BRIDGING THE GAP: AMERICA'S WEATHER SATELLITES AND WEATHER FORECASTING

JOINT HEARING

BEFORE THE

SUBCOMMITTEE ON ENVIRONMENT &
SUBCOMMITTEE ON OVERSIGHT

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

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February 12, 2015

BRIDGING THE GAP: AMERICA'S WEATHER SATELLITES AND WEATHER FORECASTING

THURSDAY, FEBRUARY 12, 2015

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENVIRONMENT &
SUBCOMMITTEE ON OVERSIGHT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittees met, pursuant to call, at 10:01 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Jim Bridenstine [Chairman of the Subcommittee on Environment] presiding.

LAMAR S. SMITH, Texas
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EDDIE BERNICE JOHNSON, Texas
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Congress of the United States
House of Representatives

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Subcommittee on Environment
Subcommittee on Oversight

Bridging the Gap: America's Weather Satellites and Weather Forecasting

Thursday, February 12, 2015
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Witnesses

Mr. David Powner, Director, Information Technology Management Issues, Government Accountability Office.

Dr. Stephen Volz, Assistant Administrator, National Environmental Satellite, Data, and Information Services, National Oceanic and Atmospheric Administration.

Mr. Steven Clarke, Director, Joint Agency Satellite Division, National Aeronautics and Space Administration.

Dr. Alexander MacDonald, President, American Meteorological Society; Director, Earth System Research Laboratory, National Oceanic and Atmospheric Administration; and Chief Science Advisor, Office of Oceanic and Atmospheric Research, National Oceanic and Atmospheric Administration.

Mr. John Murphy, Director, Office of Science and Technology, National Weather Service, National Oceanic and Atmospheric Administration.

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENVIRONMENT
SUBCOMMITTEE ON OVERSIGHT

HEARING CHARTER

Bridging the Gap: America's Weather Satellites and Weather Forecasting

Thursday, February 12, 2015
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose

The Subcommittees on Environment and Oversight will hold a joint hearing titled *Bridging the Gap: America's Weather Satellites and Weather Forecasting* at 10:00 a.m. on February 12th in room 2318 of the Rayburn House Office Building. Witnesses will provide an update of the operations and development of National Oceanic and Atmospheric Administration's (NOAA) polar-orbiting and geostationary weather satellite programs and discuss recent Government Accountability Office (GAO) reports on the two programs. In addition, the hearing will discuss the use of satellite data in operational and research weather models and prediction methods.

Witnesses

- **Mr. David Powner,** Director, Information Technology Management Issues, Government Accountability Office.
- **Dr. Stephen Volz,** Assistant Administrator, National Environmental Satellite, Data, and Information Services, National Oceanic and Atmospheric Administration.
- **Mr. Steven Clarke,** Director, Joint Agency Satellite Division, National Aeronautics and Space Administration.
- **Dr. Alexander MacDonald,** President, American Meteorological Society; Director, Earth System Research Laboratory, National Oceanic and Atmospheric Administration; and Chief Science Advisor, Office of Oceanic and Atmospheric Research, National Oceanic and Atmospheric Administration.
- **Mr. John Murphy,** Director, Office of Science and Technology, National Weather Service, National Oceanic and Atmospheric Administration.

Background

Recent, faulty predictions about a recent blizzard in the Northeast United States underscore the need for accurate and timely forecasting capabilities to protect lives and property. Other seasonal weather events, such as hurricanes and tornadoes, also represent a challenge for timely, accurate weather forecasts and warnings.

Over the last decade, the Committee on Science, Space, and Technology has monitored the troubled development of NOAA's weather satellite programs, which provide vital input to weather forecasts. These programs include the Joint Polar Satellite System (JPSS), its predecessor, the National Polar-orbiting Operational Environmental Satellite System (NPOESS), and the Geostationary Operational Environmental Satellite System (GOES).

NOAA's satellite systems form the fundamental base for the nation's forecasting ability, providing the majority of the data used in American weather models. A report by the National Research Council found that 80% of the data assimilated into numerical weather models comes from satellites.[1] Satellite data is able to significantly enhance forecasting accuracy. For example, in 2010, data from polar-orbiting satellites helped meteorologists predict the arrival of "Snowmageddon" five days in advance, and early forecasts of Superstorm Sandy's track were aided by polar-orbiting satellites, according to a study by the European Centre for Medium-Range Weather Forecasts.[2,3]

Due to a series of management problems, delays, and increased costs, NOAA's weather satellite programs now face a likely gap in satellite coverage and data. NOAA has recently revised its estimate of the length of a potential data gap from 15 months down to 3 months, but the GAO questioned NOAA's methodology for this estimate. Without this data, the ability of American weather models to accurately predict weather events will be greatly diminished. In its 2013 update on NOAA's satellite programs, GAO noted that, "According to NOAA program officials, a satellite data gap would result in less accurate and timely weather forecasts and warnings of extreme events, such as hurricanes, storm surges and floods. Such degradation in forecasts and warnings would place lives, property, and our nation's critical infrastructures in danger."[4]

Satellites provide a plethora of data that are used in many forecasting products. The satellites gather information about the earth's atmosphere, land surface, oceans, and the space environment.[5] Satellites transmit data in a raw format. Processing centers on the ground then format the data to account for calibrations such as time and earth location. Further processing separates the data into specific parameters such as temperature. This data is then used to derive

[1] National Research Council, national Academy of Sciences, "Fair Weather Report: Effective Partnership in Weather and Cliamte Services," 2003, available at: http://www.nap.edu/catalog/10610/fair-weather-effective-partnerships-in-weather-and-climate-services

[2] NOAA, *Suomi NPP: Improving U.S. Weather Forecast Accuracy from Space*, December 3, 2012, available at: http://www.nesdis.noaa.gov/npp_launch.html

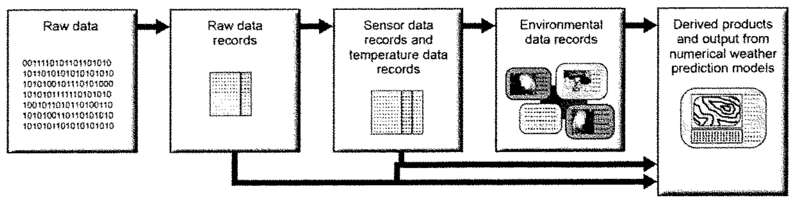
[3] European Centre for Medium-Range Weather Forecasts, "Annual Report: 2012," p.5, available at: http://www.ecmwf.int/publications/annual_report/2012/pdf/Annual-report-2012.pdf

[4] GAO-13-283, February 2013, p. 70.

[5] GAO, "Polar Weather Satellites: NOAA Needs to Prepare for Near-Term Data Gaps," GAO-15-47, January 2015, p.5.

weather and climate products.[6] Combinations of the various data records are used to create forecasts from the numerical weather models. These models are then used by meteorologists to produce forecasts for American citizens.

The figure below from GAO depicts a simple representation of the stages of satellite data.[7]



Source: GAO analysis of NOAA information. | GAO-15-47

GAO Recommendations

JPSS

In its 2015 update, GAO continues to raise concerns about NOAA's polar satellite program, specifically noting that the program is facing an unprecedented gap in satellite data.[8] NOAA has recently revised its estimate of the length of a potential gap from 15 months down to 3 months. GAO notes that this new estimate "was based on inconsistent and unproven assumptions and did not account for the risk that space debris pose to S-NPP's life expectancy."[9]

While the Agency has improved its efforts in contingency plan building, it has yet to address a number of shortfalls, such as assessing costs and impacts of gap mitigation alternatives, as well as tracking potential mitigation efforts.[10] In addition, NOAA has not prioritized the most beneficial and feasible gap mitigation efforts.[11] In order to reduce risks, GAO lists five recommendations for the satellite system in its 2015 report.[12]

1. Track completion dates for all risk mitigation activities.

2. Update the program's assessment of potential polar satellite data gaps to include more accurate assumptions about launch dates and the length of the data calibration period, as

[6] GAO, "Polar Weather Satellites: NOAA Needs to Prepare for Near-Term Data Gaps," GAO-15-47, January 2015, p.5.
[7] Ibid. p.6.
[8] Ibid, p.42.
[9] Ibid.
[10] Ibid.
[11] Ibid.
[12] Ibid., p. 43.

well as key risks such as the potential effect of space debris on JPSS and other polar satellites' expected lifetimes.

3. Revise the polar satellite contingency plan to address the shortfalls noted in GAO's report, such as identifying the Department of Defense and Japan's plans to continue weather satellite observations. GAO recommends that the plan include: recovery time objectives for key products, completing the contingency plan with selected strategies, identifying opportunities for accelerating calibration and validation of products, providing an assessment of available alternatives based on their costs and potential impacts, establishing a schedule with meaningful timelines and linkages among mitigation activities, and defining completion dates for testing and validating the alternatives.

4. Investigate ways to prioritize mitigation projects with the greatest potential benefit to weather forecasting in the event of a gap in JPSS satellite data and report recommendations to the NOAA program management council; and

5. Ensure that the relevant entities provide monthly and quarterly updates on the progress of all mitigation projects and activities during existing monthly and quarterly management meetings.

GOES

NOAA's Geostationary Operational Environmental Satellite System (GOES) also remains a concern. The program faces challenges in maintaining its schedule due to delays in instrument testing and integration. The program has experienced delays in key milestones which could further delay the scheduled launch of March 2016.[13] GAO notes that, "costs are increasing faster than expected for key program components."[14] NOAA is continuing to monitor defects during its testing phase, but needs to more accurately define defect metrics and track defect resolutions.[15] Further delays in the GOES program, as well as any problems with operational satellites, could lead to a gap in data coverage. In its most recent report, GAO provides four recommendations to help reduce risks to the GOES program:[16]

1. Investigate and address inconsistencies totaling hundreds of thousands of dollars in monthly earned value data reporting for the Geostationary Lightning Mapper (GLM) and the Advanced Baseline Imager (ABI) instruments.

2. Address shortfalls in defect management identified in this report, including the lack of clear guidance on defect definitions, what defect metrics should be collected and reported, and how to establish a defect's priority or severity.

[13] GAO, "Geostationary Weather Satellites: Launch Date Nears, but Remaining Schedule Risks Need to be Addressed," GAO-15-60, January 2015, p.40.
[14] Ibid.
[15] Ibid.
[16] Ibid, p. 41.

3. Reduce the number of unresolved defects on the GOES ground system and spacecraft.

4. Add information to the GOES satellite contingency plan on steps planned or underway to mitigate potential launch delays, the potential impact of failure scenarios in the plan, and the minimum performance levels expected under such scenarios.

