (NSTC)–2 of May 5, 1994 wherein the military and civil meteorological programs were merged into a single program. Within NPOESS, NOAA is responsible for satellite operations, the Department of Defense (DOD) is responsible for major acquisitions, and NASA is responsible for the development and infusion of new technologies. In 2000, the NPOESS program anticipated purchasing six satellites for $6.5 billion, with a first launch in 2008. Costs have since escalated dramatically and the expected date of first launch slipped to 2013. By November 2005, it became apparent NPOESS would overrun its cost estimates by at least 25 percent, triggering a so-called Nunn-McCurdy review by the Department of Defense.

[2] National Research Council, *Earth Science and Applications from Space: Urgent Needs and Opportunities to Serve the Nation,* Washington, D.C.: The National Academies Press, 2005.

ment was based on the observed precipitous decline in funding for Earth-observation missions and the consequent cancellation, descoping, and delay of a number of critical missions and instruments.[3] The report also identified the need to evaluate plans for transferring capabilities from some canceled or scaled back NASA missions to the NOAA–DOD NPOESS satellites. Since the publication of that report, NPOESS and NOAA have experienced the problems noted above and NASA has canceled additional missions, delayed the Global Precipitation Mission (GPM) another 2.5 years, and made substantial cuts in its Research and Analysis program.[4]

This hearing also occurs shortly after the completion of the first National Academies *Decadal Survey in Earth Science and Applications from Space* and the recent release by the Intergovernmental Panel on Climate Change of their Fourth Assessment Report. In addition, as you are all aware, there have been numerous news accounts in recent days regarding the fate of a particular spacecraft—QuikSCAT, which measures sea surface wind speed and direction.

Sustained Earth Observations for Operations, Research, and Monitoring

Scientific breakthroughs are often the result of new exploratory observations, and therefore new technology missions stimulate and advance fundamental knowledge about the planet. Analysis of new observations can both test hypotheses developed to elucidate fundamental mechanisms and lead to the development of models that explain or predict important Earth processes. The data from these new technology missions sometimes provide early warning of changes in the Earth system that are critical to our well-being, such as declining ice cover in the Arctic Ocean, developing holes in the protective ozone layer, or rising sea level. To determine the long-term implications of the changes or to uncover slowly evolving dynamics, the measurements must be continued, usually with one or more follow-on missions.

Access to uninterrupted space-based global observations of the atmosphere, oceans, and land surface have enabled breakthroughs in predicting natural climate variability beyond the day-to-day weather time scale. Today's coupled climate models, initialized by global satellite observations, now routinely issue short-term climate forecasts from seasons out to a year in advance with the realistic prospect of extension to years and decades. To discriminate between natural climate variability and anthropogenic climate change requires instrument accuracy and stability greater than is normally required to support weather prediction. Interruptions to the continuity of these climate data records without such accuracy and stability can induce uncertainty that may be as large, or larger, than the climate signal being monitored.

Sometimes data from a new technology mission become critical to an operational system, such as the wind speed and direction measurements from NASA's QuikSCAT mission and precipitation measurements from NASA's Tropical Rainfall Measurement Mission (TRMM), both of which are used in weather and climate forecasting. An obvious but often difficult consequence is that these *research* measurements need to be transitioned into *operational* systems and continued for many years. This is a recognized and well-studied challenge, but, the record of transitioning new technology into the operational system is, at best, mixed.[5] More often than not, the operational utility of data from these research missions is realized toward the end of the design life of the instruments. By then however, it is usually too late to begin the planning of a follow-on operational mission if continuity is to be maintained.

The difficulties in combining the climate and weather requirements on NPOESS as well as the problem in executing what is sometimes referred to as the transition from NASA "research" missions to NOAA operations (which, is effectively the source of the current controversy surrounding the aging QuikSCAT spacecraft) are different aspects of an overarching problem: *the United States lacks a coherent strategy to manage its Earth observation programs in general and its climate observations in particular.* The Nunn-McCurdy certification of NPOESS exposed the difficulty in

[3] *Ibid,* Table 3.1, p. 17.
[4] Total R&A for NASA science missions was cut by about 15 percent in the President's 2007 budget (relative to 2005). In addition, the cuts were made retroactive to the start of the current fiscal year. Over the last 6 years, NASA R&A for the Earth sciences has declined in real dollars by some 30 percent.
[5] Transition failures have been exhaustively described in previous NRC reports. See National Research Council, *Extending the Effective Lifetimes of Earth Observing Research Missions,* Washington, D.C.: The National Academies Press, 2005 and National Research Council, *Satellite Observations of the Earth's Environment: Accelerating the Transition from Research to Operations,* Washington, D.C.: The National Academies Press, 2003. These publications are also available on-line at *<http://www.nap.edu/catalog/11485.html>* and *<http://www.nap.edu/catalog/10658.html>,* respectively.

sustaining long-term climate observations within a program managed by agencies with different priorities and missions. Whereas NOAA and DOD have complementary priorities with respect to weather prediction, the same does not hold for climate. Moreover, the stability, calibration, and technology refresh requirements for climate observations call for a flexible systems approach consisting of a mix of small climate-specific satellites, formation flying, and single sensor "free flyers", as opposed to the (small school bus) one-size fits all series of "*Battlestar Gallactica*" NPOESS platforms.

Our ability as a nation to sustain climate observations has also been complicated by the fact that no single agency has the mandate and requisite budget for providing routine climate observations, prediction, and services. As stated in the January 2007 National Research Council pre-publication of the "Decadal Survey," *Earth Science and Applications from Space:*[6]

> The Committee is concerned that the Nation's institutions involved in civil space (including NASA, NOAA, and USGS) are not adequately prepared to meet society's rapidly evolving Earth information needs. These institutions have responsibilities that are in many cases mismatched with their authorities and resources: institutional mandates are inconsistent with agency charters, budgets are not well-matched to emerging needs, and shared responsibilities are supported inconsistently by mechanisms for cooperation. These are issues whose solutions will require action at high-levels of the government.

For example, in a recent NRC review of NASA's 2006 Draft Science Plan[7] the Committee noted that the "NASA/SMD (Science Mission Directorate) should develop a science strategy for obtaining long-term, continuous, stable observations of the Earth system that are distinct from observations to meet requirements by NOAA in support of numerical weather prediction." Accordingly, the Decadal Survey committee recommended that, "The Office of Science and Technology Policy, in collaboration with the relevant agencies, and in consultation with the scientific community, should develop and implement a plan for achieving and sustaining global Earth observations. This plan should recognize the complexity of differing agency roles, responsibilities, and capabilities as well as the lessons from implementation of the Landsat, EOS, and NPOESS programs."

I will now turn to the specific questions about the programs under consideration: *What are the potential lost capabilities in climate monitoring, modeling, and forecasting?*

NPOESS: As noted in a recent NASA–NOAA report, which was performed at the request of the White House Office of Science and Technology Policy, "For more than thirty years, NASA research-driven missions, such as the EOS, have pioneered remote sensing observations of the Earth's climate, including parameters such as solar irradiance, the Earth's radiation budget, ozone vertical profiles, and sea surface height. Maintaining these measurements in an operational environment provides the best opportunity for sustaining the long-term, consistent, and continuous data records needed to understand, monitor, and predict climate variability and change."[8] However, the Nunn-McCurdy certification placed a priority on the continuity of operational weather measurements at the expense of climate measurements. In addition, the post-certification constellation eliminated the "mid-morning" orbit and reduced the planned acquisition of six spacecraft to four. NASA and NOAA have completed their preliminary assessments of the impacts of these changes, focused primarily on the de-manifested sensors. Their assessment is documented in a white paper prepared for OSTP. Rather than go into the details of their assessment or repeat it here, a brief summary of the climate impacts associated with de-manifestation of these sensors is included in the Appendix.

QuikSCAT: QuikSCAT continues to function well and provide all-weather observations of ocean surface wind speed and direction, although it is five-years beyond its design lifetime and it is operating on a backup communication system. Should QuikSCAT fail, the United States would have to rely on the ASCAT instrument on the European MetOp system and on data currently provided by the WindSat spacecraft. Both of these systems have drawbacks compared to QuikSCAT—ASCAT has

[6] National Research Council, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond,* The National Academies Press, Washington, D.C., 2007. Available online at: <*http://www.nap.edu/catalog/11820.html*>.

[7] National Research Council, *A Review of NASA's 2006 Draft Science Plan: Letter Report*, The National Academies Press, Washington, D.C., 2006. Available online at: <*http://www.nap.edu/catalog/11751.html*>.

[8] "Impacts of NPOESS Nunn-McCurdy Certification on Joint NASA-NOAA Climate Goals," NOAA-NASA Draft White Paper, January 8, 2007.

large gaps in coverage compared to QuikSCAT and analyses to date of WindSat data expose serious concerns about the utility of passive polarimetric measurements of surface wind speed and direction in low and high wind regimes for research and operational applications. Further, the capabilities of the successor to Windsat, the MIS instrument planned for NPOESS, are still unknown and NOAA does not plan to incorporate the instrument on NPOESS until launch of the second spacecraft in 2016 at the earliest. The National Academies Decadal Survey recommended a follow-on mission to QuikSCAT—XOVWM—to be launched in the 2013–2016 time frame. It is my understanding that the Survey's choice of this time period, *versus* one sooner, was based on an examination of expected resources and the need to launch other priority missions.

GOES-R: the loss of HES is of higher priority for numerical weather prediction and monitoring of coastal waters than it is for climate. The impact to climate research is the loss of ability to track changes in the intensity and frequency of extreme events such as hurricanes, floods, wildfires, and harmful algal blooms as modulated by climate variability and change.

Overview of Climate Needs

The climate community has three basic observational needs: (1) sustained (continuous, and often overlapping) measurements of certain key climate parameters critical to monitor long-term climate trends and to validate climate models, (2) observations to initialize and force coupled climate prediction models, and (3) new or improved measurements of additional key parameters to advance climate science and reduce uncertainty in our understanding of climate processes and interactions within the coupled climate system. It is the first and second category of needs which are now threatened by NPOESS, though the third category—and indeed all of Earth science—is implicitly threatened by the cost overruns of NPOESS, which have had great impact on already-tight Earth Science budgets. This impact will increase as the agencies attempt to assure continuity of the most critical of climate records by altering upcoming flight manifests, restoring instruments to NPOESS, or designing "gap-filler" missions.

Mitigation Challenges

Any strategy to mitigate the impacts of the loss of these sensors begins with a prioritization of their importance and an assessment of the cost and risk of various recovery options. Such an assessment is the subject of the ongoing National Research Council study that I chair; it is also the subject of an Office of Science and Technology Policy (OSTP)-requested study that is being executed by NASA and NOAA. The range of options under study include re-manifesting selected sensors to the NPOESS platforms, making use of ongoing and planned missions by international partners, launching selected sensors on missions of opportunity or on new spacecraft, and assimilating data from multiple sources to help reconstruct the lost data.

It is also important to recognize the limitations of some of the climate sensors on NPOESS even before the Nunn-McCurdy actions. For example, from its sun-synchronous orbit, altimeter measurements of sea-surface height (SSH) via the ALT instrument would contend with the effects of tidal aliasing. The precise record of SSH that began with the Topex/Poseidon mission (and continues with Jason-1 mission, which should overlap with the 2008 of Jason-2) derives from instruments on spacecraft that are *not* in sun-synchronous orbit. Moreover, as emphasized repeatedly in recent NRC studies, the generation of credible climate records requires investments in pre-launch instrument characterization, on-orbit calibration and validation, and a ground support system that has the requisite resources to archive, disseminate, analyze, and periodically re-analyze the data. Appropriate investments in this critical part of the chain from raw data to climate data record were never part of the NPOESS program. Indeed, their absence is indicative of the problem that arises when the very different needs of the climate community are effectively piggybacked on the needs of numerical weather forecasters from both the DOD and civil communities.

Recovery strategies also must take account of plans for execution of the NRC Decadal Survey. The Decadal Survey was sponsored by NASA (Office of Earth Science), NOAA (NESDIS), and the USGS (Geography). While cognizant that space-based observations were only part of a credible Earth observing system, it was charged with:

- Articulating priorities for Earth system science and the space-based observational approaches to address those priorities.

- Establishing individual plans and priorities within the sub-disciplines of the Earth sciences as well as providing an integrated vision and plan for the Earth sciences as a whole.

The relevance of the recommended Decadal Survey missions mapped against demanifested NPOESS sensors is shown in Table 1 below. It is important to note that the decadal strategy covers all of Earth science, including but not limited to climate science. Though I am limiting my remarks here to discuss those elements related to climate and of relevance to the NPOESS and GOES-R considerations, I support the report's call for a balanced Earth Science program. Of particular interest for NPOESS mitigation strategies in the near-term is the recommendation for an early start of the CLARREO radiance mission. A more capable ocean vector wind follow-on to QuikSCAT—XOVWM—is also called out to start in the period from 2013–2016.

In summary, our climate monitoring capabilities are neither adequate to meet the needs of the climate research community nor the needs of decisionmakers. The NPOESS descopes highlight what has for too-long been a precarious and loosely coordinated series of climate observations in which the long-term generation and support of climate data records are left out of key agency's long-term planning. The Nunn-McCurdy certification of NPOESS has exposed the fact that we do not have an agreed upon national strategy for long-term, continuous, and stable observations of the Earth system. As the recent Decadal Survey committee pointed out, sustained measurements with both research and operational applications do not fall clearly into any one agency's charter. This results in a metaphorical relay race between NASA and NOAA, where no runner is waiting to be passed the baton.

As it pertains to climate monitoring, the relative roles and responsibilities of NASA and NOAA remain uncertain. As a direct consequence, we are faced with a likely gap in critical long-term climate records and a diminished capability to understand and predict climate and related changes on our planet for generations to come. As we seek to mitigate this situation, applying a band-aid if you will, I urge members of this Committee to carefully consider how we might avoid having a similar hearing in the not too distant future. Right now, we are in a reactive mode with respect to what can only be referred to as the NPOESS debacle. Our nation needs a deliberate, forward looking, and cost-effective strategy for satellite-based environmental monitoring. The Nation requires a coherent strategy for Earth observations which provides for operational climate monitoring and prediction, scientific advances, *and* the continuation of long-term measurements. The Nation *deserves* such a strategy. Thank you for the opportunity to appear before you today on this important topic. I am prepared to answer any questions you may have.

Table 1. Contributions of recommended Decadal Survey missions to continuation or expansion of Environmental Data Records (EDRs) as defined by the NPOESS Integrated Operational Requirements Document (2001). Current status of NPOESS's planned capabilities to obtain the EDRs is also shown.

