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HEARING ENTITLED
TO OBSERVE AND PROTECT: HOW NOAA PROCURES DATA
FOR WEATHER FORECASTING

BEFORE THE
U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

MARCH 28, 2012

Good afternoon Chairman Harris, Ranking Member Miller, and members of the Committee, my name is Eric Webster, and I am the Vice President and Director of Weather Systems at ITT Exelis. I appreciate your leadership and efforts to examine how NOAA procures data for weather forecasting, and I appreciate the opportunity to testify.

This is a sort of homecoming for me, as I was privileged to be a staffer on this Subcommittee for five years from 2001 to 2005 under Chairman Sherwood Boehlert and led examinations into NOAA's weather satellite programs. I then served in the George W. Bush Administration as NOAA's head of Congressional Affairs and a senior policy advisor on weather satellites. During that time, the Committee conducted 12 NOAA satellite oversight hearings. My position at ITT Exelis has brought me full circle, as I now oversee the building of next generation instruments for GOES-R and JPSS. So my advice to the staff is to be careful as you never know where you might end up.

People often joke about endeavors being not as hard as "rocket science." But our engineers will tell you the design and manufacture of these highly sensitive instruments - which must survive the extreme forces of a rocket launch, the harsh environment of space, have the sensitivity to tell variation of sea surface temperature to a tenth of a degree from 22,300 miles away, and work 24/7 for several years – is much more difficult than rocket science.

While I have played a role in this discussion for more than 10 years, this is the first time the broader scientific and technical processes that drives decision making for requirements and eventual procurement have been brought to the forefront. If done properly, this process leads to an optimal combination of systems and data that ultimately helps forecasters save lives. So I commend the Committee for taking a more holistic view of the situation beyond the normal inquiries into the cost and schedule difficulties of the major programs.

Why are these weather observations and forecasts so important? The government, many industries, and our citizens rely daily on these forecasts for military operations, for logistics and transportation flow, for agriculture, for normal quality of life, and for warnings to save lives and property. In fact, the weather affects more than one-third of our nation's GDP.

We often forget the U.S. has the most natural hazards and severe weather on the globe ranging from tornadoes, hurricanes, hail, damaging winds, winter storms, floods, wildfires, extreme temperatures, poor air quality to drought. To measure, monitor and forecast the weather, NOAA uses more than 100 different observing systems (such as satellites, radars, radiosondes, data from air planes, ocean buoys, soil moisture sensors, and a network of 11,000 volunteers with small weather stations in their backyards). NOAA also utilizes data and information from commercial and international observing systems to help augment its resources. To the public and through its accurate forecasts, it is a seamless effort, but behind the scenes it is a large undertaking and NOAA deserves credit for making it work.

However, the cost and maintenance of NOAA systems adds up to billions of dollars a year with nearly $2 billion a year just in satellite costs. Given the fiscal constraints and budgetary crisis we are facing, and the need to continue to improve our capabilities to save lives and livelihoods, NOAA must constantly examine and re-examine its priorities for observing systems to provide the best value for the taxpayers' investment.

While observations are critical and tend to receive much of the attention, it is important to note observations alone do not make the forecast. The observations must be broken down into useable information through data assimilation. This requires very sophisticated models run on supercomputers and then exported to computer workstations for forecasters, who in turn must effectively translate and communicate the information. Finally, it is an understanding public whose responsibility it is to take action based on the information. Each part of this system is important and must work in concert. If not, the most advanced and expensive observing systems would not improve the forecast or save lives. In fact, I often wonder if providing shelters for people living in mobile homes in the Southeast U.S. would save more lives than new satellite instruments or radars – but that is probably the subject for another hearing.

I was asked to describe the types of data generated by space-based sensors and the importance of such data in weather forecasting, including the role of this data within the context of the current mix of observing systems.

There are two major orbits for weather satellites, one is called a polar low-earth orbit and the other is geostationary orbit. Polar satellites fly about 520 miles above the earth in a pattern from pole to pole and, as the earth rotates, the satellites gather global data, roughly seeing the same spot twice a day. They circle the globe about every 90 minutes. These satellites are critical to provide data and measurements used in global weather forecast models and critical for two to seven day forecasts. Polar satellites can be thought of as forecasting satellites. These satellites also provide the only visible imagery of high latitude regions such as Alaska, where geostationary satellites are effective due to the curvature of the earth.