Satellite Data Gap and Components of Weather Legislation

Due to the potential for gaps in satellite coverage and data, the Committee remains committed to the tenants of weather focused legislation to address shortcomings in weather forecasting abilities.

The Weather Forecasting Improvement Act (last year H.R. 2413 introduced by Environment Subcommittee Chairman Jim Bridenstine) prioritizes the mission of NOAA on the protection of lives and property, and makes more of its funds available to improve weather-related research and operations through advances in observational data, modeling, and computing capabilities. The bill directs NOAA to use quantitative, cost-benefit assessments in deciding how to obtain data for forecasts. It also directs NOAA to prepare a report outlining the options for commercial opportunities to obtain space-based weather observations.

Historical Context

National Polar-orbiting Operational Environmental Satellite System

In the 1960s, the United States began operating two polar-orbiting meteorological satellite systems: one managed by NOAA and another by the Air Force. Polar-orbiting satellites transverse the globe from pole to pole, with each orbit defined by the time of day they pass over the equator: early morning, late morning, and afternoon. Unlike geostationary weather satellites, which offer persistent coverage over an area, each polar-orbiting satellite makes approximately 14 orbits per day and is able to view the entire Earth's surface twice per day.

In 1994, as part of the Clinton-Gore Administration's Reinventing Government initiative, a Presidential Decision Directive required NOAA and the Department of Defense (DOD) to merge the civilian and military polar-orbiting satellite systems into one program, the National Polar-orbiting Operational Environmental Satellite System (NPOESS). To manage the program, DOD, NOAA, and NASA formed a tri-agency Integrated Program Office. Overall responsibility for the management of the system and satellite operations was assigned to NOAA. The DOD was responsible for acquisition of the sensors, satellite bus, and launch vehicle, while NASA was responsible for facilitating the development and incorporation of new technologies.[17]

By 2009, the life-cycle cost estimate of NPOESS had ballooned to at least $14.9 billion for four new satellites, the first of which was projected to launch in 2014. In June 2009, an

[17] GAO, "Polar-Orbiting Environmental Satellites: Changing Requirements, Technical Issues, and Looming Data Gaps Require Focused Attention," GAO-12-604, June 2012, p.12.

Independent Review Team (IRT) determined that the NPOESS program had a low probability of success.[18]

Joint Polar Satellite System

In February 2010, the Office of Science and Technology Policy announced that the program would be split, with NOAA and the DOD creating their own programs, establishing requirements, and transferring existing NPOESS contracts to new programs.[19] Satellites flying in orbits to collect early-morning observations would be developed and launched by DOD, while NOAA's Joint Polar Satellite System would collect observations in the afternoon orbit. These orbits provide adequate coverage of the earth during various times of the day and collect information for weather models.

In 2010, NOAA estimated that the life cycle costs of the JPSS program would be approximately $11.9 billion. Though data monitoring requirements for the program had not changed, NOAA's JPSS program office made plans to remove key requirements to keep the program within the prescribed budget. Meanwhile, DOD decided to terminate its program and reassess its requirements.[20]

The following table from GAO[21] compares the planned costs, schedule and scope of the three programs over time.

Figure 1: Temporal Comparison of NPOESS and JPSS

[18] NOAA, NESDIS, "Joint Polar Satellite System," Fiscal Year 2011 Budget Highlights," Available at: http://www.corporateservices.noaa.gov/nbo/fy11_budget_highlights/JPSS_Budget_Highlights.pdf

[19] Office of Science and Technology Policy, Restructuring the National Polar-Orbiting Operational Environmental Satellite System, 2010, Available at: http://www.whitehouse.gov/sites/default/files/npoess_decision_fact_sheet_2-1-10.pdf

[20] GAO-12-604, June 2012, p.12.

[21] GAO, "Polar Weather Satellites: NOAA Needs to Prepare for Near-Term Data Gaps," GAO-15-47, January 2015, p.12.

Key area	NPOESS after it was restructured (as of June 2006)	NPOESS prior to being disbanded (as of February 2010)	JPSS program (as of May 2010)	JPSS program (as of June 2012)	JPSS program (as of September 2013)
Life cycle	1995-2026	1995-2026	2010-2024	2010-2028	2010-2025
Estimated life cycle cost	$12.5 billion	$13.95+ billion[a]	$11.9 billion (which includes about $2.9 billion spent through fiscal year 2010 on NPOESS)	$12.9 billion (which includes about $3.3 billion spent through fiscal year 2011 on NPOESS and JPSS)	$11.3 billion (which includes about $4.3 billion spent through fiscal year 2012 on NPOESS and JPSS)
Number of satellites	4 (in addition to S-NPP)	4 (in addition to S-NPP)	2 (in addition to S-NPP)	2 (in addition to S-NPP)	2 (in addition to S-NPP)
Number of orbits	2 (early morning and afternoon; would rely on European satellites for midmorning orbit data)	2 (early morning and afternoon; would rely on European satellites for midmorning orbit data)	1 (afternoon orbit) (DOD and European satellites would provide early and midmorning orbits, respectively)	1 (afternoon orbit) (DOD and European satellites would provide early and midmorning orbits, respectively)	1 (afternoon orbit) (DOD and European satellites would provide early and midmorning orbits, respectively)
Launch schedule	S-NPP by Jan. 2010 First satellite (C1) by Jan. 2013 C2 by Jan. 2016 C3 by Jan. 2018 C4 by Jan. 2020	S-NPP no earlier than Sept. 2011 C1 by March 2014 C2 by May 2016 C3 by Jan. 2018 C4 by Jan. 2020	S-NPP—no earlier than Sept. 2011 JPSS-1 available in 2015 JPSS-2 available in 2018	S-NPP—successfully launched in Oct. 2011 JPSS-1 by March 2017 JPSS-2 by Dec. 2022	S-NPP—successfully launched in Oct. 2011 JPSS-1 by March 2017 JPSS-2 by Dec. 2021
Number of sensors	S-NPP: 4 sensors C1: 6 sensors C2: 2 sensors C3: 6 sensors C4: 2 sensors	S-NPP: 5 sensors C1: 7 sensors[b] C2: 2 sensors C3: 6 sensors C4: 2 sensors	S-NPP: 5 sensors JPSS-1: 5 sensors[c] JPSS-2: 5 sensors	S-NPP: 5 sensors JPSS-1: 5 sensors JPSS-2: 5 sensors Free flyer-1 and-2: 1 sensor and 2 user services systems[d]	S-NPP: 5 sensors JPSS-1: 5 sensors JPSS-2: 5 sensors[e] No free flyers[f]

[a]Although the program baseline was $13.95 billion in February 2010, we estimated in June 2009 that this cost could grow by about $1 billion. In addition, officials from the Executive Office of the President stated that they reviewed life cycle cost estimates from DOD and the NPOESS program office of $15.1 billion and $16.45 billion, respectively.

[b]In May 2008, the NPOESS Executive Committee approved an additional sensor—Total and Spectral Solar Irradiance Sensor—for the C1 satellite.

[c]The five sensors are the Advanced Technology Microwave Sounder, Clouds and the Earth's Radiant Energy System (CERES), Cross-Track Infrared Sounder, Ozone Mapping and Profiler Suite, and Visible Infrared Imaging Radiometer Suite. NOAA committed to finding an alternative spacecraft and launch accommodation for the Total and Spectral Solar Irradiance Sensor, the Advanced Data Collection System, and the Search and Rescue Satellite-Aided Tracking system.

[d]NOAA planned to launch two stand-alone satellites, called free flyer satellites, to accommodate the Total and Spectral Solar Irradiance Sensor, the Advanced Data Collection System, and the Search and Rescue Satellite-Aided Tracking system.

[e]In its fiscal year 2014 budget request, NOAA transferred responsibility for two sensors to NASA—the Radiation Budget Instrument (formerly known as CERES) and OMPS-L and plans to accommodate these sensors on the JPSS-2 satellite as long as they do not impact the likelihood of mission success.

[f]NOAA canceled Free flyer-1 and established Free flyer-2 as a new program outside the JPSS program. This new program, called the Solar Irradiance, Data, and Rescue (SIDAR) mission, is to accommodate the Total and Spectral Solar Irradiance Sensor, the Advanced Data Collection System, and the Search and Rescue Satellite-Aided Tracking system.

By 2011, NOAA and NASA had established separate but co-located JPSS program offices, each with different roles and responsibilities. NOAA is responsible for programmatic activities related to the JPSS satellite development, including managing requirements, budgets, and interactions with satellite data users. NASA is responsible for the development and integration of sensors, satellites, and ground systems.

The joint NASA and NOAA JPSS team launched the Suomi National Polar-orbiting Partnership (S-NPP) satellite in October 2011, the first of a new generation of satellites. S-NPP will collect remotely-sensed land, ocean and atmospheric data during the afternoon orbit.

Geostationary Satellite System

In addition to polar-orbiting satellites, NOAA also operates Geostationary Observational Environmental Satellites (GOES). NOAA's GOES satellites operate from a geosynchronous orbit 22,300 miles above the Earth, which means they orbit the equatorial plane of the Earth at a speed matching the Earth's rotation. This vantage point allows the satellites to essentially 'hover' continuously over one position on the surface of the earth, and serve as a fixed eye on the continental United States though with limited coverage of the Earth's poles.

The GOES system operated by NOAA utilizes two satellites – one fixed on the eastern United States and the other on the western United States. At any given time, the GOES system also includes a third on-orbit 'spare' called into duty either as an emergency back-up to the primary satellites, or naturally sequenced into operations once an older satellite's service has degraded.

The next-generation of the GOES satellites, known as the GOES-R, is under development. GOES-R is expected to significantly improve weather data and will be able to transmit that data at faster rates more frequently. Both improvements will enhance the quality and timeliness of information to the user.

Life cycle cost estimates for the GOES-R series now stand at $10.86 billion through 2036 – an increase of $3.2 billion over the estimate for a two satellite system in 2007. The first of the series is scheduled to launch in March 2016.[22]

The following table illustrates key changes to the program since August 2006.