Descoped/degraded EDR	NPOESS status	Relevant decadal survey contribution
Soil moisture	Degraded	SMAP
Aerosol refractive index/single-scattering albedo and shape	Demanifested	ACE
Ozone total column/profile	Reduced Capability (Column only)	GACM
Cloud particle size distribution	Demanifested	ACE
Downward LW radiation (surface)	Demanifested	CLARREO
Downward SW radiation (surface)	Demanifested	CLARREO
Net solar radiation at TOA	Demanifested	CLARREO
Outgoing LW radiation (ToA)	Demanifested	CLARREO
Solar irradiance	Demanifested	CLARREO
Ocean wave characteristics/significant wave height	Reduced Capability	XOVWM
Sea surface height/topography—basin scale/global scale/mesoscale	Demanifested	SWOT

EDR dependent on CMIS replacement	NPOESS sensor	Relevant ESAS contribution
Atmospheric vertical moisture profile	CrIS/ATMS/CMIS (replacement)	PATH, GPSRO, CLARREO
Atmospheric vertical temperature profile	CrIS/ATMS/CMIS (replacement)	PATH, GPSRO, CLARREO
Global sea surface winds	CMIS (replacement)	XOVWM
Imagery	VIIRS/CMIS (replacement)	HyspIRI
Sea surface temperature	VIIRS/CMIS (replacement)	PATH
Precipitable water/Integrated water vapor	CMIS (replacement)	ACE
Precipitation type/rate	CMIS (replacement)	PATH
Pressure (surface/profile)	CrIS/ATMS/CMIS (replacement)	GPSRO, CLARREO
Total water content	CMIS (replacement)	ACE
Cloud ice water path	CMIS (replacement)	ACE
Cloud liquid water	CMIS (replacement)	ACE
Snow cover/depth	VIIRS/CMIS (replacement)	SCLP
Global sea surface wind stress	CMIS (replacement)	XOVWM
Ice surface temperature	VIIRS/CMIS (replacement)	
Sea ice characterization	VIIRS/CMIS (replacement)	SCLP, ICESat–II

NOTE: MetOp contributions to EDRs and space weather-related EDRs are not listed here.

APPENDIX: BRIEF SUMMARY OF CLIMATE IMPACTS DUE TO DE-MANIFESTED NPOESS SENSORS[9]

The certification eliminated five key NPOESS "climate" sensors—TSIS, ERBS, ALT, OMPS-Limb, and APS. Either as result of an instrument descope or as a result of the reduction from three orbits to two, the certification also impacted the capability of CMIS, VIIRS, and CrIS measurements that support climate research.

1. Total Solar Irradiance Sensor (TSIS), a de-manifested sensor:

Impact: These measurements monitor the energy of the sun incident on Earth. Measurements of TSI are essential to discriminate between natural and anthropogenic causes of climate change. Further, these measurements can be accurately determined only above the atmosphere. Any interruption of the 28-year data record of Total Solar Irradiance jeopardizes our ability to confidently resolve small changes in this most fundamental variable and adds uncertainty to climate change attribution.

2. Earth Radiation Budget Sensor (ERBS), a de-manifested sensor:

Impact: This measurement monitors the incoming and outgoing energy to the Earth-atmosphere system that maintains climate and it can be accurately determined only above the atmosphere. Overlap between space-based sensors is critical to confidently detect and monitor the small changes in the Earth's radiation balance capable of affecting climate.

3. OCEAN Altimeter (ALT), a de-manifested sensor:

Impact: Ocean topographical data are vital to study the role of ocean circulation and the associated thermal transport in the climate system, sea level rise, assessing the severity of hurricanes, tracking costal ocean currents, and aiding in the forecasting of natural disasters. Sea level measurements are the climate change indicators of most direct concern for a substantial proportion of the U.S. and the world's population, most of whom live near the coast. These observations provide critical input to El Niño and short-term climate forecasts.

4. Ozone Mapping and Profiler Suite Limb Subsystem (OMPS-Limb), a demanifested sensor:

Impact: Stratospheric ozone absorbs incoming solar ultraviolet radiation that can be harmful to humans and other organisms. Anthropogenic emissions of halogen-

[9] Adapted from "Impacts of NPOESS Nunn-McCurdy Certification on Joint NASA-NOAA Climate Goals," NOAA-NASA Draft White Paper, January 8, 2007.

containing gases (*e.g.,* Freon®) are now known to destroy stratospheric ozone. The Montreal Protocol on Substances Depleting the Ozone Layer has resulted in successful international actions to reduce atmospheric concentrations of halogen-containing gases. The continuation of stratospheric ozone observations is crucial to monitor and evaluate the recovery of the ozone layer.

5. Aerosol Polarimetry Sensor (APS), a de-manifested sensor:

Impact: Aerosol properties are a high priority in the U.S. Climate Change Science Program. The effects of aerosols on global temperature and cloud properties are significant and may be comparable in importance to the role played by "greenhouse" gases, such as carbon dioxide and methane, which contribute to the warming of the Earth's surface. Given the expected continued industrialization of developing nations such as China and India, aerosol observations are a critical climate variable.

6. Conical Microwave Imaging Scanner (CMIS), a de-scoped sensor:

Impact: The original CMIS design was to provide information on the following essential climate variables: sea surface temperature (SST), sea ice and snow cover extents, vegetation, ocean surface wind speed, water vapor, and precipitation rates. Specifications for the reduced capability MIS will not be available until September. Serious concern exists regarding the SST and wind vector retrievals from such an instrument.

Senator NELSON. Thank you, Dr. Busalacchi.

Senator Sununu, you have to leave, so you are recognized.

Senator SUNUNU. Well, I'll start with you, Dr. Busalacchi. You talk about the need for a more integrated strategy, better coordination between NASA and NOAA, but in your statement you didn't actually make any recommendations as to how the system or the approach can be improved. Do you have any recommendations for us as to specific changes, modifications in either the planning process or the technology use?

Dr. BUSALACCHI. That is what our Committee is going to be taking on over the next 6 months. Among the issues are: How do you maintain the long-term climate record and insert new technology? And so, there needs to be a phasing and better collaboration between the two agencies, where we can insert new technology into the data stream while maintaining the current record.

This also requires us—that we start looking at, in advance—the issue we have right now is—once the research satellite is up, and is proven valuable—even though it's a research satellite, by the time that satellite passes its design lifetime, it's almost too late to start planning the replacement operations. And so, at the very beginning of the research satellite mode, NASA and NOAA need to be getting together—and that's begun within the past 2 years as a result of a working group between the two agencies—to start looking at the follow-on before the data record is broken; start planning, where appropriate, the follow-on operational sensor.

Senator SUNUNU. Well, I hope your Committee will forward its recommendations when you have them. Thank you.

Dr. Freilich, you talked a little bit about the VIIRS sensor, maybe some of the problems that you've had with that sensor. I missed that part of your testimony, or—you know, I don't know a great deal about the technology. Could you describe, in a little bit more detail, what the issues are with the VIIRS?

Dr. FREILICH. The primary outstanding issue—and there have been many issues that have been solved so far—the primary outstanding issue is, one, related to the accuracy of the radiometer measurements at high spatial resolution that are specifically used to measure ocean color and productivity near the coast. And it's especially clear near the coastline. It's called "optical crosstalk." And——

Senator SUNUNU. Well, will that—will those issues be resolved, or will that capability not be included in the final product?

Dr. FREILICH. At present, we are testing the first flight unit, which is to fly on NPP, the NPOESS Preparatory Program. That test is being done in the Integrated Project Office. NOAA–DOD are providing that instrument. Based on those tests, and NASA, NOAA, and IPO analyses of those tests, we are moving forward— or they are moving forward to try and find mitigation strategies. Some may involve changes to the design of the instrument, some may involve smaller changes. At the moment, that's where we are, though, we're testing the first flight——

Senator SUNUNU. Understood. Do you think that the GAO assessment was a fair assessment? And was there anything in the GAO study that you think either overstated problems or were—was there anything left out of the GAO evaluation that you would have liked to have seen?

Dr. FREILICH. I thought that it—overall, that it was a fair assessment of the NPOESS program.

Senator SUNUNU. You talked a little bit about QuikSCAT in your statement. I think you indicated that there was a proposal, at this point, for a 2013 mission to replace, or build on, some of these capabilities. Does a sensor for these wind currents at ocean level need its own platform, or could sensing equipment for that—those parameters be included on other platforms in the future?

Dr. FREILICH. Let me clarify, sir. The Decadal Survey recommended two things for NOAA. One of them is that they—that NOAA continue the QuikSCAT-level time series of measurements of ocean surface wind speed and direction over the ocean under all weather conditions. And the second recommendation was that, starting in the 2013–2016 time frame, the NRC recommended, that NOAA operationalize an advanced scatterometer instrument.

Senator SUNUNU. And my question is, would that advanced scatterometer equipment need its own platform, or could it be incorporated onto another platform?

Dr. FREILICH. It does not need its own platform.

Senator SUNUNU. QuikSCAT is an independent platform right now, correct?

Dr. FREILICH. It is. Actually, I was the principal investigator for—mission principal investigator for QuikSCAT. I also helped to design NASA's other two recent scatterometers. Those other two— NSCAT and SeaWinds—were instruments that were provided to another platform, and QuikSCAT is its own integrated single mission. So, we've actually flown scatterometers both as instruments on other platforms and as a dedicated mission, like QuikSCAT.

Senator SUNUNU. One final question for, Dr. Holland. You just made a reference that I didn't quite understand. You said, in your statement, that if there was a tropical storm off the coast of Florida today, and we were trying to predict its path, the forecast of that path would be dependent on observations in China from 7 days ago. That doesn't seem to make sense to me. It seems that the projection of its path today, for the coming days, would be dependent on existing conditions, not just in Florida, but around the world today, but not on conditions from 7 days ago.

Dr. HOLLAND. The problem is—and we found this out very early on, when we started doing computer-based modeling of the atmosphere—that if there is—an error gets into the modeling system, when that error is in there, and we bring new data into the system, the data are used to modify the monitoring system. And let's take an almost trivial example. Say there was no data between where that error occurred—no additional data brought in—and, when you got the hurricane, an error would still be there by the time it got there. There are other data along the way, and there are modifications to that error. But the point, nevertheless, remains that you can't have a significant—significant error in the analysis—not just the forecast, the analysis and the ongoing forecast over Florida or over the East Coast or in other parts of the North Atlantic, based on problems that have occurred earlier on in the forecast analysis process.

A good example of this is that when we first started computer-based modeling of the atmosphere here, we started doing it on a regional basis. We found that didn't work. We then went to a hemispheric basis, and we found that didn't work. And we found we actually had to go to a global basis even just to run the regional models for the Florida region.

And I think it's an important point that is often overlooked in this, this overall process. The local observations in the vicinity of the hurricane are extremely important, but so are the observations taken elsewhere in the globe over the longer periods, and especially as you go out to 4 or 5 day time periods.

Senator SUNUNU. Thank you, Mr. Chairman.

Senator NELSON. Thank you, Senator.

Would you put up this chart, please?

This is what has happened to the sensors that were originally planned on the combination NOAA and DOD, (Department of Defense) satellite, called NPOESS. Several of the sensors that were canceled, four that were canceled. We had four that were degraded. There are only 5 remaining sensors that will go on the new NPOESS.

The aerosol polarimetry sensor, radar altimeter, survivability sensor, total solar irradiance sensor—they're gone. The conical scan, the microwave, the Earth radiation belt sensor, the ozone mapper, the space environmental sensor—they're degraded.

Now, if the community—between the Defense establishment and the weather establishment, thinks that all of these things are needed, but we are down to the point at which we're canceling two-thirds of the sensors on this thing, I want to ask Dr. Holland and Dr. Busalacchi, what's going to be the impact to weather forecasting if those de-manifested sensors are not restored to NPOESS?

Dr. HOLLAND. Thank you, Mr. Chairman.

Senator NELSON. And then, I want you to answer, what's going to be the impact on climate study?

Dr. HOLLAND. I will address the impact on the weather sensors. I'll leave it to my colleague to address the climate study.

Senator NELSON. OK. And let me just say, I've got to end this hearing at 11:30, because we've got a major vote that's going to occur at that point. So, if you will keep your answers very concise.

Dr. HOLLAND. I'll be very brief. I can say that there have been a number of peak bodies that have met and discussed this topic from the weather perspective. The impact will be substantial. I don't want to go into the details of the substantial nature of that. To some extent, the current observing system can be stretched to accommodate some of the impact. It cannot accommodate all of the impact. And the reality is that there will be forecasts and warnings of severe weather and other atmospheric phenomena that are not as good as they should be; indeed, not even up to the—to what we would have expected to be happening in the future. And, as some research instruments degrade and disappear, that problem will only get worse.

Senator NELSON. Dr. Busalacchi?

Dr. BUSALACCHI. With respect to climate, that chart up there really illustrates—to abuse the words of Neil Armstrong—right now we're taking one giant leap backward for mankind. Five of those sensors—total solar irradiance, the major driving energy force for the planet—we'd be breaking a 20 year record. In terms of the debate between anthropogenic forcing and natural variability, we've seen that these changes are small. They actually have been decreasing, but we still need to continually monitor.

Earth radiation budget, we need to monitor what's coming into our planet, what's going out, so we can, again, understand how the temperature is rising on our planet.

Ocean surface topography, we need to monitor, globally, sea-level rise. And these observations are the major input that drives short-term climate forecasts and our ability to predict the El Niño phenomenon.

Stratospheric ozone looks at the vertical resolution of stratospheric ozone, the depletion of the ozone layer, and now the recovery, post-Montreal Protocol. Without that Limb sounder, we will not have that ability to resolve the vertical abundance of ozone.

Atmospheric aerosol properties is another—once you get beyond greenhouse gases, one of the largest uncertainties is—in the coupled climate system is atmospheric aerosols. With the continued industrialization of China and India, as a Nation we need to be monitoring and understanding, What are these direct, and these indirect, effects of aerosols?

And we've already discussed the issue of surface winds from scatterometry. From the climate perspective, the surface winds are the major forcing function that moves heat around the ocean, and that's what modulates the coupled climate system and allows us to have this predictive capability.

So, without those five sensors, we're going to be going blind with respect to our ability to monitor and predict climate in the years to come.

Senator NELSON. All right.

Ms. Kicza, you've heard the statements of these two gentlemen. Why did we let our—do you agree with those statements? And why did NOAA and NASA let it get into this condition?

Ms. KICZA. Yes, sir, I do agree with the statements, in terms of the severity of the impact of the decisions, relative to the NPOESS Nunn-McCurdy certification. What I will also acknowledge is that it is critically important that we maintain continuity with the NPOESS platform. And the tri-agency Executive Committee jointly came to the conclusion that, in order to preserve weather continuity and to maintain a technical complexity of the system to allow us to deliver in the 2013 time frame, that we had to reduce the number of sensors on the platform.