Geostationary satellites fly about 22,300 miles above the earth and constantly stare at the United States from Atlantic Ocean to Pacific Ocean from a fixed location relative to earth. These satellites are critical for monitoring severe weather, such as hurricanes and tornadoes, and providing real-time data on weather parameters for the U.S. Geostationary satellites can be thought of as now-casting.

While there are many types of space-based sensors, it is imagers and sounders that provide the majority of the data and information used for weather models and by forecasters. Imagers, true to their name, take pictures and gather information at a specific spot on the surface of the land, ocean, or ice. They also take pictures and measurements of clouds and their movements, as well as water vapor transport which is invisible to the naked eye, all critical to severe weather forecasts. When you see the pictures of hurricanes on television or the Internet, they come from space-based imagers. Imager capability is measured in how small area they can see, how quickly they can scan to the next spot, and how many channels or bands it has to measure different chemical compositions making up temperature, moisture, pressure, wind and other attributes such as volcanic ash, hot spots for fires, etc.

Sounders work technically in a similar way to imagers, but instead of taking pictures of the surface, they are taking 3-D pictures of the atmospheric column from space to near surface. Their performance is measured by the number of different slices of the atmospheric column they produce and the sensitivity to differentiate chemical compositions of temperature, moisture, pressure, wind, etc. The atmosphere is where the weather is created, mixed, moves, and evolves. If imagers are our sight, sounders are our feeling, our hearing, our tasting and our smelling of the atmosphere. Thus, these measurements are particularly important for the creation of weather forecast models.

In general, weather observing systems measure the same or similar parameters of temperature, moisture, pressure, wind, etc., regardless of if it is a space-based sensor, radiosone/weather balloon, aircraft sensor, radar, ocean buoy or small weather station at your local elementary school. The difference is in the breadth of coverage, the latency or timing of the data, its sensitivities, and its biases.

No one observing system can meet all the requirements. Data from each system plays an important role in the development of weather forecast models and in warnings of severe weather. They complement each other and fill in the gaps and limitations of the others – or, as they say in NOAA, they act as a network of networks. Most of these other systems can even be more sensitive than spaced-based sensors because they are much closer to the observation, but they cannot provide the sheer breadth, abundance and consistency of coverage. It is difficult to judge relative importance of each capability – but I understand doing so is one of the goals of this hearing.

Global weather forecast models are critical to initialize the whole forecasting process and rely mostly on data from polar sounders because of the global reach (remember 70 percent of the earth is covered by ocean, with few in-situ measurements) and their ability to measure the atmospheric columns – where the weather is being created. The National Weather Service has been able to forecast the likelihood of severe weather and potential tornadoes in specific areas of the country days in advance mostly because of polar sounders. After global forecast models are created, the National Weather Service then creates regional models and finally localized forecasts that are higher in resolution and thus more sensitive to particular conditions and small features that may be smoothed out by the global models.

Similarly geostationary imagers are critical for visualization of large movements of clouds, storms, and other features that drive weather in the U.S. They are especially crucial for monitoring hurricanes and ocean storms. However, forecasters rely much more on radar, radiosondes, local weather stations and other data sets for specific short-term forecasts and local warnings. There are exciting commercial capabilities in the use mesonets and lidar to measure the boundary layer and wind which can further improve forecasts, especially at a hyper-localized level.

I did want to briefly mention a related and important topic known as space weather. NOAA is also responsible for space weather forecasts. Space weather consists of charged particles, radiation, winds and "storms" ejected from the sun, which can quickly reach the earth and have a significant negative impact on satellite operations, the power grid, airline communications over the poles, and GPS signals (which control banking transactions and other critical IT functions). Radiation from solar storms can also harm the astronauts on the space station if not properly warned in advance. Satellite instruments are the best way to measure the different types and parameters of space weather. In fact, no other observing systems have the capability to provide the necessary measurements to allow for analysis and forecasting. Both geostationary and polar satellites carry instruments measuring space weather.