Figure 3: Key Changes to the GOES-R Program[23]

	August 2006 (baseline program)	September 2006	November 2007	February 2011	August 2013
Number of satellites	4	2	2	4	4
Instruments	• Advanced Baseline Imager • Geostationary Lightning Mapper • Magnetometer • Space Environmental In-Situ Suite • Solar Imaging Suite (which included the Solar Ultraviolet Imager, and Extreme Ultraviolet/X-Ray Irradiance Sensor) • Hyperspectral Environmental Suite	• Advanced Baseline Imager • Geostationary Lightning Mapper • Magnetometer • Space Environmental In-Situ Suite • Solar Ultraviolet Imager • Extreme Ultraviolet/X-Ray Irradiance Sensor	No change	No change	No change
Number of satellite products	81	68	34 baseline 34 optional	34 baseline 31 optional	34 baseline 31 optional
Life cycle cost estimate (in then-year dollars)	$6.2 billion – $11.4 billion (through 2034)	$7 billion (through 2028)	$7.67 billion (through 2028)	$10.86 billion (through 2036)[a]	$10.86 billion (through 2036)
Estimated launch dates for GOES-R and GOES-S	GOES-R: September 2012 GOES-S: April 2014	GOES-R: September 2012 GOES-S: April 2014	GOES-R: December 2014 GOES-S: April 2016	GOES-R: October 2015 GOES-S: February 2017	GOES-R: by March 2016 GOES-S: by June 2017[b]

Source: GAO analysis of NOAA data. | GAO-15-60

[a]Based on NOAA's fiscal year 2012 budget estimate, $7.64 billion of this cost estimate was for the first two satellites in the series, GOES-R and GOES-S. The cost for the remaining two satellites—GOES-T and GOES-U—was estimated at $3.22 billion.

[b]Program documentation shows that the launch commitment dates were changed to the first quarter of 2016 and the second quarter of 2017, respectively. The launch dates in this chart reflect the latest month in which launch can occur and still meet the launch commitment dates.

[22] GAO, "Geostationary Weather Satellites: Launch Date Nears, but Remaining Schedule Risks Need to be Addressed," GAO-15-60, January 2015, p.8.

[23] Ibid.

Additional Reading

- Government Accountability Office, "Polar Weather Satellites: NOAA Needs to Prepare for Near-Term Data Gaps," GAO-15-47, January 2015, Available at: http://www.gao.gov/products/GAO-15-47

- Government Accountability Office, "Geostationary Weather Satellites: Launch Date Nears, but Remaining Schedule Risks Need to be Addressed," GAO-15-60, January 2015, Available at: http://www.gao.gov/products/GAO-15-60

Chairman BRIDENSTINE. The Subcommittees on the Environment and Oversight will come to order.

Without objection, the Chair is authorized to declare a recess of the Subcommittee at any time. Is there any objection? No objection.

Good morning. Welcome to the today's hearing: "Bridging the Gap: America's Weather Satellites and Weather Forecasting." In front of you are packets containing the written testimony, biographies, and Truth in Testimony disclosures for today's witnesses.

For opening statements, I will recognize myself for five minutes and then I will turn to the Ranking Member and the Chairman on Oversight and the Ranking Member on Oversight.

Good morning, and welcome to the first Environment Subcommittee hearing for the 114th Congress. I want to thank the Full Committee Chairman, Lamar Smith, for his continued leadership.

I would like to congratulate Mr. Loudermilk of Georgia for his assignment as the Chairman of the Oversight Subcommittee. Welcome, and congratulations.

I would like to welcome back the Ranking Member, Ms. Bonamici of Oregon, who I look forward to working with in this Congress, and we have worked very well together in the past and looking forward to another great Congress.

And I would like to congratulate Mr. Beyer of Virginia for his assignment as the Ranking Member of Oversight on this Subcommittee, so congratulations and welcome.

This Committee has held numerous hearings over the years on NOAA's weather satellite programs. Today we continue this oversight by examining the status of NOAA's two primary satellite systems, the Joint Polar Satellite System (JPSS) and the Geostationary Environmental Operational Satellite System (GOES). These satellites collect vital data that is fed into the numerical weather models that are used by meteorologists to make our forecasts, and where I come from in the great State of Oklahoma, critically important data for predicting thunderstorms and tornados.

These two programs comprise the lion's share of funding for NESDIS, the satellite office at NOAA. In the newly released Fiscal Year 2016 budget request, NESDIS accounts for over $2 billion, roughly 40 percent of the NOAA's total budget. Just seven years ago, in 2008, NOAA's budget for satellites was less than $1 billion and was roughly one-quarter of NOAA's overall spending. The NESDIS budget has grown dramatically over the last decade.

In addition, recent reports from the GAO highlight continuing challenges with NOAA's satellite programs. The JPSS program has been plagued with increasing costs and delays, meaning we are probably facing a gap in satellite coverage and data. Estimates of the data gap range from an optimistic three months in some cases to possibly as much as five years, depending on circumstances, in the worst-case scenario outlined by the GAO. With a gap, our ability to predict weather would be dramatically degraded, putting lives and property in danger. This is especially important to me, as my home state is Oklahoma, and we are regularly ravaged by tornados.

Likewise, the GOES program has also experienced increasing lifecycle costs and project delays. With the first satellite launch now pushed back to March 2016, it is important that the program adhere to its already-delayed schedule and prevent another gap in satellite coverage and data.

Given the criticality of JPSS and GOES to our forecasts, it is imperative we ensure these programs receive the adequate support and oversight to avoid further delays and costs overruns.

I hope we can use this hearing to determine how to keep these programs from slipping further and mitigate any possible gaps. However, the failures of these programs to stay on track so far highlight a recent track record for our satellite programs that is less than good, and that the paradigm of owning and operating large monolithic satellites might not be the way forward.

To address this problem, we should look to augment our satellite systems through commercial means, just as the Department of Defense and NASA have done. There is a burgeoning commercial industry that has incredible potential to assist us in providing accurate information to protect American lives and property, disaggregate risk, and save the taxpayers' dollars. We need to have the most resilient space-based weather data architecture ever. Instead of continuing down the path of large government-owned satellites that are prone to cost overruns and delays, as we look forward into the future, we must look outside the box for new methods of providing essential weather data. For example, there are private companies such as PlanetIQ, Spire, GeoOptics, Tempus Global Data and HySpecIQ that have plans to launch constellations of GPS Radio Occultation and Hyperspectral Sounding satellites, two sources of data that can greatly enhance our forecasting ability. Considering options that reduce the burden on massive government satellite systems will allow us to more accurately predict weather in future architecture paradigms.

It has become increasingly difficult to remain optimistic about the future of U.S. weather forecasting, which currently lags behind the UK, Europe, and Canada in terms of accuracy, when we have satellite programs that are plagued with increasing costs and perpetual delays. The prospect of gaps in satellite data are even higher. We need to look for ways to reduce government burdens and eliminate these types of problems while increasing our ability to protect American lives and property.

I look forward to hearing from our witnesses today, and I would like to recognize our Ranking Member, the gentlelady from Oregon, for an opening statement.

[The prepared statement of Mr. Bridenstine follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON ENVIRONMENT
CHAIRMAN JIM BRIDENSTINE

Good morning and welcome to the first Environment Subcommittee hearing of the 114th Congress. I want to thank the Full Committee Chairman, Lamar Smith, for his continued leadership. I'd like to congratulate Mr. Loudermilk of Georgia for his assignment as the Chairman of the Oversight Subcommittee. Finally, I also want to welcome back the ranking member, Ms. Bonamici of Oregon, with whom I have worked closely during my time in Congress. I look forward to working with you this Congress.

This Committee has held numerous hearings over the years on NOAA's weather satellite programs. Today we continue this oversight by examining the status of NOAA's two primary satellite systems, the Joint Polar Satellite System (JPSS) and the Geostationary Environmental Operational Satellite System (GOES). These satellites collect vital data that is fed into numerical weather models used by meteorologists to make our forecasts.

These two programs comprise the lion's share of funding for NESDIS, the satellite office at NOAA. In the newly released Fiscal Year 2016 budget request, NESDIS accounts for over $2 billion dollars, roughly 40% of the NOAA's total budget. Just seven years ago, in 2008, NOAA's budget for satellites was less than $1 billion and was roughly one-quarter of NOAA's overall spending. The NESDIS budget has grown dramatically over the last decade.

In addition, recent reports from the Government Accountability Office highlight continuing challenges with NOAA's satellite programs. The JPSS program has been plagued with increasing costs and delays, meaning we are probably facing a gap in satellite coverage and data. Estimates of the data gap range from an optimistic three months, to possibly five years in the worst case scenario outlined by GAO. With a gap, our ability to predict weather would be dramatically degraded, putting lives and property in danger.

This is especially important to me, as my home state of Oklahoma is regularly ravaged by tornadoes. Likewise, the GOES program has also experienced increasing life-cycle costs and project delays. With the first satellite launch now pushed back to March 2016, it is important that the program adhere to its already-delayed schedule to prevent another gap in satellite coverage and data.

Given the criticality of JPSS and GOES to our forecasts, it is imperative we ensure these programs receive the adequate support and oversight to avoid further delays and costs overruns. I hope we can use this hearing to determine how to keep these programs from slipping further and mitigate any possible gaps.

However, the failures of these programs to stay on track so far highlight a recent track record for our satellite programs that is poor, and that the paradigm of owning and operating large monolithic satellites is broken. To address this problem, we should look to augment our satellite systems through commercial means, just as the Department of Defense and NASA have done. There is a burgeoning commercial industry that has incredible potential to assist us in providing accurate information to protect American lives and property, disaggregate risk, and save the taxpayers' dollars. We need to have the most resilient space-based architecture possible.

Instead of continuing down the path of large government-owned satellites that are prone to cost overruns and delays, we must look outside the box for new methods of providing essential weather data. For example, there are private companies such as PlanetIQ, Spire, GeoOptics, Tempus Global Data and HySpecIQ that have plans to launch constellations of GPS Radio Occultation and Hyperspectral Sounding satellites, two sources of data that can greatly enhance our forecasting ability. Considering options that reduce the burden on massive government satellite systems will allow us to more accurately predict the weather.

It has become increasingly difficult to remain optimistic about the future of U.S. weather forecasting, which currently lags behind the UK, Europe, and Canada in terms of accuracy, when we have satellite programs that are plagued with increasing costs and perpetual delays. The prospect of gaps in satellite data is higher than ever. We need to look for ways to reduce government burdens and eliminate these types of problems while increasing our ability to protect American lives and property.

I look forward to hearing from our witnesses today and yield back the balance of my time.

Ms. BONAMICI. Thank you very much, Mr. Chairman, and I want to begin this morning by offering my congratulations to you, Mr. Bridenstine, and to our new Oversight Subcommittee Chairman, Mr. Loudermilk, and to our Oversight Ranking Member, Mr. Beyer. I would also like to extend a warm welcome to all of the new Subcommittee members. We are very fortunate to have the opportunity to serve on the Committee on Science, Space, and Technology and to help shape policies that are critical to the long-term health and prosperity of the Nation.