In the wake of that decision, NOAA and NASA, with the Administration, have been actively engaged in identifying options to mitigate this current situation. And, in fact, as Dr. Busalacchi had indicated, we're working closely with the research community to examine those options so that, as we move forward, we move forward with the right decisions.

Senator NELSON. So, the bottom-line answer is, we let ourselves get into this position, there is no way out, except to cancel these and then try to make up for lost time later.

Ms. KICZA. We got into a position, with the NPOESS program, where we could not meet the continuity objective. That was due, in large part, to the maturity of the instruments, not being as mature as had been anticipated, and to the late understanding of that situation. As David Powner has indicated, that was recognized, as part of the Nunn-McCurdy process, and we have put steps in place, on both NPOESS and lessons learned in GOES–R, to avoid that situation in the future. That does not suggest that the decisions that were made do not have significant impact, and that's why we're also working very closely to identify how to mitigate the impacts of those decisions.

Senator NELSON. The Administration comes out with 5 year plans. Do we have, in the next 5 years, the plan to start the restoration of these instruments that have been canceled or degraded?

Ms. KICZA. Sir, as we indicated in the FY07 budget, we've already made decisions to begin to restore those capabilities. NASA and NOAA have jointly funded the OMPS-Limb sensors so that a full ozone suite can be available on the NPP spacecraft, which is scheduled for launch in 2009. As an integral part of the 2009 budget, we're actively engaged in looking at every one of those sensors, to identify options to either re-manifest them on the NPOESS platform or to look to other platforms where those sensors can be manifested so as to maintain the continuity of the climate record.

Senator NELSON. So, in the next 5 years, are we going to see all of those start to be restored?

Ms. KICZA. Those are the decisions that are being discussed, as we speak, as part of the 2009 budget development process.

Senator NELSON. I'm going to turn to my colleague here, but let me just ask this. The GAO has reported that there are too many cooks in the kitchen. You've got a hydra-headed monster here who can't decide which way it wants to go. What is your proposal for that?

Ms. KICZA. I can provide you my personal observations. I've been in this position a relatively short time, but what I have seen is, in the wake of the Nunn-McCurdy decision, the level of management attention and the level of agreement and cooperation and rapid response to any issues that have been brought forward with NOAA has been quite impressive. The Executive Committee, consisting of Dr. Sega, Dr. Griffin, and Vice Admiral Lautenbacher, meet on a regular basis formally, and they have teleconference discussions in between those formal discussions in order to make sure that decisions are made in a timely fashion.

Senator NELSON. It's been said, in NASA circles, that NASA knows how to design, build, launch, and operate satellites, and NOAA doesn't, but NOAA was given this responsibility. What do you say to that?

Ms. KICZA. I say that we have taken close heed to the lessons learned with the NPOESS program, and we've recently made decisions on the forward strategy for the GOES–R program, in terms of the management and acquisition, in which each of us relies on our inherent strengths and competencies. As a result of that, we've made the decision to have NASA be responsible for the development of the instruments, the development of the spacecraft, and the support of the launch vehicle systems. NOAA, that has an operational record for ground systems since the early 1960s, as you've identified, has responsibility for the ground segment.

So, yes, we are paying attention to the concerns that have been expressed about falling back on where our strengths are.

Senator NELSON. So, the long and short of that is, NASA's going to take back the building and launching of the satellite, and NOAA is going to operate it.

Ms. KICZA. In the GOES–R arena, yes, that is the direction we've moved to.

Senator NELSON. How about the follow-on to NPOESS?

Ms. KICZA. In terms of the follow-on to NPOESS, that's a future discussion, sir. We have not yet addressed that.

Senator NELSON. Well, it might be instructive to hear, then, if you've decided that on GOES–R, are you going to do that on NPOESS?

OK, Senator Cantwell?

STATEMENT OF HON. MARIA CANTWELL, U.S. SENATOR FROM WASHINGTON

Senator CANTWELL. Thank you, Mr. Chairman. And thank you for holding this hearing and conducting such a thorough review of such an important area. I know that it's of specific interest to your region of the country. It is not of any less significance in our region, as weather and climate play an incredible role in everything from our hydro system to our coastline to a variety of things. So, getting this information right is important.

I hope I can enter a longer statement in the record.

Senator NELSON. Without objection.

Senator CANTWELL. I also am concerned today, I don't know where, in this short period of time we have left, to dig in, because I think that this is an issue of management and management oversight, or failure of management oversight. Maybe even from the pure structural level; failure in oversight on this budget as it relates to this contractor and the way the contract is run, and the cost overrun on this contract. The fact that a recent reassessment in baseline is now being moved away from, and it was just done last month, shows me that people haven't come with a realistic certainty here about what it's going to take to get this right. And then, there is the science itself. I could launch into the whole question of whether the Administration is even serious about getting access to this information, given what I think it means, and the importance of what it means in climate change. But I'll try to be more specific, because, first of all, I don't want anybody out there to get lost in all our acronyms.

And I want to start with you, Dr. Busalacchi, is that correct, Busalacchi? Thank you. About these national polar environmental satellites. They're there for a reason. And my understanding is, we're trying, on the climate side, I'll leave the other assessments to my colleague from Florida, but we're trying to assess, through these various sensors that are now not being funded, the change in sea-surface temperature that we know has been linked to climate change, and it also has been correlated with the intensity of hurricanes. Is that not correct? I mean, I don't know if it's all conclusive yet, but we're trying to understand that correlation. The reason why we're trying to understand that, and that the sensors that we now won't have, to better understand it, is that these sea-surface changes have dramatic impacts on the intensity, or the potential intensity, of hurricanes. And that's what we want to study and understand. Is that correct?

[The prepared statement of Senator Cantwell follows:]

PREPARED STATEMENT OF HON. MARIA CANTWELL, U.S. SENATOR FROM WASHINGTON

Thank you, Senator Nelson.

Our Nation's climate and weather satellites are among the most vital services our government provides.

By supplying critical data, satellites allow forecasters to predict dangerous weather and enable climate scientists to foresee dangerous long-term trends like global warming.

The bottom line is, satellites help protect us all.

Hurricanes threaten the Southeast and Gulf of Mexico regions. Tornados tear through towns and cities in the Midwest. And dangerous coastal storms frequent my home State of Washington.

Because of moments like these, we rely on our climate and weather satellites every day.

Our Nation's fleet of climate and weather satellites should be the best in the world, and maintaining that fleet is essential. Our citizens deserve no less.

The Problem

We are not here today, however, to simply praise the importance of our climate and weather satellites. That fact is self-evident.

We are here because the future of our climate and weather satellites is in serious doubt.

Faced with massive cost overruns and schedule delays, it is uncertain which satellite capabilities our government will be providing in the future. It is also uncertain whether the satellites of the future will protect us as much as our current satellites.

I believe that in order to fix a problem, we must first agree on what that problem is—and precisely how serious it is.

Climate Change Sensors Cut

From an initial look at the satellite program, I am particularly concerned about the elimination of key climate sensors vital to our national interest.

During a recent review of the NPOESS satellite system, most of the climate sensors were eliminated because of the program's multi-billion dollar cost overruns.

I understand that for both the National Oceanic and Atmospheric Administration (NOAA) and the Department of Defense, maintaining the weather sensors is a higher priority than climate sensors.

I am extremely concerned to see, however, that we are *cutting* our climate monitoring capabilities at the exact moment when we should be *increasing* them.

Climate change is a dangerous threat with enormous implications for our Nation. The notion that we are cutting sensors that monitor climate change—precisely when we need them the most—is unacceptable.

Poor Program Management

I am also extremely concerned about the poor management of our satellites programs.

Our climate and weather satellites were being bought under a system called "Shared System Program Responsibility". Under this system, responsibility for oversight was given to a single lead private contractor.

Senator Snowe and I have extensive experience with this type of management system through our oversight of the Coast Guard. The Coast Guard's troubled Deepwater program used a similar management system called a lead systems integrator.

The parallels between these programs' failures are extremely troubling.

For example, in both programs the lead contractors consistently received massive award fees despite repeated failures.

In the case of the NPOESS satellite program, the lead contractor has received over $123 million in award fees for "success," despite running the program billions of dollars over-budget and years behind schedule.

If that is success, I would hate to see what failure looks like.

Conclusion

When dealing with precious taxpayer dollars and the safety of our citizens, we have an obligation to do far better.

I appreciate the optimistic assessments put forth by the satellite programs, but optimism can also be very dangerous.

I believe that in this circumstance, what we need most is a candid discussion about the realities of where we're at and where we're headed. Only by directly and aggressively facing problems up-front, can we move forward successfully and responsibly.

I thank you all for being here and I look forward to your testimony.

Dr. BUSALACCHI. That is correct. And that's why it's so important—that's why it's so important we not have a break in the record, because continuity is so important, because we're looking at the time rate of change, how these extreme events may be changing on the time scales from years to decades. And so, that's why, again, it's so important that we not have these breaks in the record. And, as that chart shows, that's what we're up against.

And with respect to the previous discussion, as it pertains to NPOESS, the NPOESS priority ended up being weather. What we've learned for climate, we need more of an adaptive systems approach, a much more flexible approach, where we not rely on the one-size-fits-all *Battlestar Galactica* sorts of platforms that have really boxed us into and reduced our flexibility to continue some of these sensors.

Senator CANTWELL. But we're cutting that now. Is that——

Dr. BUSALACCHI. That's correct.

Senator CANTWELL.—right? We're cutting that information availability.

Dr. BUSALACCHI. That—we're cutting that. But then, we——

Senator CANTWELL. But——

Dr. BUSALACCHI.—don't know what we're replacing it with.

Senator CANTWELL. For us in the Northwest, we know that—we know that every 300 years we're going to have a tsunami. To know that, analyze it, study that, study that impact and have plans in our community, is critically important. to not have continuity in climate change information, to me it is shortsighted and absurd, to be throwing out this information at a time when we know that climate change is having an impact and that we need to understand its impact on our weather.

Now, to the contract, because I think this is very important. This contract included an award fee incentive making it possible for contractors to earn up to 20 percent of the total estimated cost. Is that not correct, Mr. Powner or Ms. Kicza?

Ms. KICZA. Yes, the contract, prior to the Nunn-McCurdy, did have a 20 percent total fee.

Senator CANTWELL. And usually, I think GAO, you did an analysis that determined that less than 1 percent of DOD-awarded contracts provided award fees in excess of 15 percent?

Mr. POWNER. Yes, there was also—if you look at this, the IG actually did some very detailed work on this award fee structure. And the bottom line on all this, Senator Cantwell, is that the contractor was receiving award fees at a time when this program was performing quite poorly. And that since has changed, but there was a long stretch where award fees were paid when performance was quite poor.

Senator CANTWELL. How is that possible?

Mr. POWNER. One item that we pointed out in our many reviews of NPOESS is the lack of contractor oversight. When you start looking at oversight of contractors and oversight of subcontractors below prime—below the prime contractor, there were a lot of issues there, from the oversight of the prime contractor all the way down to subs.

Senator CANTWELL. Well, I might come to this hearing with a little less anger about that situation if I hadn't sat through so many Deepwater oversight hearings about lead systems integrators, and lead system integrators writing their own ticket. To me, this shared system performance responsibility is very similar to a lead systems integrator. The fact that we awarded bonus contracts on top of the nonperformance, in addition to the nonperformance, in and of itself, that is now leading us to this conclusion that we are going to cut sensors on vital climate change information, is just a failure. And we need to correct this.

I want to get back to the agency individuals who are testifying here today. Do you believe that the, either Dr. Freilich or Ms. Kicza, do you believe the agency, in light of the Northrop Grumman performance, profit award fee of $123 million, was justified? Do you believe that was justified, the award bonus?

Ms. KICZA. Ma'am, I believe that there were failures in the award fee process. And, in fact, in response to recommendations from both the GAO and IG, we have changed both the structure of the award fee process, as well as the Fee-Determining Official. And, in fact, the last two award fees for the contractor have been substantially less, and/or zero, as a direct result of the failures that resulted in the Nunn-McCurdy process.

Senator CANTWELL. But there was a profit award fee of $123 million.

Ms. KICZA. I acknowledge that that fee was paid, yes. And——

Senator CANTWELL. Was that justified, yes or no?

Ms. KICZA. Ma'am, I would have to defer that to the Air Force that has the acquisition responsibility.

Senator NELSON. But you all have a responsibility for NPOESS.

Ms. KICZA. And, as I indicated, in response to the failures that were recognized and that led to the Nunn-McCurdy process, the last two award fees have been reduced and—and, in fact the last one has been zero——

Senator NELSON. But the——

Ms. KICZA.—in direct response——

Senator NELSON.—original one that——

Ms. KICZA.—to the failure.

Senator NELSON.—Senator Cantwell brought up was paid.

Ms. KICZA. That is correct.

Senator NELSON. Even though this thing was a disaster, they still got, how much, Senator Cantwell? $123——

Senator CANTWELL. $123 million.

Senator NELSON.—million award fee.

Senator CANTWELL. We started at a $6.5 billion cost estimate, and then it went to $12.5 billion. And I think, in and of itself, we could digest that. But I think we are far from understanding, in addition to the fact that we aren't going to get sensors on climate change, that costs are going to be contained at this level. Are you willing to guarantee that this new baseline cost estimate is the true cost estimate and we're not going to see any additions in an increase in that? Do you think that's a realistic estimate?

Ms. KICZA. Ma'am, what I can tell you, is that, in the last 18 months, the NPOESS program has significantly increased the government oversight. In fact, we've added a 32 percent larger staff, both technical and program control staff. And in the past 18 months, this program has been on budget and on schedule.

Now, as Mr. Powner acknowledged, we have significant risk ahead. We are not through this yet. But I will assure you that continued vigilance in management oversight and in technical oversight will be applied to this program.

Senator CANTWELL. I'm looking for information here, but it appears that, even though you had new deadlines that were just set recently, I think, in the last month, that those deadlines won't be met, that the DOD Under Secretary for Acquisition issued a memo extending these deadlines from a few months to even a year past the new targets. Is that correct, from the June date?

Ms. KICZA. Ma'am, you're referring to some deadlines for documents, and the Defense Acquisition Executive within the DOD did recently extend those documents to a later due date. And the fact of the matter is that the program was focusing on dealing with the issues, and the Defense Acquisition Executive acknowledged that, and, as a result, extended the due date for specific key documents.

Senator CANTWELL. And what do those documents entail?

Ms. KICZA. If I could take that question for the record, I have it here, but I'd have to search through my things. One is the MOU. There are four key documents, and I'll provide that information for the record.

Senator CANTWELL. I think that'll be very important, because it appears to me that several deadlines are going to be revised, only from a month ago, and that we are already behind schedule. Now, I'm happy to see those documents, and happy to see, but I think you can see where my concern is, is that, what safeguards we have in place now that we are going to prevent further cost overruns, that are going to have the program on target and on budget. I don't know, Mr. Powner, if you have ideas about the additional risk and oversight that we should be implementing.