As the next generation weather satellite systems GOES-R and JPSS come on-line and the data is fully assimilated into models, there will be significant improvements in weather forecasting. These next generation space-based sensors will provide more information, be more accurate, and provide the data much more quickly than ever before. Further studies and research should then be conducted to reevaluate the relative importance of the new systems in the global forecasts models.

The larger question is if we can afford the tremendous costs of these satellites, which touches on the next question I was asked to address regarding the current process by which space-based observing systems are designed and procured to meet data requirement of the National Weather Service, including any processes that evaluate and prioritize these requirements.

NOAA's requirements process for spaced-based observing systems seems to be the same as for all NOAA observing systems. Requirements are first developed by operational users or researchers within NOAA and the scientific community. The requirements must be supported, vetted and approved by program leadership, and then senior officials within the supportive line-office. Once verified, requirements are presented to NOAA's Observing System Council (NOSC) for further validation and prioritization.

Recently, there have been discussions about the use of simulations and experiments to help prioritize requirements and study the impact of observing systems on forecast models and forecast accuracy itself. One type, Observing System Simulations Experiments (OSSEs), use model simulations of "nature" and simulations of new or modified observing systems to gauge their impact on forecasting. These experiments are highly theoretical and could be biased toward the creator's desires. They also require tremendous computation power and thus are expensive, but do allow for experiments where no observing system exists.

Observing Systems Experiments (OSEs) add or subtract data from an existing observation used in a specific forecast, such as the demonstrations NOAA conducted for the large snowstorms in February 2010. In this example, NOAA subtracted data from polar instruments to show the negative impact to the forecast. The results showed a significant underestimate in the amount of snowfall for the event. Another tool just starting to be used in the U.S. is called "adjoint experiment." This technique measures the amount of forecast error reduction accumulated by each observation based on global forecast model. European researchers using this technique recently affirmed the importance of polar sounders as the most important observation for global forecast models.

I do believe more extensive use of these tools can help NOAA make better assessments of observational needs, as well as compare existing, modified and potentially new observing systems. However, each has its strengths and weaknesses and requires additional expenditures, especially in the case of OSSEs, and will not fix many of the problems in the actual design and procurement of these systems.

Assuming requirements are finalized, and the decision is made for a space-based capability built by the U.S. government to meet the requirements, the next step is for NOAA's satellite division to work with NASA as the procurement agency to take the requirements and turn them into instrument specifications.

At ITT Exelis, our team in Fort Wayne, Indiana, has decades of experience with the difficulties in transitioning the requirements and user needs into actual space-based sensors providing data for use in models and products. ITT Exelis has built every imager and every sounder for NOAA's polar program (POES) since the 1970s, including the next generation CrIS sounder flying on NPP and scheduled for the JPSS program. We have also built all the imagers and sounders for NOAA's geostationary program (GOES) since early 1990s, including ABI imager for the GOES-R program.

In naming and prioritizing requirements, the factors most benefiting the end data products must be balanced against what is technically possible, than the benefit has to be quantified, and compared to the cost impact on the system to be designed - a standard cost/benefit trade. What makes it so complex in the case of space-based observing systems is that very few, if any, organizations or individuals really understand the entire value chain. NOAA understands the benefits to the users, NASA understands how to translate the user characteristics into hardware specifications, and industry understands the cost of implementing those specifications at the system level.

The process must also include the broader budget discussion within NOAA's budget assumptions and then approval within NOAA, the Department of Commerce, the Office of Management and Budget and ultimately with Congress.

In the case of GOES-R, system requirements were determined over the course of a two to three year "formulation phase," involving three industry teams and a review team consisting of combined NASA and NOAA representatives. NASA took an initial set of NOAA requirements, translated them into instrument level specifications, then all of the parties went through an iterative process whereby industry did cost and performance trades, and presented the results back to the NASA/NOAA review team. NOAA was the interface with the users, and NASA bridged the gap with industry. In this way, the instrument level requirements were tweaked and finalized. In the final phase of formulation the three industry teams competed for the most efficient, highest performing design. Throughout the process, NASA was able to modify requirements according to feedback from NOAA regarding the relative benefit, and from industry regarding the cost to implement.