This morning's hearing is a fitting way to undertake our work. Oversight of NOAA's weather satellites has been a longstanding bipartisan effort of this Committee, spanning many Administrations and sessions of Congress, and it is my hope that this hearing is just the beginning of a productive and bipartisan working relationship.

Now, Mr. Chairman, I doubt that the average American spends much time thinking about the weather satellites managed by NOAA. We might, but I do know that one of the first things many of us do each morning is turn on the television or get on the internet or our favorite app to read the day's weather forecast, and that is because weather is important, affecting everything from our commute to the food on our table. In fact, a 2009 study from the American Meteorological Society stated that U.S. weather forecasts generated $31.5 billion in profits compared to costs of $5.1 billion.

On this Committee, we have worked on finding ways to improve forecasting to protect the American people and the economy from the impacts of severe weather, and I am proud to be working the Chairman on bipartisan legislation, the Weather Forecasting Improvement Act, to advance NOAA's weather research enterprise and improve the products and services offered by the National Weather Service. That effort is important and ongoing.

But meanwhile, any loss of coverage from the polar satellites or the geostationary satellites would have very serious consequences regarding the accuracy and timeliness of our weather forecasts and the capabilities of the Weather Service. Unfortunately, years of trouble and mismanagement in the polar satellite program mean that we will have a gap in coverage within the next decade, with the worst-case scenario being a gap lasting more than five years. In addition, there remains a chance that we face a gap in geostationary satellite coverage as well.

I am certain that we will hear from today's witnesses about progress that has been made in this area, and I am pleased that NOAA and NASA are working to get these programs back on track. I applaud you for your efforts, but we are here today to emphasize the importance of maintaining focus on getting these programs where they need to be to protect American people and our economy. It may be possible to reduce the gap in coverage if there is optimal performance by our current satellites that enables them to greatly exceed their design lives. Additionally, if JPSS–1 and GOES–R launch on time, that may reduce the gap in coverage. It is still important that prudent managers have plans in place in the event of failure, and it is also critical that any gap mitigation strategy is well developed and ready to implement.

Unfortunately, the testimony today from GAO highlights a number of concerns with these contingency plans, specifically with NOAA's plans to respond to the near-term data gap for our polar satellites.

So the questions and issues for our witnesses today are quite simple: How can we best minimize the duration and impact of a gap in the polar program? How can we avoid a gap in the geostationary program? And are plans to fill gaps in coverage appropriately mature, prioritized, and ready to implement?

The American public may not spend much time thinking about where their weather forecasts come from, but they will notice if those forecasts aren't reliable. I am looking forward to hearing from the witnesses from GAO, NOAA and NASA to discuss how their agencies' plans to address the looming gap in satellite coverage.

Thank you, Mr. Chairman, and I yield back.

[The prepared statement of Ms. Bonamici follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON ENVIRONMENT
MINORITY RANKING MEMBER SUZANNE BONAMICI

Thank you, Mr. Chairman. I'd like to begin this morning by offering my congratulations to you, Mr. Bridenstine, the new Chairman of the Environment Subcommittee, to our new Oversight Subcommittee Chairman, Mr. Loudermilk (Loudermilk), and to new Oversight Ranking Member Mr. Beyer. I'd also like to extend a warm welcome to all of the new Subcommittee members. We are fortunate to have the opportunity to serve on the Science Committee and to help shape policies that are critical to the long-term health and prosperity of the nation.

This morning's hearing is a fitting way to undertake our work. Oversight of NOAA's weather satellites has been a long-standing bipartisan effort of this Committee—spanning many Administrations and sessions of Congress. It's my hope that this hearing is just the beginning of a productive and bipartisan working relationship.

Mr. Chairman, I doubt the average American spends much time thinking about the weather satellites managed by NOAA, but I do know one of the first things many of us do each morning is turn on the television or get on the internet or our favorite phone app to read the day's weather forecast.

That's because weather is important, affecting everything from our commute to the food on our table. In fact, a 2009 study from the American Meteorological Society stated that U.S. weather forecasts generated $31.5 billion in benefits compared to costs of $5.1 billion.

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Unfortunately, years of trouble and mismanagement in the polar satellite program mean that we will have a gap in coverage within the next decade, with the worst case scenario being a gap lasting more than five years. In addition, there remains a chance that we face a gap in geostationary satellite coverage as well.

I am certain that we will hear from today's witnesses about the significant progress that's been made in this area, and I am pleased that NOAA and NASA are working to get these programs back on track. I applaud you for your efforts, but we are here today to emphasize the importance of maintaining focus on getting these programs where they need to be to protect American people and our economy.

It may be possible to reduce the gap in coverage if there is ptimal performance by our current satellites that enables them to greatly exceed their design lives. Additionally, if JPSS-1 and GOES-R launch on time, that may reduce the gap in coverage. It's still important, that prudent managers have plans in the event of failure, and it's also critical that any gap mitigation strategy is well developed andready to implement.

Unfortunately, the testimony today from GAO highlights a number of concerns with these contingency plans, specifically with NOAA's plans to respond to the near-term data gap for our polar satellites.

The questions for our witnesses today are simple: How can we best minimize the duration and impact of a gap in the polar program? How can we avoid a gap in the geostationary program? And, are plans to fill gaps in coverage appropriately mature, prioritized, and ready to implement?

The American public may not spend much time thinking about where their weather forecasts come from, but they will notice if those forecasts aren't reliable. I'm looking forward to hearing the witnesses from GAO, NOAA, and NASA discuss the agencies' plan of action to address the looming gap in satellite coverage.

I'm also interested in learning how NOAA and NASA are working to ensure that we don't face a similar situation in the future. The President's fiscal year 2016 budget request includes $380 million for a Polar Follow-On program. How will this program make our satellite program more robust? Do we need to rethink or modify the model we use for acquiring weather data?

Mr. Chairman, let me end by again offering my congratulations. I look forward to working with you and the Subcommittee on important issues like those we are discussing today. Thank you and I yield back the balance of my time.

Chairman BRIDENSTINE. Thank you, Ms. Bonamici. I now recognize the Chair of the Oversight Committee, the gentleman from Georgia, for an opening statement.

Mr. LOUDERMILK. Good morning, and thank you, Mr. Chairman, and congratulations to you, the Ranking Members of both Subcommittees, and especially thank the members of the Oversight Subcommittee for being here today.

And Mr. Chairman, thank you for holding this hearing today. This is our first joint Environmental and Oversight Committee hearing of the 114th Congress, and I look forward to working with you on the oversight of environmental issues important to all of us.

We are here today to hear from GAO, NOAA, and NASA regarding the progress of NOAA's polar orbiting and geostationary satellite programs, respectively JPSS and GOES–R, as well as how the data collected by weather satellites turns into weather forecasts depended on by so many in the United States, and quite frankly, around the entire world.

GAO recently published a report detailing its concern that the NOAA polar satellite program, JPSS, is facing an unprecedented gap in satellite data. GAO believes that, while JPSS remains within its new lifecycle cost estimate and schedule baselines, recent rises in component costs and technical issues during development increase the likelihood of a near-term data gap. Additionally, although NOAA has recently reduced its estimated potential gap from fifteen to only three months, GAO notes that this assessment was based on incomplete data, such as the risks posed by space debris to satellite hardware. GAO estimates in its report that a data gap may occur earlier and last longer than NOAA anticipates.

Perhaps even more troubling is the potential data gap facing NOAA's GOES–R program, the geostationary satellite system. Since its inception, the GOES–R program has undergone significant increases in cost and reductions in scope, and as GAO's report indicates, NOAA has yet to reverse or even halt this trend. The program was originally planned to launch mid-2012, a date that has now been pushed back to March of 2016. NOAA will retire one of its two operational satellites this year and move its backup satellite into orbit. This means we will face a period of up to 17 months without a backup satellite in orbit.

History has shown us that backups are sometimes necessary to reduce risk to public safety and the economy. In 2008 and 2012, the agency was forced to use backup satellites to cover problems with operational satellites, a solution we may once again find ourselves needing.

When talking about the consequences of a gap in weather data, the first thought in the minds of many is of the devastating effects of extreme weather on the ground. My professional and personal history, however, demands that I discuss another type of weather with which I have quite a bit of experience, and that is aviation weather.

As a private pilot, I know the importance of having accurate and timely weather forecasts to assess flying conditions. Pilots must evaluate conditions on the ground and in the sky throughout the entire flight process, from preflight planning to takeoff and landing. If a pilot does not know which aviation-specific weather conditions to expect, such as embedded thunderstorms, turbulence, and freeze levels, that pilot runs the risk of what we call getting behind the plane. That is a general aviation phrase which means that the plane is responding to the weather and the pilot is responding to the plane, and that is a situation that spells trouble for even the most seasoned pilots.

From this perspective, you can see how a gap in weather data, and consequently less accurate forecasts, could negatively affect not only commercial flight safety, but also the $1.5 trillion in total economic activity that the aviation industry contributes to the national economy.

I hope that today's hearing will shed some light on the complex issue and cost demands facing NOAA's weather satellite programs and that the Subcommittees will walk away better equipped to consider these issues moving forward.

Thank you, Mr. Chairman, and I yield back.

[The prepared statement of Mr. Loudermilk follows:]

PREPARED STATEMENT OF OVERSIGHT SUBCOMMITTEE CHAIRMAN BARRY LOUDERMILK

Good morning, Mr. Chairman, and thank you for holding this hearing today. This is our first joint Environment and Oversight Subcommittee hearing of the 114th Congress, and I look forward to working with you on the oversight of environmental issues important to us both.

We are here today to hear from GAO, NOAA, and NASA regarding the progress of NOAA's polar orbiting and geostationary satellite programs, respectively JPSS and GOES-R, as well as how the data collected by weather satellites turns into weather forecasts depended on by so many in the United States, and quite frankly, around the world.

GAO recently published a report detailing its concern that the NOAA polar satellite program, JPSS, is facing an unprecedented gap in satellite data. GAO believes that, while JPSS remains within its new lifecycle cost estimate and schedule baselines, recent rises in component costs and technical issues during development increase the likelihood of a near-term data gap. Additionally, although NOAA has recently reduced its estimated potential gap from 15 to only 3 months, GAO notes that this assessment was based on incomplete data, such as the risks posed by space debris to satellite hardware. GAO estimates in its report that a data gap may occur earlier and last longer than NOAA anticipates.