Mr. POWNER. One comment about those documents. We're about—we're getting ready to ink a new contract on NPOESS, and some of those documents include an integrated master schedule, an overall testing plan. Those are types of things you want solidified before you enter into a new contract, because what does that mean? That means that there are likely contract mods, and that typically equates to cost increases. So, if you look at our latest report, we think it's very important that they actually get those documents approved as quickly as possible. In fact, we recommended that they be approved in April. And, as you're pointing out, it's been extended even further.

Senator CANTWELL. But you want those documents to be correct, as well——

Mr. POWNER. Absolutely.

Senator CANTWELL.—correct? So, basically, submitting a schedule that's not realistic or hasn't answered the questions about technology, simply for the purposes of saying that you have a schedule, is not valid, as well as maybe not even just having done the homework, in and of itself.

Mr. POWNER. And if you look at the approval of those documents, it's basically just calling for an adherence to DOD policy. When you come out of a Nunn-McCurdy review, it—those dates were set, basically, on a template that's followed based on other DOD programs. So, that's one of the concerns we have about this interagency cooperation, because if we can't agree to a simple Memorandum of Understanding on how the program's going to be run, going forward, that's an issue.

Senator CANTWELL. Senator Nelson, if you would like, I'm sorry, thank you, I know I was over my limit.

Senator NELSON. Well, you're welcome. And you brought out very, very important information here. I am mindful of the fact that we're supposed to have this vote at 11:30.

I want to put into the record, following up your conversation from the Department of Defense Acquisition, Technology, and Logistics, Kenneth Krieg, a memo dated June 2007, of which all of the Nunn-McCurdy replanned dates for various action items for this NPOESS satellite that have already been late, every one of them have been given a new date that is further delayed by at least a year, and, in most cases—in some cases, a one-year delay.

The most recent document, which we will enter into the record, on the status of the acquisition decision, memorandum documents, also from Mr. Krieg's office, that's pointing out that three of those that were given a September 2007 completion date, that are now behind schedule in their work.

[The information previously referred to follows:]

June 7, 2007

THE UNDER SECRETARY OF DEFENSE
Washington, DC.

Memorandum for Program Executive Officer for Environmental Satellites

Subject: National Polar-orbiting Operation Environmental Satellite System (NPOESS) Acquisition Decision Memorandum (ADM) Amendment

After considering your April 2, 2007, request for an amendment to the June 5, 2006, NPOESS ADM, I am resetting the delivery date for selected acquisition documents to the following:

Action item	Original date	New date
#1 Alternate Management Plan	June 2007	Sept. 1, 2007
#3 Award Fee Plan	Unspecified	Oct. 1, 2007
#7 Acquisition Program Baseline	Sept. 1, 2006	Dec. 1, 2007
#7 Acquisition Strategy Report	Sept. 1, 2006	Sept. 1 2007
#7 Test and Evaluation Master Plan	Sept. 1, 2006	Mar. 1, 2008
#7 Systems Engineering Plan	Sept. 1, 2006	Sept. 1, 2007
#8 Two Orbit Plan	Nov. 15, 2006	Oct. 1, 2007
#10 Fill IPO Vacancies	Aug. 4, 2006	Sept. 1, 2007
#15 LSP/PMSP COORD	Sept. 2006	Sept. 1, 2007
#16 DMS/POI Plan COORD	Sept. 2006	Sept. 1, 2007
#17 Tri-Agency MOA Coord	Aug. 4, 2006	Sept. 1, 2007
#18 SME Review of IMP/IMP	Apr. 2007	Sept. 1, 2007
#19 Quarterly IBR Status Report to MDA	Sept. 2006	Sept. 1, 2007

As provided above, the Acquisition Program Baseline must be completed and signed by December 1, 2007, to support the annual delivery of the Selected Acquisition Report. The Test and Evaluation Master Plan (TEMP) shall complete coordination and be signed by March 1, 2008. To ensure that this March I, 2008, due date is satisfied, a draft submission of the TEMP should be provided to DOT&E and NSSO DT for review and comment by September 1, 2007.

KENNETH J. KRIEG,
Under Secretary of Defense for Acquisition, Technology and Logistics.

Status of Acquisition Decision Memorandum Documents (07/09/07)

Document Title (ADM Action Number)	Due Date (revised date)	Current Status
Alternate Management Plan **(ADM-1)**	June 07 Sept 1 07	The AMS team provided its final Phase I report on 26 June and made several recommendations and observations which will be reviewed by the PEO.
Award Fee Plan **(ADM-3)**	September 06 October 1 07	IMFP approved by all principals in February and March. Working on Award Fee Plan
Acquisition Program Baseline **(ADM-7)**	September 06 Dec 1 07	Will release plan in Summer (NGST contract definization date)
Acquisition Strategy Report **(ADM-7)**	September 06 Sept 1 07	IPO working comments from SAF 3 ltr coordination. PEO (Bucher) revising to capture restructure and comments provided.
System Engineering Plan **(ADM-7)**	September 06 Sept 1 07	IPO submitted the SEP to the agencies on 7 June for signature by the EXCOM members. As of July 9, package being hand carried to Gen Mashiko for review and signature.
Test and Evaluation Master Plan **(ADM-7)**	September 06 March 1 08	IPO has provided additionally requested documents to AFOTEC. AFOTEC has resumed its review Per discussion with Mr. Krieg office, interim TEMP NLT Dec 2007.
Two-Orbit Program Plan **(ADM-8)**	November 06 October 1 07	PEO has met with EUMETSAT. Waiting for EUMETSAT comments to Part 2. Will submit plan to agencies for review in July/August timeframe.
Logistics Support Plan/Product Support Management Plan **(ADM-15)**	September 06 Sept 1 07	A4 (Depot Maintenance), requiring preparation of Depot Source of Repair, has not concurred with plan. Preparing decision paper - proceed with DSOR or seek relief through EXCOM
Diminishing Manufacturing Sources/Parts Obsolescence Plan **(ADM-16)**	September 06 Sept 1 07	IPO submitted the signed DMS to the agencies on 5 July for signature by the EXCOM members.
NPOESS Tri-Agency MOA **(ADM-17)**	September 06 Sept 1 07	Agency concerns to date have been resolved. SAF ready to go to Top-4 coordination; NOAA waiting for Sega's signature before seeking Lautenbacher's signature. Both will need Department clearance. NASA – package has been signed by Scolese
Integrated Master Schedule **(ADM-18)**	September 06 Sept 1 07	IMP/IMS review conducted April 07 and referenced at June EXCOM. Recommendations will be provided to agency PEMs

Work Completed | In work – On schedule | In work – behind schedule | Work delayed

Response from Mr. Krieg's office approves dates except as noted above

Senator NELSON. So, if it is this hydra-headed monster that the GAO tells us is unable to crack the whip and keep this going, we'd like you all to come back to us with additional information as to how you're going to get it on schedule.

Senator CANTWELL. Mr. Chairman, I think we should go even further, having a second to look over these memorandum documents, I think you're pointing to the very issue, the fact that there are several agencies involved here.

But, now that there has been intensity and light shown on this issue, I would hate to see the agencies continue to try to post dates that aren't realistic. And there is just something striking about the fact that we are less than 30 days from when the plan was originally made, and we're already submitting date changes to that plan. It says to me the original plan and proposal wasn't accurate or thought out in the details, to say nothing of the larger discussion, which I think we should be having in the U.S. Senate, and that is, do we want to do without these sensors? I would say no. I would say that we need to find a way to move forward on these climate change sensors, particularly to the continuity and the vital information that we are getting from this.

I think that we, and the Nation, have all been shocked by the impact that Hurricanes Rita and Katrina had on our coastal regions, and the significant amount of damage and impact of storm intensity. And to have good data about correlations and impacts of that, the difference between the various causes of those issues, are vitally important. So, I would hope, besides just scrubbing the oversight and management and delivery dates of the current contract, we'd look at this larger issue.

Senator NELSON. Before we have to adjourn I will submit, for the record, on my behalf and on other members of the Committee behalf, detailed questions that we would like you to respond in writing.

But before we have to adjourn because of the vote, I want to get into the loss of climate monitoring capability. The downgrading of this monitoring of, not only NPOESS, but also the GOES–R, this is occurring, very interestingly, at a time when the international scientific community has reached a consensus that: human activity is the cause for increasing atmospheric carbon dioxide concentrations, and that these elevated CO_2 concentrations have resulted in significant global warming.

It's interesting that all this is going on at the same time that this is happening with these satellites. From these assessments, it's clear that continued research and monitoring, as well as aggressive action to limit greenhouse gases, is needed. We're going through this daily. We just went through it last month with regard to the energy bill. But, at the same time, the Administration has refused to limit these greenhouse gases. And the decreases in the Federal climate science budget, reports of political appointees that are interfering with dissemination and discussion of Federal climate science, and the lack of an effective national assessment of climate change impacts, point to an Administration's silence in this global climate change debate. And so, the decommissioning of these climate sensors scheduled for NPOESS and the GOES–R satellite is another indication of the lack of interest in the Administration or the political will to deal with this.

So, I want to ask some questions. The National Research Council, the American Association for the Advancement of Science, and NOAA and NASA raise concerns about the loss of climate data and climate monitoring capability as a result of decommissioning of these sensors. So, other than what you've already told us on a budget issue, what's going on here? Were these sensors cut from these programs because of a lack of emphasis on climate change and global warming?

Dr. Freilich?

Dr. FREILICH. Well, sir, let me say that in the FY08 budget request that you're looking at right now, on the research side NASA will be launching seven research missions—not NPOESS, but seven research missions—between now and 2013 to address many of the climate science questions that have been raised. Among those are the ocean surface topography mission to measure—continue the measurements of global sea-surface elevation and sea-level rise; the orbiting carbon observatory, to make first-ever measurements of sources and sinks on 1,000 kilometer sort of scales, globally; and several others. NPP is one of those——

Senator NELSON. All right. Well——

Dr. FREILICH.—but we have many other research missions that will be launched.

Senator NELSON. All right. Let me ask you about the radar altimeter. This is a sensor that would provide critical data on the health of the coastlines and prediction sea-level rise, something that the two Senators here have a considerable interest in for the people that live along the coastline of this country. So, could you tell me why that sensor was decommissioned?

Dr. FREILICH. I cannot say why it was decommissioned, in detail, for NPOESS, except as part of the refocusing of NPOESS on its weather focus. However—again, to point out—NASA started out with the TOPEX/Poseidon radar altimeter mission. We are now flying the Jason-1 radar altimeter mission. And, in June 2008, we will be launching the follow-on to that, the ocean surface topography mission, with our international partner, the French Space Agency. So, we have established, and continue to launch, through OSTM, these high-precision radar altimeters to measure global sea-level rise.

Senator CANTWELL. Mr. Chairman?

Senator NELSON. Ms. Kicza, why was the radar altimeter decommissioned?

Ms. KICZA. Dr. Freilich correctly assessed it, we kept our focus on maintaining weather continuity.

I would like to add to what Dr. Freilich has indicated. This next mission is the Ocean Surface Topography Mission. It's the follow-on to Jason-1. NOAA, in fact, is a partner in that effort, and we're supporting the ground system as part of a research-to-operations activity. And we're now actively engaged with EUMETSAT for looking at Jason-3, which is the follow-on to the OSTM mission. And that, too, is part of the dialogue that we're having with the Administration on continuity of this critical measurement.

Senator NELSON. Senator Cantwell?

Senator CANTWELL. Well, I just wanted to jump in there on this question, because I heard Dr. Freilich's testimony earlier, and we're talking about different information, aren't we, Dr. Busalacchi? I mean, the fact that you would say, "OK, we're going to solve this problem by having, a measurement on a certain time and basis from these airplanes, *versus* the constant continuity of information on temperature over a long period of time, and changes to that temperature, is what is essential in measuring this impact of climate change surface temperature on sea level to the intensity." That's what we're trying to measure. So, to think that you're going to have some missions, which I think also have been underfunded, and say that that is a substitute for this, I think, is not understanding, or not portraying the science in the right way.

Senator NELSON. And before you answer that, let me just corroborate what the Senator has said. The President's budget for NASA's Earth Science program was $1.5 billion for Fiscal Year 2008, the one that we're planning for. That's $500 million less than was recommended by the Earth Decadal Survey.

Dr. BUSALACCHI. That is correct.

As I said in my written testimony, right now we do not have a single agency within this country that has the mandate, nor the budget, for operational climate monitoring, operational climate prediction, and the offering of operational climate services. It's like during World War II—coming out of World War II we developed numerical weather prediction and operational sense. Within the past 20 years, we're moving into that direction for the country with respect to operational climate.

Two years ago, the interim report of the Decadal Survey indicated that this system of environmental satellites is at risk of collapse. That was very prescient. That was 1 year in advance of the Nunn-McCurdy certification process. Earlier this year, the Decadal Survey stated that, in the short period since this interim report, budgetary constraints and programmatic difficulties at NASA have greatly exacerbated this concern. At a time of unprecedented need, the Nation's Earth observation programs, once the envy of the world, are in disarray. And, as Senator Nelson pointed out, the FY08 budget request is not adequate to implement the recommendations of the Decadal Survey.

Senator CANTWELL. But, Dr. Busalacchi, I was being more specific. Are these planes a substitute?

Dr. BUSALACCHI. As Dr. Holland said, we need to look at the total system. It's not either/or. It's planes, it's *in situ,* and it's the satellites. We need to take a systems approach, and we haven't been doing that. That's part of the national strategy that we need to have, that I was alluding to in my testimony.

Senator NELSON. Well, I——

Senator CANTWELL. Well, I'll—go ahead, Mr. Chairman.

Senator NELSON. Well, I want to ask both of you—Dr. Holland and Dr. Busalacchi—what is your opinion? Is politics driving some of these technical decisions that is lessening the emphasis on instruments that are measuring climate change?

Dr. BUSALACCHI. Well, I'll—I'd have to say that I was a NASA employee for 19 years, and moved to the university in 2000. I've seen—since I joined the agency, in 1982—since I joined NASA, in

1982, I've seen a distinct change in the emphasis on the science. And whether or not you want to call it politics or not, clearly there has been a shift in the emphasis within the agency for exploration, turning our eyes and ears of satellites to outer space, and defocusing the emphasis on planet Earth. That is a stated fact.

Senator NELSON. Dr. Holland?

Dr. HOLLAND. I think it's fair to say that there are political decisions being made which negatively impact our capacity to understand the weather system. Whether that is a deliberate policy or not, I'm not in a position to know.