This approach takes time and money. NOAA, with the help of NASA, spent more than $100 million on the GOES-R imager (ABI) and GOES-R sounder (HES) formulation phases, and the entire process took four to five years. The approach seems to have worked well for the GOES-R imager ABI as the requirements have been stable and ITT Exelis is in production on the first flight unit expected to be delivered early next year. But, it has taken nearly 12 years to get to this point.

For the GOES-R advanced sounder (HES), the requirements never really solidified properly, as too many priorities were collected into one system (sounding, coastal monitoring, and a backup for ABI). The requirements were still unstable in the final days of the formulation; the cost of developing the combined system along with the costs to assimilate the data into user products were not solidified and kept growing; and NOAA, NASA, the Department of Commerce, OMB and Congress were all still reeling from the cost and technical problems on the NPOESS program. Thus the decision was made not to go forward with an advanced sounder for GOES-R. At that time, I believe it was the right decision.

For the next generation polar program, which began as NPOESS and is now the JPSS program, similar requirements definitions were made and prioritized nearly 15 years ago, except the Department of Defense, NOAA and NASA all played a role, which made it even more difficult and challenging to transfer the requirements into actual space instruments. For example, the polar imager (VIIRS) requirements were expanded to include functions and capabilities of other instruments (low light and ocean color), causing technical challenges that persist today. The original requirements for the advanced sounder (CrIS) we are building demanded a very compact instrument making the design especially complicated. This requirement turned out to be more stringent than was necessary. All these debates, changes, and back and forth regarding the specific requirements and the end user needs, negatively impact the ability of industry to meet cost, schedule and performance, and increase the overall risk to the programs.

There are many significant pressures on this process beyond the technical experts at NOAA, NASA and in industry. There are continual technology advancements, and there are procurement officials, budget managers, oversight teams, NESDIS/NOAA leadership, continued review by NOAA's NOSC, NASA leadership, OSTP, OMB, GAO and you here in Congress all playing a significant role in how these requirements become reality in observing systems. So even if the requirements process worked flawlessly, there are many other important factors built into the system, which make it hard to turn requirements into actual observing systems. NOAA will likely face a gap in critical polar coverage because of our collective inability to turn the requirements into observing systems

In conclusion, I was asked to provide recommendations on how best to evaluate the most cost-effective and diverse combination of observing systems to meet the National Weather Service's forecasting needs.

I do believe NOAA and the National Weather Service are doing a pretty good job under very difficult circumstances. They are using a combination of U.S. government owned systems, commercial systems and international capabilities to put together a network of networks providing increasingly better forecasts and understanding into earth systems. But many unmet requirements and areas for improvement remain.

NOAA should increase its use of OSSEs, OSEs and adjoint experiments with proper oversight and funding. These tools can help to prioritize unmet needs and identify more cost-effective and perhaps technically superior solutions to existing observations systems. I believe a reexamination of an advanced geostationary sounder, requirements for a polar imager, and new technologies to measure 3-D winds are warranted.

NOAA and NASA must find ways to reduce costs, as the current GOES-R and JPSS programs are likely unsustainable. GOES-R is $8 billion for two satellites, sensors, ground systems and operations. For example, of the total program cost, the imager, which is the most advanced ever designed and built, is less than 10 percent. JPSS is $13 billion for two satellites, sensors, ground systems and operations. While amortizing out to the mid-2020s can lessen the sting of the total price tag, these costs are having a tremendous effect on the rest of NOAA's mission today and nearly assuring no new observing systems, especially from space can be acquired.

NOAA should examine different procurement models such as fixed price, modifying existing instruments (rather than building new) to meet requirements at lower costs and risks, and the potential to buy more data from commercial observations and networks.

In summary, space-based sensors are critical to weather forecasting both for global weather models and severe warnings. Requirements for observation systems should be driven by scientific tools and experiments to maximize capabilities and overall effectiveness to produce actionable data to protect lives and livelihoods. However, it is exceedingly difficult to turn the requirements into actual observing systems. Finally, the cost of NOAA's main satellite programs are likely unsustainable given our fiscal situation. More than ever, hard choices need to be made and new ways of doing business must be explored, such as relying more on commercial capabilities for unmet needs.