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I hope that today's hearing will shed some light on the complex schedule and cost demands facing NOAA's weather satellite programs and that the Subcommittees will walk away better equipped to consider these issues moving forward.

Chairman BRIDENSTINE. Thank you, Mr. Loudermilk. I now recognize the Ranking Member from the Subcommittee on Oversight, the gentleman from Virginia, for an opening statement.

Mr. BEYER. Thank you, Mr. Chairman. I would like to add my congratulations to Chairman Bridenstine and Chairman Loudermilk, and we are really looking forward to working with you. I am thrilled to work with Ranking Member Bonamici, and just join myself with all the comments welcoming the various folks.

I am told that historically, this Committee has been a haven of bipartisanship, and in the area of oversight, I really hope that we can work together to improve the quality of government services and protect taxpayer interests, and from my side, I am really looking forward to working with my colleagues on both sides of the aisle.

You know, six years ago I had the remarkable responsibility to lead the transition team for President-Elect Obama at the Department of Commerce. Seventy-seven days, 6:00 in the morning until midnight. I learned to drink coffee for the first time. And I very quickly discovered that the number one problem in the Department of Commerce were the weather satellites, that the things we saw were the cost overruns were many multiples of the original idea. There were no reliable launch dates at all. We couldn't get the equipment to work. The satellites were loaded up with lots and lots of different ideas but none of which could work out. They had this tripartite management system with DoD, NASA and NOAA, and no one was in charge, so it was actually very encouraging to see how far we have come in these six years to have narrowed it to where we are.

But we still had a rocky acquisition with the new series of weather satellites, and the polar orbiting satellites especially have been troubled. Costs have doubled. The money is now buying just two satellites instead of the original intention to acquire six, and the satellites that fly will be less capable because the instruments are going to be reduced from 13 down to just 5, and they are still years behind schedule.

By comparison, the geostationary satellites seem to be models of efficiency, but they too have had trouble too with cost growth and areas of delays. As satellites that have a critical role in weather forecasting, losing coverage of either system could have serious, perhaps catastrophic effects on public safety. Both the Joint Polar Satellite System and the Geostationary Operational Environmental Satellites face this possibility of a gap in coverage, and I hope that if we learn only one thing today, learning how to really address this gap, will help us go forward.

At this point, the only way to avoid the gap is to be very, very lucky, and that is not a really good plan. You know, the problem is that the cost of these satellites distorts all the rest of NOAA's budget and limits the agency's resources for the many, many other important functions that they have—research into weather, oceans, climate science. Surely NOAA understands that the JPSS program represents a failure and an unsustainable model, so going forward, we have to find a more efficient, reliable means to put these instruments into orbit, and Mr. Chairman, I was interested in your alternatives.

GAO has been working with this Committee on these satellite programs for ten years. Without their expert and committed assistance, the Congress and the public would know far less about the risks in these programs. Every GAO product and team has to be measured on its own terms, but this group that has been working on the satellites system is among our very best, and I think the Committee has to be very grateful for their service.

For all the lessons that can be learned from the JPSS and GOES acquisitions, the most important immediate challenge has to be to complete both projects as expeditiously as possible. It is great that we have a pretty reliable launch date, but we have got to get them in orbit, checked out, and bring their data online as quickly as possible, and after years of truly worrisome reports, it appears that NOAA and NASA have good management teams in place and the contractors are now delivering as promised, and the Committee wants to be as helpful and supportive as we can as we reach this last stretch going into launch.

At the same time, the news from GAO that NOAA is not well positioned on the data-gap mitigation plans in place is disappointing, and I hope we learn more today about we are going to do that.

Mr. Chairman, I yield back.

[The prepared statement of Mr. Beyer follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON OVERSIGHT
MINORITY RANKING MEMBER DONALD S. BEYER, JR.

I want to associate myself with the comments from my colleague, Ranking Member Bonamici, in welcoming everyone. I am told that historically, this Committee has been a haven of bipartisanship. In the area of oversight, I hope that we can work together to improve the quality of government services and protect taxpayer interests. I am looking forward to working with my colleagues on both sides of the aisle.

NOAA has had a rocky acquisition with the new series of weather satellites. The Polar Orbiting satellites have been particularly troubled. The costs have doubled. More money is buying just two satellites instead of the original intention to acquire six satellites. The satellites that fly will be less capable, with instruments reduced from 13 to just 5. Finally, the satellites are years behind schedule. By comparison, the Geostationary satellites are models of efficiency, but they have had trouble too with cost growth in some areas and delays.

As satellites that have a critical role in weather forecasting, losing coverage of either system could have serious, perhaps catastrophic effects on public safety. Both the Joint Polar Satellite System (JPSS) and the Geostationary Operational Environmental Satellites (GOES) face a possibility of a gap in coverage—with the risks on JPSS being so high that a gap appears to be almost unavoidable. At this point, the only way to avoid such a gap is to be very, very lucky. Luck is not a plan, and bad luck is as probable as good luck.

The cost of these satellites distorts NOAA's budget, and limits the agency's resources for weather forecasting and important research into weather, oceans and climate science. Surely NOAA understands that the JPSS program represents a failure and an unsustainable model. Going forward the agency has to find a more efficient, more reliable means to put its instruments on orbit.

GAO has been working with this Committee on these satellite programs for ten years. Without their expert and committed assistance, the Congress and the public would know far less about the risks in these programs. Every GAO product, and team, has to be measured on its own terms. The group that has worked on the satellites system is among the best this Committee has ever worked with and we are very grateful for your help.

For all the lessons that can be learned from the JPSS and GOES acquisitions, the most important immediate challenge has to be to complete both projects as expeditiously as possible. We must get working satellites on orbit, checked out, and bring their data on-line as quickly as possible.

After years of truly worrisome reports, it appears that NOAA and NASA have good management teams in place and the contractors are now delivering as promised. The Committee wants to be helpful and supportive as we reach the last stretch going into launch.

At the same time, the news from GAO that NOAA is not well positioned with data-gap mitigation plans in place is disappointing. This is an issue I want to hear more about and I hope we can leave this hearing with a clear commitment to preparing for what to do should the worst happen.

Chairman BRIDENSTINE. Thank you, Mr. Beyer.

If there are other Members who wish to submit additional opening statements, your statements will be added to the record at this point.

At this time I would like to introduce our witnesses. Our first witness today is Mr. David Powner, Director of Information Technology Management Issues at the GAO. Our second witness is Dr. Stephen Volz, Assistant Administrator of the National Environmental Satellite Data and Information Service—NESDIS—at the National Oceanic and Atmospheric Administration—NOAA. Our third witness today is Mr. Steven Clarke, Director of the Joint Agency Satellite Division at the National Aeronautics and Space Administration. We will also be joined for questioning by Dr. Alexander MacDonald, Director of the Earth System Research Laboratory at NOAA, Chief Science Advisor for NOAA's Office of Oceanic and Atmospheric Research, and this year's President of the American Meteorological Society. Finally, we are joined for questioning by Mr. John Murphy, Director of the Office of Science and Technology at the National Weather Service for NOAA. Thank you, gentlemen, for all being here.

Pursuant to the Committee rules, all witnesses will be sworn in before they testify, so if you would please stand up and raise your right hand? Do you solemnly swear or affirm that the testimony that you are about to give will be the truth, the whole truth and nothing but the truth, so help you God? You may be seated. Let the record reflect that the witnesses answered in the affirmative. Thank you.

In order to allow for discussion, please limit your testimony to five minutes for your opening statements. Your entire written statement will be made part of the record.

I now recognize Mr. Powner for five minutes to present his testimony.

TESTIMONY OF MR. DAVID POWNER, DIRECTOR, INFORMATION TECHNOLOGY MANAGEMENT ISSUES, GOVERNMENT ACCOUNTABILITY OFFICE

Mr. POWNER. Chairmen Bridenstine, Loudermilk, Ranking Members Bonamici, Beyer, and Members of the Subcommittees, two years ago, GAO added potential gaps in weather satellite coverage in consultation with this Committee as a high-risk area demanding immediate attention from NOAA management.

Gaps in weather satellite coverage are likely and could affect lives and our economy. This morning I will provide a brief update on these gaps, contingency plans to address the gaps, and an update on the JPSS and GOES satellite acquisitions.

Starting with JPSS, an $11.3 billion acquisition that is to result in two polar orbiting satellites expected to be launched in March 2017 and December 2021. There has been significant progress on both the flight and ground components, and the program is expecting to meet its cost and schedule targets. However, since July 2013, cost estimates have gone up two percent, or over $220 million. The ATMS and CriS instruments have had the most significant increases. Although this doesn't sound like much, if this cost growth continued annually, the program would surpass its cost baseline by 2018 and end up costing $2 billion more through 2025.

The launch date of March 2017 looks good, but a key instrument to watch is ATMS. Its delivery slipped 12 months to March 2015 as we reported last month but we have now learned that there is another three month slip to June. Schedule reserves continue to dwindle, and oversight of this June delivery is very important to make sure that the March 2017 launch date holds.

A key risk to the current operational satellites to note is space debris. NASA recently updated its assessment of orbital debris, which concluded an increased likelihood at the altitude where the JPSS satellites operate. The current operational satellite that was originally intended as a demonstration satellite was not built with the appropriate shielding to protect against small debris the way the first JPSS satellite is currently being constructed.

The likely gap in satellite coverage is 11 months. The current operational satellite is expected to last through October 2016, and with the March 2017 planned launch date and the six month checkout, NOAA could very well be facing a gap in coverage from October 2016 through September 2017, as shown on the one-page summary in my written statement. Any issues with space debris or delays in the JPSS launch or the checkout period would result in a larger gap.

Multiple alternatives exist to prevent or reduce the impact of the gap. The best alternatives according to experts include extending the use of legacy satellites like POES and obtaining data from European mid-morning satellites, obtaining additional observations from commercial aircraft and radio occultation, enhancing forecast models, and increasingly high-performance computing capacity.

NOAA has improved its satellite gap contingency plans by, among other things, adding more alternatives, which now total 21 mitigation projects. However, there are three things we would like to see more done.

NOAA needs to, one, update its polar satellite gap assessment to include changes in the current satellite's expected lifespan; two, revise its contingency plan to include an assessment of alternatives based on cost, and three, prioritize the mitigation projects in its plan.

Moving now to GOES, a $10.8 billion acquisition that will result in four geostationary satellites with the first expected to be launched in March 2016. The GOES program continues to make excellent progress as all six satellite—as all six instruments have completed testing and the program is well into the integration and testing phases. The program is currently operating within its $10.8 billion lifecycle cost estimate but we saw a slight increases in both the ground system and two instruments but we think overall the program is on solid cost footing.