I would, however, like to just address the altimeter, since you also addressed that. We've focused on the climate side of things. That altimeter is absolutely crucial, from a hurricane forecasting point of view, because without it we don't have the information of the subsurface ocean energy which is critical to understanding and predicting, in particular, the rapid intensification of hurricanes, as we've seen in the last few years, with Hurricane Rita and Hurricane Katrina, moving over that deep, warm pool in the Gulf of Mexico.

Senator NELSON. That was the radar altimeter that you're talking about. That begs the question; the decision to remove those sensors, that would have increased our capability to monitor climate change and tracking the hurricanes. What do you think we ought to do?

Dr. HOLLAND. I guess I'm a fan of Satchel Paige, and I don't think we should spend too much time looking backward, because they might be catching up. What I'd rather say is, what has happened has happened, and I think it now behooves us to make sure that we take the best possible technical and scientific decisions, without any political interference, to be able to move forward.

Senator NELSON. Do you think, with all of these studies that are coming up, that we're going to be in a position where we can make those decisions without political interference?

Dr. HOLLAND. I really am not in a position to be able to answer that. I think it behooves you and your colleagues to also make sure that happens. I come from the scientific side. All I can say is that the best science and the best technology is not being applied fully to the problem, at present.

And I want to emphasize a point, here, and that is, it's very easy to concentrate on a specific instrument or a specific type of instrument. What—there are significant problems with the entire forecast and warning process, and that it is like a chain. And if one link is weakest, that's where the chain disappears. And I think what we really need to do—and I'm sure we're not doing this, at present—is taking a proper integrated look at the entire process and how all of the relevant elements fit within that.

Senator NELSON. Well, hopefully that will occur. But, in case some of you feel like we've been too rough on you, let me just assure you, there is a lot at stake, and there are millions of people that live close to the coast in this country that are depending on the U.S. Government to get it right. And the hard questions need to be asked, and they need to be answered.

We'll go back, this will be the concluding thought, the GAO, which is a nonpolitical and it's not only a bipartisan, it's a nonpartisan group of people who analyze what went wrong and what to do about it. They've clearly stated, and we see some evidence, since there is still slippage in this program, that the decision-making has not been coalesced around a significant point, but that it's still split up, which is part of the reason that GAO has testified that it's gotten us into the fix that we're in, in the first place. So, what we would like you to do, since we have the responsibility of looking over the shoulder of the Executive Branch, is to make sure that you report to us on how that's been fixed, the new time schedules that you're on, what instruments are going to be ready and when, and give us a realistic time schedule, as well as a cost estimate, because it's this branch of government that has to appropriate the money. And then, hopefully we can get this problem straightened out.

I want to thank you all for your testimony. I want to thank you for your patience. I would love to come up and greet you, but we are down to 7 minutes to vote.

So, with that, the meeting is adjourned.

[Whereupon, at 11:15 a.m., the hearing was adjourned.]

APPENDIX

PREPARED STATEMENT OF HON. DANIEL K INOUYE, U.S. SENATOR FROM HAWAII

Observations from our weather and environmental satellites are critically important for the Nation's weather forecasting and research, as well as climate change science. I come from a state that is surrounded by the ocean, and my constituents rely on these eyes in the sky to provide accurate and timely information.

Both the Central Pacific Hurricane Center in Honolulu and the National Hurricane Center in Miami rely on satellite data to improve storm watches and warnings. Hawaii is at risk for hurricanes, and while storm frequency seems to be reduced when compared to the Atlantic, it only takes one major storm to wreak havoc on an island.

These two centers track these devastating storms from start to finish and issue warnings for all our coastal communities that are at risk from landfall.

Weather and environmental satellite observations also contribute to our increased understanding of the impacts of climate change—another topic of critical importance to the Nation.

In Hawaii, satellite-derived measurements of sea surface temperature, for example, can be used to predict the health of coral reefs—particularly coral bleaching events.

The scientific community is concerned that the United States is losing key satellite observing capabilities, particularly for climate research and accurate weather forecasts. A number of satellite programs have experienced difficulties, including cost overruns and schedule delays.

We need to be proactive in addressing these problems and employing the technologies necessary to ensure accuracy in forecasting and research. The citizens of Hawaii and other coastal states deserve no less.

PREPARED STATEMENT OF HON. OLYMPIA J. SNOWE, U.S. SENATOR FROM MAINE

Thank you, Mr. Chairman, for holding this hearing on the state of our Nation's environmental and weather satellite infrastructure. Given that satellites provide over 90 percent of our Nation's weather prediction capabilities, it is critical that we ensure our forecasters have nothing less than the best available data so they can provide precise, advance warnings of impending storms. Today's discussion is particularly timely, in light of this week's leadership change at the National Hurricane Center and the ongoing debate regarding the replacement of the QuickSCAT satellite.

I would like to thank our witnesses, Administrator Kizca, Mr. Powner, and Doctors Freilich, Holland, and Busalacchi, for appearing before this committee today to discuss this vital concern. I look forward to hearing your testimony about how we can improve our Nation's weather and environmental satellite systems and continue providing accurate and timely weather and climate predictions for the American people.

This hearing coincides with a change in leadership at the National Hurricane Center announced by NOAA just 2 days ago amid conflicting reports about the Center's ability to continue providing precise hurricane tracking and other vital predictions. I look forward to the release later this month of a NOAA report detailing the circumstances that led to this decision, and in the meantime, it is imperative not only that our forecasters have the tools they need to develop accurate hurricane track projections, but also that the public has enough confidence to heed those warnings once issued. We all saw the devastation wrought upon the Gulf Coast during Hurricane Katrina nearly 2 years ago. We must not lose sight of the Hurricane Center's remarkable precision of prediction and rapid dissemination of information that resulted in wide-scale evacuations and preparations that saved thousands of lives during that terrible storm.

I commend NOAA's scientists for their extraordinary accomplishments in improving the forecasts of hurricanes. Over the past 15 years our 2 day forecasts have improved by 50 percent—cutting the difference between the forecast and the actual landfall to an average of 111 miles. This is a reflection of the dedicated researchers throughout NOAA. Quite frankly, this work has saved resources and lives. It has been estimated that each mile of evacuated coastline costs reach $1 million dollars and with the improved forecast state and Federal officials have been able to reduce the economic and human repercussions of hurricanes both before they hit, and in their aftermath.

However, our instruments are aging, and development of their replacements—notably the National Polar-orbiting Operational Environmental Satellite System, or NPOESS (EN-pose)—has been plagued by cost overruns and setbacks to vital instruments. This program, initially budgeted at $6.5 billion, has swelled to nearly twice that cost, reduced the number of satellites by a third, and suffered significant reductions in instrumentation. If the trend of forecasting improvements is to continue as it has in the past several decades, we cannot allow these development setbacks to continue.

The next generation of satellites is capable of providing additional forecasting information that will not only improve our Nation's weather and climate forecasting, but also accrue societal benefits in agriculture, energy, and the mitigation of climate change. Unfortunately, the investment into this infrastructure has not been commensurate with the potential dividends. In a 2007 report, the National Research Council of the National Academies stated that, "the United States' extraordinary foundation of global observations is at great risk." Furthermore, the report called it "imperative" NOAA fill the data gap that would result from the demise of its QuikSCAT satellite, which contributes to the forecasting of hurricanes, as well as other storms like the one that battered the Coast of Maine on Patriot's Day. With the failure of QuickSCAT's main transmitter last year, a medium and long-term plan must be established to replace this information before the backup transmitter fails as well.

The GAO has suggested that NOAA must incorporate lessons from past mistakes in developing realistic costs and schedules, and government officials must provide unwavering oversight to hold the agency accountable. I strongly agree with this assessment and look forward to hearing from our witnesses today to determine how our Nation's environmental satellites can upgrade to the next generation in an effective and financially responsible manner.

Thank you, Mr. Chairman.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO DR. MICHAEL H. FREILICH

Question 1. What are the options for replacing QuikSCAT in terms of the various levels of capability that such a replacement could provide, and the trade-offs in terms of timing for making such a replacement operational?

Answer. The National Oceanic and Atmospheric Administration (NOAA) is evaluating several options for addressing its ocean vector wind requirements and has contracted with NASA's Jet Propulsion Laboratory (JPL) to support NOAA in these endeavors, which includes examination of QuikSCAT replacement and QuikSCAT enhancement options. NASA stands ready to assist NOAA.

Question 2. Do you have good cost estimates for such various options?

Answer. NASA is supporting NOAA in the development of the options. Cost estimates on the preferred option will be developed by NASA's JPL as study products and released by NOAA at the appropriate time.

Question 3. When will NOAA and NASA make a decision regarding a replacement for QuikSCAT?

Answer. The Decadal Survey identifies a sea surface wind vector scatterometry mission, the Extended Ocean Vector Winds Mission (XOVWM), as a mid-decadal priority for NOAA. NASA continues to work closely with NOAA to support an efficient transition of ocean surface vector wind measurements from research to operations. NOAA will make the decision regarding the preferred option for a QuikSCAT replacement based on its analysis of competing options and priorities.

Question 4. NASA and NOAA released a report in January of this year with recommendations for recovering from the descopes of the Nunn-McCurdy process. What are your two agencies doing to implement those recommendations and are those plans part of your current operating plans and budgets?

Answer. NASA is a member of the NPOESS Executive Committee (EXCOM) and continues to participate in the management and oversight of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program. From a programmatic standpoint, in the Agency's support role to the NPOESS Program, NASA has provided five extra full-time technical staff to the NPOESS Integrated Program Office to lend increased monitoring support.

In April 2007, NASA and NOAA provided resources from core programs to allow the OMPS-Limb instrument to be re-manifested on NPP, thus restoring the full set of nadir total ozone measurements and the limb profiling capabilities for NPP. As the Earth Science Decadal Survey committee was finalizing its notional mission set and sequence, the full impact of the removal of the climate sensors from the NPOESS program was just coming to light. NASA and NOAA, in consultation with the National Research Council, have structured a follow-on activity wherein a subset of the Decadal Survey committee, augmented by others they may deem necessary, would hold a workshop and provide input on how the agencies might mitigate the impact of the changes to NPOESS. The NRC workshop was held in June, in time to provide recommendations useful for helping to determine the FY 2009 budget requirements.

Question 5. NASA has a satellite, Deep Space Climate Observatory (DSCOVR), with a space weather monitoring instrument. DSCOVR sits in a storage container at the Goddard Space Flight Center with no plans for flight. Why doesn't NASA make DSCOVR available to NOAA for its space weather mission?

Answer. Although it is possible to refurbish a satellite that began development 9 years ago, there are certain hurdles to pursuing this course: (1) the DSCOVR payload does not provide all of the capabilities needed by NOAA for operational space weather predictions; (2) the DSCOVR measurements also would do nothing to replace the de-manifested NPOESS climate sensors nor satisfy recommendations of the Decadal Survey, and (3) refurbishment funding requirements are estimates only based on there being no problems with a stored, decade-old spacecraft and instruments. We will now expand on these two issues.

A NASA technical study conducted from mid-May through June 2007 examined the documentation related to the state of the DSCOVR spacecraft and instruments when placed into storage in November 2001, the tasks required to refurbish and launch the DSCOVR mission to the Earth-Sun L1 point, the availability of people having the necessary skills to conduct the refurbishment activities given the state of the available documentation, and the approximate durations of the refurbishment and launch campaign activities. The study concluded that refurbishment of the spacecraft could be completed within 15 months of initiation. The fifteen months refurbishment period estimate does not include time to acquire and accommodate the low energy ion sensor, which was not part of the original DSCOVR payload and which is required by NOAA for space weather predictions. The study assumed no schedule or cost estimate for problems which might have occurred during the decade of storage. The cost was then estimated at $23 million in FY 2007 dollars for refurbishment alone. The study also estimated the mission operations and data analysis costs to be an additional $23 million for the baseline two-year mission. Launch vehicle costs for a delivery to the L1 orbit are estimated to be approximately $150 million.

Discussions between NASA and NOAA through much of July identified the fact that the existing DSCOVR space weather instrument suite does not include a low-energy ion sensor which is part of the ACE complement and which is required by NOAA for their operational space weather predictions. These discussions also addressed possible mechanisms for transfer of the DSCOVR assets from NASA to NOAA, and mechanisms for reimbursement of NASA for refurbishment of DSCOVR by the Goddard Space Flight Center development team.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO DR. MICHAEL H. FREILICH

Question 1. Will the loss of climate science sensors have a significant impact on the goals of the U.S. Climate Change Science Program (CCSP)?

Answer. Absolutely. The U.S. Climate Change Science Program (CCSP) is critically dependent on the availability of long-term, stable data sets that allow it to address the extent to which the Earth system is changing over long (multi-decadal) time periods. Any gaps or termination of data records will be critical. As an external verification, the recently released National Research Council (NRC) report reviewing CCSP, "Evaluating Progress of the U.S. Climate Change Science Program: Methods and Preliminary Results" (released September 13, 2007) says the following in its summary (page 5): "The loss of existing and planned satellite sensors is perhaps the single greatest threat to the future success of CCSP."

Question 2. Will the loss of climate science sensors have a significant impact on the goals of the International Panel on Climate Change?

Answer. Absolutely. The success of the International Panel on Climate Change (IPCC) process is critically dependent on the availability of good data, especially the long-term data sets needed to document the evolution of climate forcing and Earth system response. Without such long-term data sets, the IPCC scientists will have to deal with less certain estimates of changes in Earth system forcing as well as in overall response.

Question 3. What data gaps do you expect and how will they affect climate change research in the U.S.—particularly with regard to the multi-decadal data sets that are critical for understanding global warming?

Answer. NASA and National Oceanic and Atmospheric Administration (NOAA) are looking for ways to minimize data gaps in several areas, as detailed below:

- *Total Solar Irradiance:* NASA's top priority for data continuity is to maintain the 30-year record of total solar irradiance data. To that end, NASA will launch the Total Irradiance Monitor (TIM) on the Glory spacecraft in December 2008. Approximately 6–12 month overlap between orbiting solar irradiance instruments is essential for consistent mission-to-mission calibration and the resulting monitoring of solar input to the climate system.
- *Atmospheric Ozone Composition:* NASA and the National Oceanic and Atmospheric Administration (NOAA) have jointly agreed to fund the Ozone Mapping and Profiling Suite (OMPS)-Limb instrument as part of the NPOESS Preparatory Project (NPP) mission, scheduled for launch in September 2009. This addition will allow the first vertically resolved ozone measurements.
- *Moderate Resolution Land Surface Imagery:* The currently operational Landsat 7 spacecraft is expected to last through 2010. NASA is attempting to minimize the gap in the 30-year record of moderate resolution land surface imagery through the Landsat Data Continuity Mission (LDCM), scheduled for launch in July 2011.
- *Ocean Altimetry:* Current ocean altimetry data is provided by the Topographic Experiment for ocean circulation (TOPEX)/Poseidon and Jason-1 missions. Future data will be acquired by the Ocean Surface Topography Mission (OSTM), scheduled to launch in June 2008. Plans for continuing the precision measurement of global sea level change beyond the Ocean Surface Topography Mission (OSTM) are not firm, putting the presently 15-year time series in jeopardy beyond the lifetime of OSTM.
- *Surface Vector Winds:* NASA's Quick Scatterometer (QuikSCAT) satellite has been on-orbit for over 8 years, 5 years longer than its baseline mission. Responsibility for developing an operational satellite to continue these measurements was assigned to NOAA in the recent Earth Science Decadal Survey. NASA is providing its expertise to support NOAA as that agency makes its decisions about a follow-on mission. In addition to contributions to weather prediction and marine hazard forecasting, scatterometer wind measurements are fundamental for the calculation of wind-forced ocean circulation (ocean transport accounts for approximately half of the total equator-to-pole meridional heat transport on Earth).