We have more doubts whether GOES will meet its scheduled launch date because we are seeing delays in key testing dates and also because the spacecraft integration testing has moved to 24 hours a day, seven days a week testing schedule. Maintaining this March 2016 launch date is crucial because an operational GOES satellite is expected to reach the end of its useful life by April of this year, and GOES–R is expected to have a 6-month checkout period. Therefore, there may be no backup from April 2015 through September 2016. GOES's latest contingency plan released in February of 2014 overall looks very good but we would like to see more focus on preventing additional launch delays.

In summary, on the JPSS, we have more concerns about cost and schedule, while on GOES we are more concerned about the launch date. Both programs are likely to face gaps, and improvements to contingency plans need to continue.

This concludes my statement.

[The prepared statement of Mr. Powner follows:]

United States Government Accountability Office

Testimony

Before the Subcommittees on Environment and Oversight, House Committee on Science, Space, and Technology

For Release on Delivery
Expected at 10 a.m. ET
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ENVIRONMENTAL SATELLITES

Improvements Needed in NOAA's Mitigation Strategies as It Prepares for Potential Satellite Coverage Gaps

Statement of David A. Powner
Director, Information Technology Management Issues

February 2015

GAO Highlights

Highlights of GAO-15-386T, a testimony before the Subcommittees on Environment and Oversight, House Committee on Science, Space, and Technology

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Improvements Needed in NOAA's Mitigation Strategies as It Prepares for Potential Satellite Coverage Gaps

Why GAO Did This Study

NOAA is procuring the next generation of polar and geostationary weather satellites to replace aging satellites that are approaching the end of their useful lives. Both new sets of satellites will provide critical weather forecasting data over the next two decades. GAO has reported that gaps in polar satellite coverage and in backup coverage for geostationary satellites are likely in the near future. Given the criticality of satellite data to weather forecasts, concerns that problems and delays on the new satellite acquisition programs will result in gaps in the continuity of critical satellite data, and the impact of such gaps on the health and safety of the U.S. population, GAO added mitigating weather satellite gaps to its High-Risk List in 2013 and it remains on the 2015 update to the High-Risk List.

GAO was asked to testify on two recently released reports on NOAA's satellite programs, specifically on (1) the JPSS program's status, the potential for a gap and mitigation alternatives, and contingency plans, and (2) the GOES-R program's status, potential for a gap, and contingency plans.

What GAO Recommends

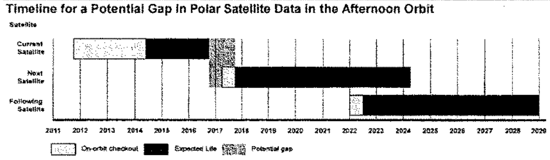
In its recently issued reports, GAO recommended that NOAA update its polar data gap assessment, address shortfalls in both its polar and geostationary contingency plans, and prioritize mitigation projects most likely to address a gap in polar satellite coverage. NOAA concurred with GAO's recommendations and identified steps it is taking to implement them.

View GAO-15-386T. For more information, contact Dave Powner at (202) 512-9286 or pownerd@gao.gov.

What GAO Found

The National Oceanic and Atmospheric Administration's (NOAA) $11.3 billion Joint Polar Satellite System (JPSS) program has recently completed significant development activities and remains within its cost and schedule baselines; however, recent cost growth on key components is likely unsustainable, and schedule delays could increase the potential for a near-term satellite data gap. In addition, while the program has reduced its estimate for a near-term gap in the afternoon orbit, its gap assessment was based on incomplete data. A gap in satellite data may occur earlier and last longer than NOAA anticipates. The figure below depicts a possible 11-month gap, in which the current satellite lasts its full expected 5-year life (until October 2016) and the next satellite is launched in March 2017 and undergoes on-orbit testing until September 2017.

Timeline for a Potential Gap in Polar Satellite Data in the Afternoon Orbit



Source: GAO analysis based on NOAA and NASA data. | GAO-15-386T

Multiple alternatives to prevent or reduce the impact of a gap exist. Key options for reducing the impact of a near-term gap include extending legacy satellites, obtaining additional observations such as data from aircraft, advancing data assimilation and a global forecast model, and increasing high performance computing capacity. While NOAA has improved its contingency plan by identifying mitigation strategies and specific activities, the agency's plan has shortfalls such as not assessing the cost and impact of available alternatives. In addition, NOAA has not yet prioritized mitigation projects most likely to address a gap, and key mitigation projects have been delayed. Until the agency addresses these shortfalls, the agency will have less assurance that it is prepared to deal with a near-term gap in polar satellite coverage.

NOAA's $10.8 billion Geostationary Operational Environmental Satellite-R (GOES-R) program has also made major progress on its first satellite. However, the program has continued to experience delays in major milestones and has not efficiently closed defects on selected components, both of which could increase the risk of a launch delay. As the GOES-R program approaches its expected launch date of March 2016, it faces a potential gap of more than a year during which an on-orbit backup satellite would not be available. Specifically, there could be no backup from April 2015 (when an operational satellite is expected to reach its end-of-life) through September 2016 (after GOES-R completes its post-launch test period). Any delay to the GOES-R launch date would extend the length of time without a backup satellite and, if an operational satellite were to experience a problem during that time, there could be a gap in GOES coverage. NOAA has improved its plan to mitigate gaps in satellite coverage, but it does not yet include steps for mitigating a delayed launch.

Chairman Bridenstine, Chairman Loudermilk, and Members of the Subcommittees:

Thank you for the opportunity to participate in today's hearing on two satellite program acquisitions within the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA). Both the Joint Polar Satellite System (JPSS) and the Geostationary Operational Environmental Satellite-R series (GOES-R) programs are meant to replace current operational satellite programs, and both are considered critical to the United States' ability to maintain the continuity of data required for weather forecasting.

As requested, this statement summarizes our two recent reports on (1) the JPSS program's status, key risks and risk mitigation alternatives, and contingency planning, and (2) the GOES-R program's status, testing plans and procedures, and contingency planning.[1] In preparing this testimony, we relied on the work supporting those reports. They each contain a detailed overview of our objectives, scope, and methodology, including the steps we took to assess the reliability of cost and schedule data. As noted in those reports, we found that cost and schedule data for both the JPSS and GOES-R programs were sufficiently reliable for our purposes.

All of our work for the reports was performed in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Since the 1960s, the United States has used polar-orbiting and geostationary satellites to observe the earth and its land, ocean, atmosphere, and space environments. Polar-orbiting satellites constantly

[1]GAO, *Polar Weather Satellites: NOAA Needs to Prepare for Near-term Data Gaps*, GAO-15-47 (Washington, D.C.: Dec. 16, 2014) and *Geostationary Weather Satellites: Launch Date Nears, but Remaining Schedule Risks Need to be Addressed*, GAO-15-60 (Washington, D.C.: Dec. 16, 2014).

circle the earth in a nearly north-south orbit, providing global coverage of conditions that affect the weather and climate. As the earth rotates beneath it, each polar-orbiting satellite views the entire earth's surface twice a day. In contrast, geostationary satellites maintain a fixed position relative to the earth from a high orbit of about 22,300 miles in space.

Both types of satellites provide a valuable perspective of the environment and allow observations in areas that may be otherwise unreachable. Used in combination with ground, sea, and airborne observing systems, satellites have become an indispensable part of monitoring and forecasting weather and climate. For example, polar-orbiting satellites provide the data that go into numerical weather prediction models, which are a primary tool for forecasting weather days in advance—including forecasting the path and intensity of hurricanes. Geostationary satellites provide the graphical images used to identify current weather patterns and provide short-term warning. These weather products and models are used to predict the potential impact of severe weather so that communities and emergency managers can help prevent and mitigate its effects.

Federal agencies are currently planning and executing major satellite acquisition programs to replace existing polar and geostationary satellite systems that are nearing the end of their expected life spans. However, these programs have troubled legacies of cost increases, missed milestones, technical problems, and management challenges that have resulted in reduced functionality and major delays to planned launch dates over time. We and others—including an independent review team reporting to the Department of Commerce and its Inspector General—have raised concerns that problems and delays with environmental satellite acquisition programs will result in gaps in the continuity of critical satellite data used in weather forecasts and warnings.

According to officials at NOAA, a polar satellite data gap would result in less accurate and timely weather forecasts and warnings of extreme events, such as hurricanes, storm surges, and floods. Such degradation in forecasts and warnings would place lives, property, and our nation's critical infrastructures in danger. The importance of having such data available was highlighted in 2012 by the advance warnings of the path, timing, and intensity of Superstorm Sandy. Given the criticality of satellite data to weather forecasts, concerns that problems and delays on the new satellite acquisition programs will result in gaps in the continuity of critical satellite data, and the impact of such gaps on the health and safety of the U.S. population, we concluded that the potential gap in weather satellite data is a high-risk area. We added this area to our High-Risk List in 2013 and it remains on the 2015 update to the High-Risk List that was issued yesterday.[2]

Overview of the JPSS Program

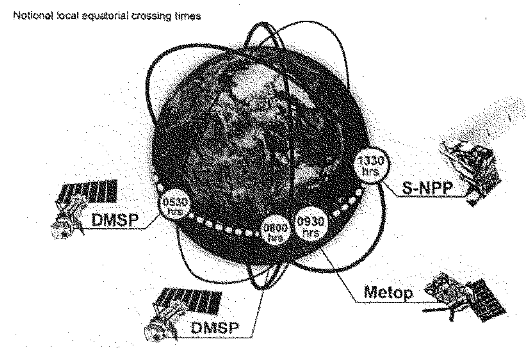
For over 40 years, the United States has operated two separate operational polar-orbiting meteorological satellite systems: the Polar-orbiting Operational Environmental Satellite series, which is managed by NOAA, and the Defense Meteorological Satellite Program (DMSP), which is managed by the Air Force.[3] Currently, there is one operational Polar-orbiting Operational Environmental Satellite (called the Suomi National Polar-orbiting Partnership, or S-NPP) and two operational DMSP satellites that are positioned so that they cross the equator in the early morning, midmorning, and early afternoon. In addition, the government relies on data from a European satellite, called the Meteorological Operational satellite, or Metop.[4] Figure 1 illustrates the current operational polar satellite constellation.

[2]Every two years at the start of a new Congress, GAO calls attention to agencies and program areas that are high risk due to their vulnerabilities to fraud, waste, abuse, and mismanagement, or are most in need of transformation. See GAO, *High Risk Series: An Update*, GAO-13-283 (Washington, D.C.: Feb. 14, 2013) and GAO, *High Risk Series: An Update*, GAO-15-290 (Washington, D.C.: Feb. 11, 2015).

[3]NOAA provides command and control for both the Polar-orbiting Operational Environmental Satellite and Defense Meteorological Satellite Program satellites after they are in orbit.

[4]The European Organisation 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 flown sequentially over 14 years. The first of these satellites was launched in 2006, the second was launched in 2012, and the final satellite in the series is expected to launch in 2017.

Figure 1: Configuration of Operational Polar Satellites



Sources: GAO, based on NPOESS Integrated Program Office, NOAA, and DOD data; NASA/Goddard Space Flight Center Scientific Visualization Studio (earth); S-NPP image provided courtesy of University of Wisconsin-Madison Space Science and Engineering Center. | GAO-15-386T

Note: DMSP—Defense Meteorological Satellite Program; Metop—Meteorological Operational (satellite); S-NPP—Suomi National Polar-orbiting Partnership; NPOESS—National Polar-orbiting Operational Environmental Satellite System; NOAA—National Oceanic and Atmospheric Administration; DOD—Department of Defense; and NASA—National Aeronautics and Space Administration.

A May 1994 Presidential Decision Directive[5] required NOAA and the Department of Defense (DOD) to converge the two satellite programs into a single satellite program—the National Polar-orbiting Operational Environment Satellite System (NPOESS)—capable of satisfying both civilian and military requirements. However, in the years after the program was initiated, NPOESS encountered significant technical challenges in sensor development, program cost growth, and schedule delays.

Faced with costs that were expected to reach about $15 billion and launch schedules that were delayed by over 5 years, in February 2010, the Director of the Office of Science and Technology Policy in the Executive Office of the President announced that NOAA and DOD would

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

no longer jointly procure NPOESS; instead, each agency would plan and acquire its own satellite system. Specifically, NOAA would be responsible for the afternoon orbit, and DOD would be responsible for the early morning orbit.

When this decision was announced, NOAA and the National Aeronautics and Space Administration (NASA) immediately began planning for a new satellite program in the afternoon orbit—called JPSS. After the February 2010 decision to disband NPOESS, NOAA established a program office to guide the development and launch of the S-NPP satellite[6] as well as the two planned JPSS satellites, known as JPSS-1 and JPSS-2. NOAA currently estimates that the life cycle costs for the JPSS program will be $11.3 billion through fiscal year 2025. The current anticipated launch dates for JPSS-1 and JPSS-2 are March 2017 and December 2022, respectively.

Over the last several years, we have issued a series of reports on the NPOESS program—and the transition to JPSS—that highlight the technical issues, cost growth, key management challenges, and key risks of transitioning from NPOESS to JPSS.[7] In these reports, we made multiple recommendations to, among other things, improve executive-level oversight, establish mitigation plans for risks associated with pending polar satellite data gaps, and establish a comprehensive contingency plan consistent with best practices. NOAA has taken steps to address our recommendations, including taking action to establish a contingency plan to mitigate potential gaps in polar satellite data.

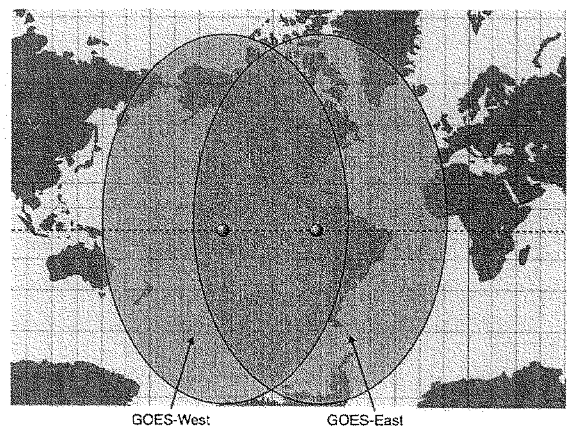
[6] S-NPP was originally planned as a demonstration satellite, but due to schedule delays that had the potential to lead to satellite data gaps, NOAA made the decision to use it as an operational satellite. This means that the satellite's data is used for climate and weather products.

[7] See, for example, GAO, *Environmental Satellites: Focused Attention Needed to Improve Mitigation Strategies for Satellite Coverage Gaps,* GAO-13-865T, (Washington, D.C.: Sept. 19, 2013); *Polar Weather Satellites: NOAA Identified Ways to Mitigate Data Gaps, but Contingency Plans and Schedules Require Further Attention,* GAO-13-676 (Washington, D.C.: Sept. 11, 2013); *Environmental Satellites: Focused Attention Needed to Mitigate Program Risks,* GAO-12-841T (Washington, D.C.: June 27, 2012); *Polar-orbiting Environmental Satellites: Changing Requirements, Technical Issues, and Looming Data Gaps Require Focused Attention,* GAO-12-604 (Washington, D.C.: June 15, 2012); *Polar Satellites: Agencies Need to Address Potential Gaps in Weather and Climate Data Coverage,* GAO-11-945T (Washington, D.C.: Sept. 23, 2011); *Polar-orbiting Environmental Satellites: Agencies Must Act Quickly to Address Risks That Jeopardize the Continuity of Weather and Climate Data,* GAO-10-558 (Washington, D.C.: May 27, 2010); *Polar-orbiting Environmental Satellites: With Costs Increasing and Data Continuity at Risk, Improvements Needed in Tri-Agency Decision Making,* GAO-09-564 (Washington, D.C.: June 17, 2009).

Overview of the GOES-R Program

In addition to the polar-orbiting satellites, NOAA operates GOES as a two-satellite geostationary satellite system that is primarily focused on the United States (see figure 2). The GOES-R series is the next generation of satellites that NOAA is planning; the satellites are planned to replace existing weather satellites, the first of which is due to reach the end of its useful life in 2015. The ability of the satellites to provide broad, continuously updated coverage of atmospheric conditions over land and oceans is important to NOAA's weather forecasting operations.

Figure 2: Approximate Geographic Coverage of the Geostationary Operational Environmental Satellites



Source: NOAA (data), Mapart (map) | GAO-15-386T

NOAA is responsible for GOES-R program funding and overall mission success, and has implemented an integrated program management structure with NASA for the GOES-R program. Within the program office, there are two project offices that manage key components of the GOES-R system. NOAA has delegated responsibility to NASA to manage the Flight Project Office, including awarding and managing the spacecraft contract and delivering flight-ready instruments to the spacecraft. The Ground

Project Office, managed by NOAA, oversees the Core Ground System contract and satellite data product development and distribution.

The program estimates that the development for all four satellites in the GOES-R series will cost $10.9 billion through 2036. In 2013, NOAA announced that it would delay the launch of the GOES-R and S satellites from October 2015 and February 2017 to March 2016 and May 2017, respectively. These are the current anticipated launch dates of the first two GOES-R satellites; the last satellite in the series is planned for launch in 2024.

In September 2010, we recommended that NOAA develop and document continuity plans for the operation of geostationary satellites that include the implementation procedures, resources, staff roles, and time tables needed to transition to a single satellite, a foreign satellite, or other solution.[8] In September 2011, the GOES-R program provided a draft plan documenting a strategy for conducting operations if there were only a single operational satellite.

In September 2013, we reported that the GOES-R program established contingency plans for the loss of its satellites and ground systems that were generally in accordance with best practices, but that the plans were missing key elements, such as working with the user community to address potential reductions in capability under contingency scenarios and identifying alternative solutions for preventing a delay in the GOES-R launch date.[9] We recommended that the program revise its contingency plans to address these weaknesses, including providing more information on the potential impact of a satellite failure and identifying timelines for implementing mitigation solutions. We subsequently assessed NOAA's progress in implementing this recommendation in our December 2014 report and will discuss our results at today's hearing.[10]

[8]GAO, *Geostationary Operational Environmental Satellites: Improvements Needed in Continuity Planning and Involvement of Key Users*, GAO-10-799 (Washington, D.C.: Sept. 1, 2010).

[9]GAO, *Geostationary Weather Satellites: Progress Made, but Weaknesses in Scheduling, Contingency Planning, and Communicating with Users Need to Be Addressed*, GAO-13-597, (Washington, D.C.: Sept. 9, 2013).

[10] GAO-15-60.

The JPSS Program Has Completed Significant Development Activities and Is Meeting Cost and Schedule Baselines, but Faces a Potential Near-term Data Gap That Mitigation Options are Unlikely to Fully Address

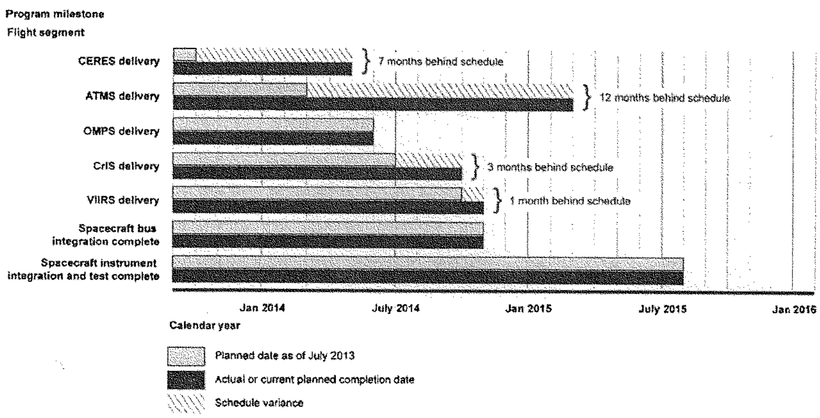
The JPSS program has recently completed significant development activities. For example, the program completed a major development milestone—the critical design review for the JPSS-1 mission—in April 2014. This is a significant accomplishment because the review affirms that the satellite design is appropriately mature to continue with development. Furthermore, NOAA is currently developing JPSS within its cost and schedule baselines.

However, while JPSS development is still within its overall life cycle cost baseline, key components have experienced cost growth. Between July 2013 and July 2014, the total program cost estimate increased by $222 million (or 2 percent). More than half of this increase was for three instruments. Program officials cited multiple reasons for these cost increases, including technical issues, additional testing, and the purchase of new parts. If JPSS costs were to continue to grow at this rate, the program could end up costing $2 billion more than expected by 2025. Therefore, moving forward, it will be important for NOAA and NASA managers to aggressively monitor and control components that are threatening to exceed their expected costs.