Question 4. The recertified NPOESS program is costing more to do less: the cost estimate increased from $6.5 billion to $12.5 billion, and the planned acquisition of 6 spacecraft was reduced to 4, with several sensors canceled or reduced in capability. Are you certain that the new cost of $12.5 billion is a realistic, firm estimate for the total cost of the program?

Answer. The restructured NPOESS program was certified by the Under Secretary of Defense (Acquisition, Technology, and Logistics). Part of this certification is that the cost estimates for the program are reasonable. The Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG) made this determination based on their review of the program plans, schedules, and program risks. NOAA and the Department of Defense (DOD) share the NPOESS costs equally and have developed budgets to support this revised estimate. The development of advanced remote sensing instruments and spacecraft will always contain some risk and uncertainty however, based on the insight available to NASA, the budget estimates should be considered reasonable.

Question 5. Can you guarantee me that the actual, full cost of the NPOESS satellites will be $12.5 billion?

Answer. NASA will provide all the support we can to assist the U.S. Air Force and NOAA achieve the Nunn-McCurdy recertified NPOESS baseline of $12.5 billion.

Question 6. What safeguards are in place to prevent costs from escalating further?

Answer. NASA believes that the U.S. Air Force and NOAA have implemented the appropriate contractual safeguards to prevent cost escalation. In our support role to the NPOESS Program, NASA has provided extra technical staffing to the NPOESS Integrated Program Office (IPO) to lend increased technical monitoring support. Further, the restructured contract has a decision point in 2010 on whether to award the option for the last two NPOESS satellites, C3 and C4. If the NPOESS Executive Committee (EXCOM; composed of the Under Secretary of Defense (Acquisition, Technology, and Logistics), the Under Secretary of Commerce for Oceans and Atmosphere, and the NASA Administrator) is not satisfied with the contractor's technical, cost, or schedule performance, there will be an opportunity at that time to make a change.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. KAY BAILEY HUTCHISON TO DR. MICHAEL H. FREILICH

Question 1. Can you provide us with an update on your discussions with National Oceanic and Atmospheric Administration (NOAA) regarding transferring the Deep Space Climate Observatory (DSCOVR) spacecraft to NOAA to meet NOAA's solar wind requirements via a public/private partnership?

Answer. NOAA and NASA technical and senior personnel met from May through July 2007 to discuss aspects of the DSCOVR spacecraft, the science capabilities of the mission in light of the National Research Council's (NRC) Earth Science Decadal Survey recommendations for NASA and NOAA, and the scope and costs of technical and programmatic options for refurbishing and launching the DSCOVR spacecraft. On May 11, 2007, NASA organized a full-day science workshop attended by more than 35 researchers from NASA, NOAA, the Department of Energy, private industry, and academia, including the DSCOVR Principal Investigator. The workshop assessed the potential contribution of DSCOVR to Earth/climate science in the areas of aerosols and clouds; ozone; radiation budget studies; and, vegetation/ecosystem studies. The workshop concluded that while DSCOVR sensors at the Earth-Sun Lagrange 1 point have the potential to make innovative measurements that could provide valuable augmentation for other low-Earth orbit and geostationary orbit measurement systems, the DSCOVR measurements would not replace the climate measurements that would have been made by the de-manifested National Polar-orbiting Operational Environmental Satellite System (NPOESS) climate sensors. The DSCOVR Workshop report had a finding: "Sensors on the DSCOVR satellite have the potential to make important and innovative measurements from a novel perspective; further, measurements enabled by the DSCOVR satellite would provide valuable augmentation to a substantial number of other measurements systems including satellite remote sensing, suborbital and ground-based measurements."

In addition, the DSCOVR measurements would not fulfill climate science measurements identified and recommended for flight by the NRC Earth Science Decadal Survey, and should not receive any funding priority over any possible Decadal Survey missions. NASA and NOAA personnel have met to coordinate communication, formats, and content of the DSCOVR technical review conducted by NASA during May and June 2007. Details of the review conclusions are presented in the answer to question 2 below. Coordination insured that the results of the NASA review were presented in a way that enabled accurate and straightforward comparisons of NASA-estimated refurbishment costs with those from the original NOAA study conducted by Lockheed Martin. The fact that the existing DSCOVR solar wind instrument suite was lacking a low-energy ion sensor necessary for NOAA's operational solar wind predictions was discovered as a result of these discussions following the NASA technical study. The NOAA study did include a cost estimate of $3 million for adding the ion sensor.

Currently the NOAA requirement to monitor space weather is being accomplished by observations from NASA's Advanced Composition Explorer (ACE) mission. ACE was launched in August 1997 and is now in its fourth two-year extended mission cycle. Based on the current rate of fuel consumption, NASA is optimistic that ACE will continue to operate through 2022. However the modification of its orbit to conserve fuel does not meet NOAA's need for 24/7 reception of its data and this effect will worsen during solar maximum. Additionally, three of the four ACE space weather sensors currently provide degraded data during strong radiation storms and cannot be relied upon as the sole data source during solar maximum which will arrive 2011–2012. Should NOAA still feel that their strategic needs are served by flying the DSCOVR mission, NASA is ready to support NOAA on a reimbursable basis with the expertise and facilities to prepare the DSCOVR satellite for launch and operations. NASA believes that the refurbishment could be accomplished within the parameters identified in response to question 2.

Question 2. Has NASA completed an investigation as to the current status of the DSCOVR spacecraft?

Answer. A technical study conducted from mid-May through June 2007 examined the documentation related to the state of the DSCOVR spacecraft and instruments when placed into storage in November 2001, the tasks required to refurbish and launch the DSCOVR mission to the Earth-Sun Lagrange 1 (L1) point, the availability of people having the necessary skills to conduct the refurbishment activities given the state of the available documentation, and the approximate durations of the refurbishment and launch campaign activities. The study concluded that refurbishment of the spacecraft could be completed within 15 months of initiation, for a cost of $32.2 million in FY 2007 dollars. The fifteen months refurbishment period estimate does not include time to acquire and accommodate the ION sensor. The study also estimated the mission operations and data analysis costs to be an additional $23 million for the baseline two-year mission. A NOAA study had lower estimates for these functions due to the use of existing NOAA facilities for mission operations and ground systems. Launch vehicle costs for a delivery to the L1 Lissajous orbit are estimated to be approximately $150 million.

The difference between the NOAA and NASA studies was the cost of the launch vehicle. The NOAA study baselined a commercial partner to whom the DSCOVR would be competitively transferred. The commercial company would then use any suitable FAA-licensed vehicle for launch, cost estimated at $27–$35 million in 2006. The NASA study baselined a government reimbursable mission using a NASA certified and acquired Evolved Expendable Launch Vehicle.

Given the state of the suspension documentation and the plans that were prepared in 2001 outlining the necessary tasks for return to flight status, the study concluded that a successful refurbishment could only be conducted with the active involvement of the DSCOVR development team at NASA Goddard Space Flight Center (GSFC); further, the study determined that the appropriate individuals still were active at GSFC, although in many cases they would have to be released from other projects, depending on when the refurbishment activities commenced. The study noted that an initial functional "aliveness" test (see question 3 below) is required prior to commencing the spacecraft refurbishment activities.

DSCOVR has been stored in the Hubble Space Telescope clean room at GSFC since November 2001, in its custom storage container and under continuous dry nitrogen purge. The DSCOVR parts inventory has been maintained by the GSFC Solar Dynamics Observatory project, and the Ground Support Equipment has been determined complete at GSFC. The Suspension Plan developed when the nearly-complete spacecraft was placed into storage has been determined to still be relevant and comprehensive.

Completion of the DSCOVR refurbishment within the cost and schedule defined above is contingent upon the successful outcome of the initial aliveness test. If that test is not fully successful, this schedule and budget will be insufficient.

Question 3. Has a "plug-in" test been accomplished?

Answer. No "aliveness" test has been conducted to verify the state of the DSCOVR spacecraft and science payload since the mission was placed into environmentally controlled storage in November 2001. This test would be required prior to initiating any refurbishment activities. If the aliveness test were to be conducted, it would need to be conducted immediately prior to refurbishment to eliminate the need for returning the spacecraft to storage followed by yet another aliveness test.

Question 4. Will NASA be able to respond to NOAA's request in a timely manner permitting NOAA to make budgetary decisions regarding use of the DSCOVR spacecraft?

Answer. Yes, NASA will respond to NOAA's request in a timely manner and has initiated a number of activities to reach that goal. The NASA Science workshop held in mid-May 2007 and attended by NOAA research and programmatic personnel (among many others) addressed the scientific utility of DSCOVR for climate research. The NASA technical review conducted during May–June and reported out in July 2007 addresses all outstanding issues associated with the refurbishment and flight of the DSCOVR spacecraft and payload. Discussions between NASA and NOAA through much of July addressed possible mechanisms for transfer of the

DSCOVR assets from NASA to NOAA, and mechanisms for reimbursement of NASA for refurbishment of DSCOVR by the GSFC development team.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. OLYMPIA J. SNOWE TO DR. MICHAEL H. FREILICH

Question 1. As we all know, NASA's QuickSCAT satellite system was not initially designed to be a component to our national hurricane tracking system. Rather, it was to be used primarily to monitor surface winds over the oceans for research purposes. However, through the tenacious work of NOAA scientists the data was evaluated and determined to be of great use elucidating the tracking of storms further out to sea and estimating the potential intensity of developing tropical storms. The added ability of QuickSCAT to track tropical storms demonstrates that satellite systems provide additional benefits beyond their original missions.

Please explain how the historical benefits of our environmental and weather satellite systems justify the Federal investment in this infrastructure.

Answer. The science community's present state of knowledge about global change—including many of the measurements and a significant fraction of the analyses which serve as the foundation for the recent report of the Intergovernmental Panel on Climate Change (IPCC)—is mostly derived from the NASA and National Oceanic and Atmospheric Administration operational satellites and *in situ* data archives. For example, using data from Earth observing satellites NASA-supported researchers are: monitoring ice cover and ice sheet motions in the Arctic and the Antarctic; quantifying the short-term and long-term changes to the Earth's protective shield of stratospheric ozone, including the positive impacts of the Montreal Protocols; discovering robust relationships between increasing upper ocean temperature and decreasing primary production from the phytoplankton that form the base of the oceans' food chain; and, using a fleet of satellites flying in formation (the "A-Train"), making unique, global, near-simultaneous measurements of aerosols, clouds, temperature and relative humidity profiles, and radiative fluxes.

Our improved understanding of Earth System processes leads to improvements in sophisticated weather and climate models, which, in turn—when initialized using the satellite data—can be used to predict natural and human-caused changes in the Earth's environment over time scales of hours to years.

Question 1a. Do you believe that our current investment in environmental satellites is satisfactory in order to maintain our current satellite capabilities as well as preserve our national leadership role in satellite technology?

Answer. NASA is presently operating an impressive set of Earth observing spacecraft, and the President's FY 2008 budget request includes funding for an additional seven identified (and one competitively selected) Earth observing missions to launch between 2008 and 2014.

The FY 2008 budget also contained funding for unspecified "future missions." These funds will be used to begin new efforts aimed at Earth Science issues. Shortly after the submission of the FY 2008 budget the National Research Council (NRC) published the Earth Science Decadal Survey. Although too late to impact the FY 2008 President's Budget Request directly, this report is being utilized by NASA to shape the plans for the use of the future mission investment lines within the Earth Science Division and to assist in the preparation of our FY 2009 budget request.

NASA is presently operating 14 Earth-observing missions carrying over 50 instruments. While 11 of these missions are indeed beyond their baseline lifetime, they continue to operate well and to provide high quality measurements for the research and operational communities. From February to April 2007, NASA's Earth Science Division conducted a "Senior Review," the biennial process to examine Earth observing missions operating beyond their baseline mission. Both the operations and science panels in the Senior Review concluded after careful technical analyses that all 11 of the operating missions were returning valuable data and were not suffering from imminent mission-threatening technical problems; the Senior Review recommended that NASA continue to fund operations and science analyses for all of these missions for at least two more years.

The President's FY 2008 budget request contains funding for the development and launch of seven new Earth observing missions between 2008 and 2014:

- OSTM (Ocean Surface Topography Mission; 6/08 launch) to continue the time series of precision global ocean sea level measurements initiated by Topographic Experiment for ocean circulation (TOPEX)/Poseidon in 1992 and presently obtained by Jason-1;

- OCO (Orbiting Carbon Observatory; 12/08 launch) to initiate global measurements of atmospheric carbon dioxide and to identify, for the first time, regional (1,000 km spatial scale) sources and sinks of CO_2;
- Glory (12/08–3/09 launch) to continue the 26-year consistent time series of solar irradiance measurements and to initiate global measurements of atmospheric aerosol concentration and scattering properties;
- Aquarius (7/09 launch) to make first-ever, global measurements of ocean surface salinity;
- NPP (National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Program; 9/09 launch) to continue the time series of key Earth Observing System (EOS) sensor measurements, and to provide risk-reduction for the tri-agency NPOESS operational satellite system;
- LDCM (Landsat Data Continuity Mission; 7/11 launch) to continue the 30-year long record of moderate-resolution land imaging; and
- GPM ((Global Precipitation Measurement) mission; 6/2013 and 6/2014 launches) to extend to the entire globe the present measurements of tropical precipitation from the presently operating Tropical Rainfall Mapping Mission (TRMM), allowing accurate, global rainfall measurements every 3 hours.

In addition to these seven missions comprising eight launches between 2008 and 2014, the FY 2008 budget request also includes funding for a small–medium Earth System Science Pathfinder (ESSP) mission which will be solicited for competitive selection late in FY 2008 with flight in the 2014–2015 time frame.

Question 2. The GAO report on the NPOESS program outlined staffing difficulties at DOD, NOAA and the NPOESS program. The GAO suggested that staffing difficulties were exacerbating the delay in implementing the project. The GAO report stated that, "As a result of the lack of a program-wide staffing process, there has been an extended delay in determining what staff is needed and in bringing those staff on board; this has resulted in delays in performing core activities, such as establishing the program office's cost estimate and bringing in needed contracting expertise." It seems clear that delayed personnel decisions are inhibiting progress on this critical project. What is the status of streamlining the process to hire additional staff to ensure that this project is receiving proper contracting and management?

Answer. Since the writing of the Government Accountability Office (GAO) report, the NPOESS Integrated Program Office (IPO) has made great strides in their hiring and program staffing. The Systems Program Director is now reporting staffing as "green" in his monthly reporting to management. In addition, the IPO has developed a Human Capital Plan to address the difficulties in staffing a three-agency program office, which was submitted for NASA's review in September 2007. The NPOESS Program Executive Officer requested five additional NASA personnel to supplement the IPO staff after the Nunn-McCurdy restructure of the program office. All NASA NPOESS positions are currently filled.

Question 3. This past January, approximately 100 experts at the National Academies participated in a priority-setting 2007 National Research Council report as requested by NOAA, NASA, and the USGS to come up with detailed recommendations to restore U.S. leadership in Earth science and application and avert the potential collapse of the system of environmental satellites. Earlier that same month, NOAA and NASA briefed the White House Office of Science and Technology Policy about which NPOESS climate instruments should be "dismantled" and which should fly on satellites due to be launched at a later time. What would you say is the reason for such a difference of thinking between the NRC experts and the NASA decision-makers as to which climate instruments should be "dismantled" and which should go forward and as early as possible?

Answer. The apparent difference in thinking is really a matter of a difference in timing. The National Research Council (NRC) Decadal Survey report and the NPOESS Nunn-McCurdy Certification happened largely in parallel; thus the NRC did not have the benefit of full knowledge of the impacts of changes in the NPOESS program in designing their recommended mission set. The NASA, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Geological Survey (USGS) asked the NRC in 2004 to conduct a Decadal Survey and develop consensus recommendations relative to the research and applications programs of the three participating agencies. An interim report was completed in April 2005 and a draft of the final report was released in January 2007.

The Nunn-McCurdy Certification of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) occurred in June 5, 2006. Due to overruns and schedule delays, the NPOESS Program had exceeded the Nunn-McCurdy threshold and it became necessary to reduce the content and overall risk of the existing NPOESS Program as a part of the Nunn-McCurdy process. Early in the certification process, the NPOESS Executive Committee decided that providing uninterrupted satellite data to support weather forecasting would take priority over climate measurements. As a result of this prioritization, five climate instruments were de-manifested from the certified NPOESS Program.

In a meeting at the Office of Science and Technology Policy (OSTP) in June 2006, NASA and NOAA agreed to develop a joint assessment of: (1)the impacts of the Nunn-McCurdy Certification on their combined climate goals, and (2) various alternatives for addressing those impacts. This joint assessment of impacts was delivered to OSTP on January 8, 2007 and was followed by additional dialogue on options for retaining these measurement capabilities. NASA and NOAA have worked diligently to develop practical and affordable alternatives to address the potential data gaps attributable to the loss of these de-manifested climate sensors.

Shortly after the Nunn-McCurdy Certification had occurred, NASA and NOAA asked the NRC to address the de-manifested climate sensors in the ongoing Decadal Survey. The NRC informed us that the writing on the Decadal Survey was completed and presently in review. Consequently, it would not be possible to make such an assessment a part of the Decadal Survey. However, it was agreed that a second NRC group with overlapping membership with the Decadal Survey would conduct a workshop to consider the impacts of the Nunn-McCurdy Certification. At this NRC workshop, held on June 19–21, 2007, NASA and NOAA presented the alternatives that they had been studying. A final report with specific recommendations is due in early 2008.

Question 3a. Have the agencies re-evaluated their satellite science programs in light of the NRC report, which came out a week after the White House briefing?

Answer. NASA is using the NRC Decadal Survey to guide future mission decisions. Conceptual studies have been undertaken for all of the missions described in the NRC draft report and specific community workshops have been held for the first four missions mentioned in the Decadal Survey.

Question 3b. In the NRC's chapter on Climate Variability and Change, they recommend restoration of five instruments essential for climate science that have been deleted from the NPOESS program. Your agencies asked for these NRC recommendations, but you do not appear to be implementing those recommendations. If you are not reconsidering restoring these climate instruments, why not?

Answer. NASA and NOAA have been considering potential options to restore the de-manifested climate sensors since the announcement of the NPOESS Nunn-McCurdy Certification in June 2006. In April 2007, the two agencies announced plans to remanifest the Ozone Mapping and Profiler Suite (OMPS) Limb on the NPOESS Preparatory Project (NPP). NASA and NOAA continue to work on options, in coordination with OSTP, to restore these de-manifested climate sensors.

Question 4. A 2005 interim report of the Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future stated, "Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important challenges for society as it seeks to achieve prosperity, health, and sustainability." The 2007 NRC report strongly backed up this declaration. Do you believe your agency is living up to this statement?

Answer. The NRC statement describes a national, and in fact, an international challenge. NASA is doing its part by providing the scientific understanding of how the Earth as a planet functions and changes. Our goal in Earth science, "Study planet Earth from space to advance scientific understanding and meet societal needs" well comports with the NRC's vision. NASA's expertise is primarily in those parts of the challenge that can best be addressed via remote sensing from space and use of that data in Earth system research and modeling. The agency has the largest such program in the world. At the national level, NASA is the largest contributor to the U.S. Climate Change Science Program, and is an active partner in related forums addressing other aspects of the Earth system. NASA continues to work with its interagency partners to advance the Nation's understanding of climate change and the Earth system. Internationally, NASA is actively engaged in a wide range of partnerships with other space programs and environmental research programs to mutually leverage our respective efforts. NASA is using the NRC's report as a guide, as the agency plans our future Earth Science programs.

Question 5. The Administration's FY 2008 NASA budget shows a modest increase for the aerospace agency—most of which will go to the International Space Station the Space Shuttle and the development of a Shuttle successor—while the funding for the science programs has will remain flat after years of cuts—now at 30 percent since 2000. While we are all captivated by the thought of men and women exploring space, I am very concerned that NASA is sacrificing research programs that are vital if we are to gain a more comprehensive knowledge of climate change on our very own Earth. If we are going to prioritize for budgetary reason, I believe we must be the stewards of our own planet. The Senate appropriators of the FY 2008 NASA science programs funding have added $25 million to these programs and have stated in their report, "The Committee is concerned that the strong, balanced science program that has served the Nation so successfully for many years is being left behind rather than being nurtured and sustained." Indeed, NASA Administrator Michael Griffin has defended the budget cuts as necessary to retool the agency for a 21st century focus on manned space travel to the Moon by 2020 and ultimately to Mars. He has also stated that he has his doubts as to whether mankind should address global warming.

Can we expect continued erosion in NASA funding for climate change data collection, monitoring, and research from NASA satellites? What are NASA priorities in relation to the U.S. Climate Change Science Program? It appears as though investigation of our own blue planet is becoming a poor stepchild to exploring other planets or the Moon.

Answer. NASA studies Earth from space to advance scientific understanding and meet the needs of humankind. NASA is committed to examining Earth's many facets from space in the same way the Agency has intensely surveyed the moon, planets and stars. From the launch of the world's first experimental meteorological satellite in 1960 to the 14 Earth-observing satellites currently in orbit, NASA drives the technological and scientific advances that help us understand our home planet.

The FY 2008 budget request for the Earth Science Division is $1.5 billion, representing 27 percent of the total funding for the four Science Mission Directorate divisions. This also represents an increase of $32.8 million over the FY 2007 request. This funding enables a wide-ranging and balanced program of activities, including:

- Developing, launching, and operating Earth-observing space missions;
- Competitively selecting and pursuing research and analysis science investigations conducted by NASA and non-NASA researchers;
- Conducting Applied Science projects that help other Federal and regional agencies and organizations to efficiently use products from NASA Earth research to advance their missions;
- Soliciting and advancing technology development efforts to enable the missions of the future; and
- Providing education and public outreach programs to make our knowledge of the Earth accessible to the world.

In particular, NASA intends to launch an additional seven Earth-observing satellites before 2013, adding new scientific capabilities and maintaining data continuity for key measurements. Further, NASA has been and will continue to be a major supporter of numerous Congressional mandates and Presidential initiatives in the area of climate science. For example, NASA is the largest contributor to the U.S. Climate Change Science Program (CCSP) and the agency's commitment to the CCSP has not decreased. In addition, NASA along with other Federal agencies contributes to U.S. leadership in such efforts as the U.S. Group on Earth Observations (USGEO) and the International Committee on Earth Observation Satellites (CEOS). Specific details on all of NASA's priorities in the area of Earth Science are detailed in the recently released "Science Plan for NASA's Science Mission Directorate 2007–2016".

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. BILL NELSON TO DAVID A. POWNER

Question. For decades, the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) had a successful partnership whereby NASA built and launched the satellites and NOAA operated them and analyzed the data. Why was that approach changed for GOES-R and NPOESS and what lessons can be learned from the experience?

Answer. Historically, the GOES programs relied on NASA to procure the satellites while NOAA managed the overall program and operated the satellites. However, NOAA found that a lesson learned on its GOES I–M series was that it needed more insight into NASA's activities. Thus, on the GOES-R series, NOAA originally planned to take more of a leadership role and to rely on NASA for expertise and advice. However, after an independent review team raised concerns with this approach, NOAA decided to return the program to the prior structure. Under the current management structure for GOES-R, NOAA is responsible for program funding, procurement of the ground elements, and on-orbit operation of the satellites, while NASA is responsible for the procurement of the spacecraft, instruments, and launch services.

The NPOESS program is a tri-agency program managed by NOAA, the Department of Defense (DOD), and NASA. It began with a May 1994 Presidential Decision Directive which required NOAA and DOD to converge their two existing polar-orbiting satellite programs into a single satellite program capable of satisfying both civilian and military requirements.[1] To manage this program, DOD, NOAA, and NASA formed the tri-agency Integrated Program Office, located within NOAA. Within the program office, each agency has the lead on certain activities: NOAA has overall program management responsibility for the converged system and for 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, including a demonstration satellite known as the NPOESS Preparatory Project (NPP), which is planned to be launched in September 2009.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO DAVID A. POWNER

Question 1. GAO has done significant work in analyzing the problems with the NPOESS program. In your opinion, is the program truly back on track, or are there stil continuing risks, particularly with respect to the Federal Government's management of the procurement and meeting administrative deadlines?

Answer. As we noted in our April 2007 report[2] and July 2007 testimony,[3] the NPOESS program office has made progress in restructuring the program. For example, we noted in our April report that the NPOESS program office has made progress in establishing an effective management structure by adding a program executive officer position senior to the program director. It subsequently revised the program office's organizational framework, realigning division managers to oversee key elements of the acquisition, as well as increasing staffing. Under this structure, the program office implemented more rigorous and frequent reviews, improved visibility into risk management, and institutionalized the use of earned value management techniques to monitor contractor performance.[4] The program executive officer implemented monthly program reviews—we observed that these briefings allow the executive officer to have direct insight into the challenges and workings of the program and allow risks to be appropriately escalated and addressed. Additionally, the NPOESS Executive Committee meets more often now than in the past.

However, significant technical challenges and risks remain in the program, particularly to two key sensors, the Visible/Infrared Imager Radiometer Suite (VIIRS) and the Cross-track Infrared Sounder (CrIS). Both sensors are to be flown on NPP in 2009 and have experienced significant developmental failures in the last year—VIIRS has experienced significant problems with a filter, and the CrIS instrument experienced a structural failure to its frame last fall. Until the sensors are delivered for integration to the satellite next spring, they remain high-risk developments.

Additionally, the program faces continuing risks in completing key acquisition documents. We had recommended that these documents be finalized before the contract negotiations were finalized. However, the NPOESS program office completed a contract modification to restructure the program in late July 2007 even though key acquisition documents remained outstanding. DOD's Under Secretary for Acquisition, Technology and Logistics extended the documents' deadlines and the program office is working to complete many of them. Finalizing these documents is critical to ensuring interagency agreement and will allow the program office to move forward in finishing other activities related to restructuring the program.

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[1] Presidential Decision Directive NSTC–2, May 5, 1994.

[2] GAO, *Polar-orbiting Operational Environmental Satellites: Restructuring Is Under Way, but Technical Challenges and Risks Remain,* GAO–07–498 (Washington, D.C.: April 2007).

[3] GAO–07–1099T.

[4] The earned value concept is applied as a means of placing a dollar value on project status. It is a technique that compares budget *versus* actual costs versus project status in dollar amounts.

Question 2. Have the three Federal agencies responsible for this program—NOAA, NASA, and DOD—fully implemented all ofGAO's recommendations?

Answer. The three agencies have not yet implemented the recommendations made in our April 2007 report.[5] In that report, we recommended that (1) the Air Force delay reassigning a key NPOESS program executive; (2) all three agencies complete and approve key acquisition documents related to program restructuring activities; (3) NOAA develop and implement a written process for identifying and addressing human capital needs and for streamlining how the program handles different agencies' administrative procedures, and (4) NOAA establish a plan for immediately filling needed positions.

The Air Force disagreed with our first recommendation and decided to continue with its plans to reassign the program's executive officer. However, over the last few years, we and others (including an independent review team and the Commerce Inspector General) have reported that ineffective executive-level oversight helped foster the NPOESS program's cost and schedule overruns. We remain concerned that reassigning the program executive at a time when NPOESS is still facing critical cost, schedule, and technical challenges places the program at further risk.

At the time of the report, all three agencies agreed with the second recommendation and noted that they were working to complete these documents. Since then, the program has completed its contract modification, but it is still working to complete some of the key acquisition documents. We remain concerned that without these documents completed, the program faces increased risk that unanticipated changes in these documents could cause further contract modifications.

The Department of Commerce recently stated that the NPOESS program is in the process of preparing a human capital plan in response to our third recommendation that it plans to complete by the end of 2007.

Regarding the fourth recommendation, at the time of the completion of our review in April 2007, over 20 critical positions remained to be filled—the majority of which were to be provided by NOAA. NOAA officials noted that each of these positions was in some stage of being filled and later reported that they had identified the skill sets needed for NOAA positions and implemented an accelerated hiring model to fill them. Additionally, NOAA stated that it had placed filling NPOESS office positions as a top priority within its workforce management office and allocated internal resources accordingly. As of our June 2007 testimony, the program office reported that 11 positions remained unfilled.

Question 3. The May 2006 IG report found that insufficient oversight—and in particular an unwillingness to challenge overly optimistic assessments—caused or exacerbated many of the problems with the satellite program. Do you believe that an atmosphere of over-optimism and insufficient oversight still exists within the satellite programs? To what extent have the agencies addressed these issues?

Answer. Given the history of problems on the program, NPOESS is now being managed with more realistic expectations and improved oversight. For example, we noted in our April report[6] that the NPOESS program office had recently implemented more rigorous and frequent reviews, improved visibility into risk management, and institutionalized the use of earned value management techniques to monitor contractor performance. We also noted that the program executive officer implemented monthly program reviews; we observed that these briefings allow the executive officer to have direct insight into the challenges and workings of the program and allow risks to be appropriately escalated and addressed. However, NPOESS still faces technical and programmatic challenges, and continued program oversight is needed to ensure that these risks are effectively mitigated.

In responding to these questions, we relied on information we previously reported on NPOESS and GOES.[7]

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[5] GAO–07–498

[6] GAO–07–498.

[7] GAO–07–1099T; GAO–07–498; GAO–06–993; GAO, *Polar-orbiting Operational Environmental Satellites: Restructuring is Under Way, but Challenges and Risks Remain,* GAO–07–910T (Washington, D.C.: June 7, 2007); *Geostationary Operational Environmental Satellites: Steps Remain in Incorporating Lessons Learned from Other Satellite Programs,* GAO–06–993 (Washington, D.C.: Sept. 6, 2006); and *Geostationary Operational Environmental Satellites: Additional Action Needed to Incorporate Lessons Learned from Other Satellite Programs,* GAO–06–1129T (Washington, D.C.: Sept. 29, 2006).

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO ANTONIO J. BUSALACCHI, JR., PH.D.

Question 1. Of the two possibilities for replacing QuikSCAT—a faster replacement with the same capabilities as QuikSCAT, or a longer delay for a more capable, next-generation scatterometer—which is preferable?

Answer. The scatterometer on the QuikSCAT spacecraft was developed in the late 1990s; it is no longer possible to "build to blueprint" a new copy of the instrument. While there might be some time saved in building another QuikSCAT instead of the more advanced scatterometer, it would not, in my view, be wise. With a relatively small increase in cost (roughly 10 percent according to estimates I have heard) and small delay in development, we could move to the much more capable dual-frequency scatterometer of the type recommended in the NRC Decadal Survey (the "XOVWM," advanced Ocean Vector Wind Mission). The benefits of an advanced Ocean Vector Wind Mission be it in support of monitoring, understanding, and prediction would far outweigh that of a short delay in coverage. The time to implement this mission is constrained by resources, not technology.

Question 2. There is an active debate in the scientific community about the long-term relationship between hurricane frequency and intensity and climate change? Could any of the sensors that were decommissioned on NPOESS and GOES-R provide data to help resolve that debate?

Answer. One of the principal shortcomings contributing to this debate is the lack of comprehensive satellite coverage prior to the 1970s. The historical data on hurricane intensity is not very good, but that is no longer the case. Looking to the future, three classes of instruments are needed to understand the time rate of change of hurricane intensity. They are the all-weather scatterometer surface winds observations for which the XOVWM would provide improved measurements, the all weather sea surface temperature (SST) observations to have been provided by CMIS (but now in doubt) as SST provides the primary energy source to the hurricane, and the precision altimeter observations of sea surface height which provide information on the heat content of the upper ocean that can influence hurricane growth or decay.

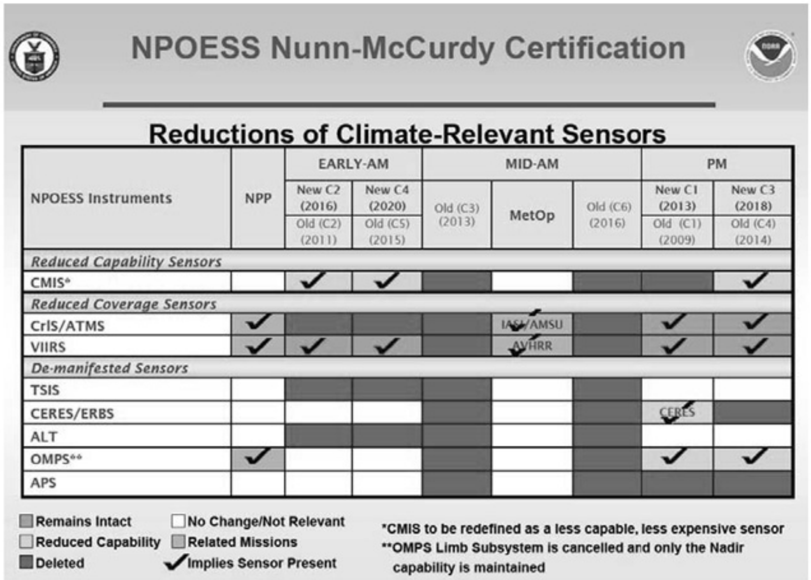
Question 3. Are you familiar with the GIFTS instrument, and would it be an acceptable alternative to the Hyperspectral Environmental Suite (HES) instrument on GOES-R?

Answer. In my opinion it is premature to consider GIFTS as an acceptable alternative to HES on GOES–R. One of the problems with NPOESS was that new technology was slated for an operational platform without an adequate demonstration of the technology. Placing GIFTS on NPOESS would be repeating the sins of the past.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO ANTONIO J. BUSALACCHI, JR., PH.D.

Question 1. From what you know of the climate sensor cuts, do you believe there will be data gaps?

Answer. Yes. Changes to the NPOESS sensor complement will affect a number of important measurements. The chart below summarizes changes to the climate-relevant sensors as a result of Nunn-McCurdy actions.

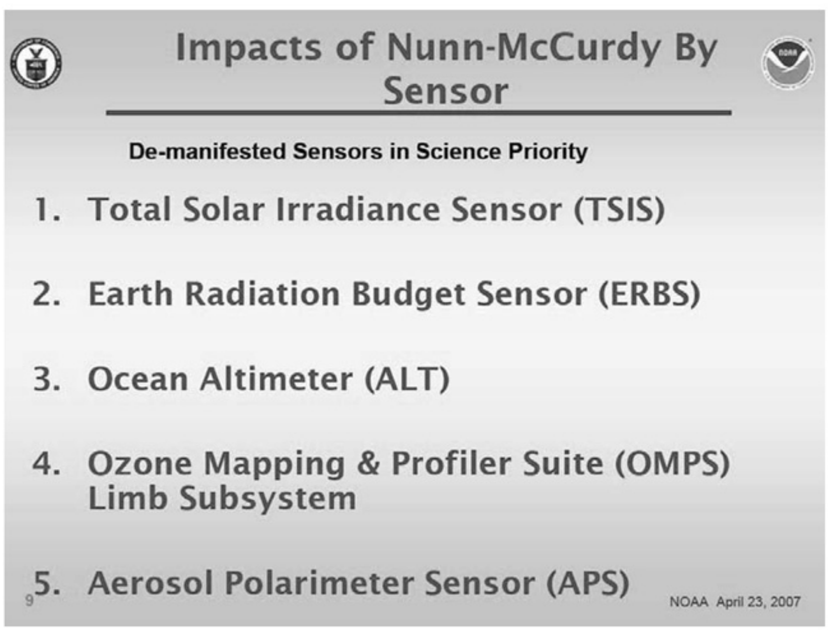


NPOESS Instruments	NPP	EARLY-AM		MID-AM			PM	
		New C2 (2016) Old (C2) (2011)	New C4 (2020) Old (C5) (2015)	Old (C3) (2013)	MetOp	Old (C6) (2016)	New C1 (2013) Old (C1) (2009)	New C3 (2018) Old (C4) (2014)
Reduced Capability Sensors								
CMIS*		✓	✓					✓
Reduced Coverage Sensors								
CrIS/ATMS	✓				✓ IASI/AMSU		✓	✓
VIIRS	✓	✓	✓		✓ AVHRR		✓	✓
De-manifested Sensors								
TSIS								
CERES/ERBS							✓ CERES	
ALT								
OMPS**	✓						✓	✓
APS								

Remains Intact · No Change/Not Relevant · Reduced Capability · Related Missions · Deleted · ✓ Implies Sensor Present

*CMIS to be redefined as a less capable, less expensive sensor
**OMPS Limb Subsystem is cancelled and only the Nadir capability is maintained

In a recent presentation to an NRC study committee that I chair, NOAA stated that the measurements in danger as a result of these actions are:



I am particularly concerned about gaps in measurements that could jeopardize the utility of the entire time-series. An outstanding question for climate science is whether and to what degree variations in the Sun's energy output contribute to the observed global warming. To answer this question requires monitoring of the Sun's brightness at all wavelengths—its total solar irradiance (TSI)—over several 11-year solar cycles (the Sun regularly brightens and dims with an amplitude of roughly 0.1 percent over the course of its 11-year activity (sunspot) cycle).

TSI cannot be measured from the ground because of the Earth's atmosphere absorbs important components of the solar spectrum, the ultraviolet region being particularly important. However, since 1978, TSI has been measured from space using radiometers placed on a series of NASA and NOAA spacecraft. Because spacecraft typically do not operate for periods longer than a solar cycle and because variations in sensor performance from one spacecraft to the next are larger than the signals we are looking for, it is critical that there be many months of overlapping operation. Absent such overlap, it would be impossible to assemble a record of TSI that distinguishes actual changes in solar output *versus* changes in sensor performance and/or changes due to the natural solar cycle.

There is a similar, but lesser concern about the radiation emitted back to space, which is what is measured by the ERBS.

As we noted in the recent workshop report from my NRC committee, although NOAA has prioritized the de-manifested sensors in its own way, it did not consider the relative priority of the descoped/reduced coverage sensors. This should not be construed as a *de facto* lower prioritization. The sea surface temperature record from CMIS, for example, is of *very* high priority and yet because CMIS was not entirely demanifested, it does not appear on the NOAA priority list.

Similarly, not all sensors which are prioritized are recommended for remanifestation on NPOESS. For example, an altimetry measurement is of very high priority to continue the sea level record, however the NPOESS orbit prohibits attaining the high precision needed to continue the record. Thus, to prevent a measurement gap, a new mission is required rather than restoration of the demanifested sensor.

Our recently released NRC workshop report "Options to Ensure the Climate Record from the NPOESS and GOES–R Spacecraft: A Workshop Report" goes into more detail on these issues.

Question 2. Do you believe that the currently-planned satellites and sensors are sufficient to meet our climate monitoring needs in the coming years?

Answer. As alluded to above given the present NPOESS debacle, the short answer is an emphatic no! In addition, it is worth emphasizing that there remains no long-term plan for many of these measurements beyond the initial missions. There is no plan for long-term continuity of precision sea level, ocean vector winds etc. as noted in workshop report. Moreover, there needs to be formal coordination between NASA and NOAA regarding the climate-relevant missions proposed by the NRC Decadal Survey (see below) and the NPOESS remanifestation exercise.

Table 2.1 Launch, orbit, and instrument specifications for the recommended NOAA missions.

[Missions are listed in order of ascending cost within each launch time frame.]

Decadal survey mission	Mission description	Orbit	Instruments	Rough cost estimate
Timeframe: 2010–2013—Missions listed by cost				
CLARREO (NOAA portion)	Solar and Earth radiation characteristics for understanding climate forcing.	LEO, SSO	Broadband radiometer	$65 M
GPSRO	High accuracy, all-weather temperature, water vapor, and electron density profiles for weather, climate and space weather.	LEO	GPS receiver	$150 M
Timeframe: 2013–2016				
XOVWM	Sea surface wind vectors for weather and ocean ecosystems.	LEO, SSO	Backscatter radar	$350 M

Table 2.2 Launch, orbit, and instrument specifications for the recommended NASA missions.

[Missions are listed in order of ascending cost within each launch time frame.]

Decadal survey mission	Mission description	Orbit	Instruments	Rough cost estimate
Timeframe: 2010–2013—Missions listed by cost				
CLARREO (NASA portion)	Solar Radiation: spectrally resolved forcing and response of the climate system.	LEO, Precessing	Absolute, spectrally-resolved interferometer	$200 M
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes.	LEO, SSO	L-band radar L-band radiometer	$300 M
ICESat-II	Ice sheet height changes for climate change diagnosis.	LEO, Non-SSO	Laser altimeter	$300 M
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health.	LEO, SSO	L-band InSAR Laser altimeter	$700 M
Timeframe: 2013–2016—Missions listed by cost				
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health.	LEO, SSO	Hyperspectral spectrometer	$300 M
ASCENDS	Day/night, all-latitude, all-season CO_2 column integrals for climate emissions.	LEO, SSO	Multifrequency laser	$400 M
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics.	LEO, SSO	Ku-band radar Ku-band altimeter Microwave radiometer	$450 M
GEO–CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions.	GEO	High spatial resolution hyperspectral spectrometer Low spatial resolution imaging spectrometer IR correlation radiometer	$550 M
ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry.	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar	$800 M
Timeframe: 2016–2020—Missions listed by cost				
LIST	Land surface topography for landslide hazards and water runoff.	LEO, SSO	Laser altimeter	$300 M
PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST.[a]	GEO	MW array spectrometer	$450 M

Table 2.2 Launch, orbit, and instrument specifications for the recommended NASA missions.—Continued

[Missions are listed in order of ascending cost within each launch time frame.]

Decadal survey mission	Mission description	Orbit	Instruments	Rough cost estimate
GRACE–II	High temporal resolution gravity fields for tracking large-scale water movement.	LEO, SSO	Microwave or laser ranging system	$450 M
SCLP	Snow accumulation for fresh water availability.	LEO, SSO	Ku and X-band radars K and Ka-band radiometers	$500 M
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction.	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder	$600 M
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport.	LEO, SSO	Doppler lidar	$650 M

[a] Cloud-independent, high temporal resolution, lower accuracy SST to complement, not replace, global operational high accuracy SST measurement.

Question 3. Will the loss of these sensors hurt our ability to observe, research, predict, and respond to climate change?

Answer. Without any doubt the answer is yes. An excellent example is the need for precision altimeter measurements that do not have a home on the NPOESS platform. These measurements of sea surface height are absolutely critical for monitoring sea level rise both globally and regionally, as well as providing a quantitative assessment as to whether or not sea level rise is accelerating. In addition, these observations provide key input to today's operational coupled ocean-atmosphere prediction models that issue short-term climate forecasts on a time scale of seasons out to a year in advance.

Question 4. Out of the climate sensors cut from the NPOESS and GOES–R satellites, what was the largest scientific loss?

Answer. This is a difficult question to answer depending on the scientific perspective; *i.e.,* monitoring, understating, prediction, or reducing uncertainty. Some might answer the loss of the Advanced Polarimeter (APS) given the present uncertainty in aerosol forcing, *or* the reduced sounding coverage of the CrIS instrument and the reduced diurnal coverage of the VIIRS instrument impacts out-monitoring capability, but overall I would point to the loss of the TSIS instrument given the importance of a stable, unbroken record of the solar radiative forcing of our planet.

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