Also, while the launch date of the JPSS-1 satellite has not yet been affected, key components, such as the satellite's major instruments, have encountered delays in development and testing. Figure 3 compares key planned completion dates for the JPSS-1 spacecraft and its instruments from July 2013 to their actual or planned completion dates as of July 2014.[11]

[11]Since the time of our analysis, some of the milestones in figure 3 were delayed further. Specifically, ATMS delivery moved from March 2015 to June 2015, CrIS delivery moved from October 2014 to February 2015, VIIRS delivery moved from November 2014 to February 2015, and the completion of spacecraft instrument integration and test moved from August 2015 to October 2015.

Figure 3: Changes in Joint Polar Satellite System (JPSS) Spacecraft and Instrument Milestones since July 2013, as of July 2014



Source: GAO analysis of NOAA data. | GAO-15-386T

Notes: (1) In January 2015, NOAA acknowledged that delivery of the ATMS instrument would likely slip an additional 3 months to June 2015, delivery of the CrIS instrument would slip 4 months to February 2015, delivery of the VIIRS instrument would slip 3 months to February 2015, and the completion of the spacecraft instrument integration and test would slip 2 months to October 2015.

(2) CERES—Cloud and Earth's Radiant Energy System; ATMS—Advanced Technology Microwave Sounder; OMPS—Ozone Mapping and Profiler Suite; CrIS—Cross-Track Infrared Sounder; VIIRS—Visible Infrared Imaging Radiometer Suite.

JPSS program officials provided multiple reasons for the schedule changes, including technical issues the Advanced Technology Microwave Sounder (ATMS) instrument experienced during testing, a schedule adjustment to align with NOAA's geostationary satellite acquisition, and the October 2013 government shutdown. These delays have caused a reduction in schedule margin prior to the JPSS-1 satellite integration and testing phase.

Further, because of the technical issues experienced on ATMS, the instrument has now become the critical path[12] for the entire JPSS-1 mission and only 1 month of schedule reserve remains until its expected delivery in March 2015.[13] It will be important for NOAA and NASA managers to quickly resolve the instrument's technical issues before it becomes a more serious threat to the mission schedule and launch date.

NOAA Anticipates a Polar Satellite Data Gap, but Its Estimate May Prove Too Optimistic

In October 2013, the JPSS program office reported that a gap between the S-NPP satellite and the JPSS-1 satellite in the afternoon orbit could be as short as 3 months, which is 15 months less than NOAA estimated in 2012. However, we believe that this estimate is likely too optimistic. There are several reasons why this potential gap could occur sooner and last longer than NOAA currently anticipates.

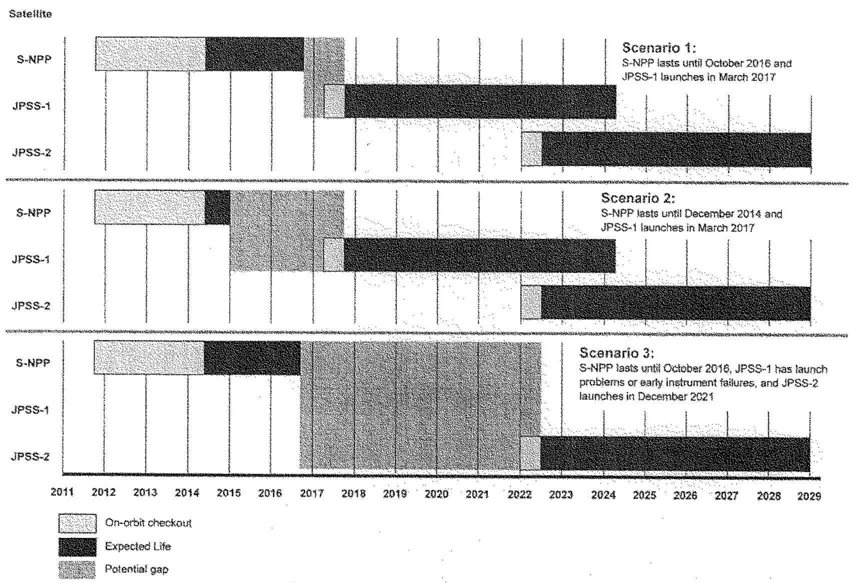
- **Inconsistent launch date plans**: The program's analysis that JPSS-1 will be operational by June 2017 is inconsistent with NOAA's launch date commitment of March 2017, given that the program office estimates 6 months for on-orbit checkout and calibration/validation before the satellite data are operational.
- **Unproven predictions about the on-orbit checkout and validation phase:** The on-orbit checkout and calibration/validation phase could take longer than the program's estimated 6 months if there are issues with the instruments or ground systems. Also, additional algorithm work may be needed after the satellite launches, which could extend the validation time frame.
- **Exclusion of a key risk:** The JPSS program's gap assessment does not factor in the potential for satellite failures from space debris that are too small to be tracked and avoided. Thus, the S-NPP mission could end earlier than its 5-year design life, resulting in a gap period that occurs sooner and lasts longer than expected.

[12] The critical path is generally defined as the longest continuous sequence of activities in a schedule. As such, it defines the program's earliest completion date or minimum duration. If an activity on the critical path is delayed by a week, the program finish date will be delayed by a week unless the slip is successfully mitigated. Therefore, the critical path is most useful as a tool to help determine which activities deserve focus and, potentially, management assistance.

[13] In January 2015, after our report was issued, NOAA reported that the delivery of ATMS was moved to June 2015 and that there is no longer schedule reserve prior to that delivery.

As a result, a gap in polar satellite data may occur earlier and last longer than NOAA anticipates. In one scenario, S-NPP would last its full expected 5-year life (to October 2016), and JPSS-1 would launch as soon as possible (in March 2017) and undergo on-orbit testing for 6 months as predicted by the JPSS program office (until September 2017). In that case, the data gap would extend 11 months. Any problems encountered with JPSS-1 development resulting in launch delays, launch problems, or delays in the planned 6-month on-orbit test period could extend the gap period to as much as 5 years and 8 months. Figure 4 depicts possible gap scenarios.

Figure 4: Potential Scenarios for a Gap in Polar Satellite Data in the Afternoon Orbit



Source: GAO analysis based on NOAA and NASA data. | GAO-15-386T

Note: S-NPP—Suomi National Polar-orbiting Partnership, JPSS-1—Joint Polar Satellite System-1, and JPSS-2—Joint Polar Satellite System-2.

NOAA officials acknowledge that the gap assessment has several limitations and stated that they plan to update it. Until NOAA updates its gap assessment to include more accurate assumptions and key risks, the agency risks making decisions based on a limited understanding of the potential timing and length of a gap.

Multiple Alternatives Exist for Mitigating a Satellite Data Gap

Experts within and outside of NOAA identified almost 40 alternatives for mitigating potential gaps in polar satellite data, which offer a variety of benefits and challenges. The alternatives can be separated into two general categories. The first category includes actions to prevent or limit a potential gap by providing JPSS-like capabilities. The second category includes actions that could reduce the impact of a potential gap by (a) extending and expanding the use of current data sources with capabilities similar to the JPSS program; (b) enhancing modeling and data assimilation; (c) developing new data sources; or (d) exploring opportunities with foreign and domestic partners.

While all of the alternatives have trade-offs, several alternatives may represent the best known options for reducing the impact of a gap:

- Extending legacy satellites, continuing to obtain data from European midmorning satellites, and ensuring legacy and European satellites' data quality remains acceptable;
- Obtaining additional observations of radio occultation[14] and commercial aircraft data;
- Advancing 4-dimensional data assimilation and the next generation global forecast model to make more efficient use of data still available and produce improved techniques for evaluating data;
- Increasing high-performance computing capacity, a key factor for enabling greater resolution in existing and future models, which drives the pace of development for assimilation of data that could further improve NOAA's models.

NOAA Improved its Polar Satellite Contingency Plan, but Delays Limit the Effectiveness of Key Mitigation Activities, and Mitigation Activities Have Not Been Prioritized

Government and industry best practices call for the development of contingency plans to maintain an organization's essential functions in the

[14]Radio occultation refers to a sounding technique in which a radio wave from an emitting spacecraft passes through an intervening planetary atmosphere before arriving at the receiver. Radio occultation techniques are used in observing atmospheric temperature profiles.

case of an adverse event.[15] NOAA developed its original polar satellite gap contingency plan in October 2012. We reported in September 2013 that NOAA had not yet selected the strategies from its plan to be implemented, or developed procedures and actions to implement the selected strategies and made a recommendation to address these shortfalls.[16]

In February 2014, NOAA updated its polar satellite gap contingency plan. NOAA made several improvements in this update, such as including additional alternatives that experts identified, and accounting for additional gap scenarios. However, additional work remains for NOAA's contingency plan to fully address government and industry best practices for contingency planning. Until NOAA fully addresses key elements to improve its contingency plan, it may not be sufficiently prepared to mitigate potential gaps in polar satellite coverage.

NOAA has also experienced challenges in implementing key activities outlined in the plan. Among a list of available alternatives, NOAA identified 21 mitigation projects that are to be implemented in order to address the potential for satellite data gaps in the afternoon polar orbit. NOAA has demonstrated progress by implementing initial activities on these gap mitigation projects.

However, NOAA has experienced delays in executing other key activities. For example:

- A planned upgrade to the National Weather Service's operational high-performance computing capacity was to occur by December 2014. According to NOAA officials, an interim upgrade is planned to occur in February 2015, with the full upgrade expected to be completed by July 2016.
- NOAA does not plan to complete observing system experiments that are to supplement its numerical weather prediction models in the absence of afternoon polar-orbiting satellite data until 4 months later than planned.

[15] See GAO, *Year 2000 Computing Crisis: Business Continuity and Contingency Planning*, GAO/AIMD-10.1.19 (Washington, D.C.: August 1998); National Institute of Standards and Technology, *Contingency Planning Guide for Federal Information Systems*, NIST 800-34 (May 2010); Software Engineering Institute, *CMMI® for Acquisition, Version 1.3* (Pittsburgh, Pa.: November 2010).

[16] GAO-13-676.

- Multiple projects have been affected by a major shortfall in the availability of high-performance computing for research and development efforts during fiscal year 2014.

Because a potential near-term data gap could occur sooner and last longer than expected, NOAA's ongoing gap mitigation efforts are becoming even more critical. According to Office of Management and Budget guidance, projects that require extensive development work before they can be put into operation are inherently risky and should be prioritized by comparing their costs and outcomes to other projects within a portfolio.[17]
However, the agency has not prioritized or accelerated activities most likely to address a gap because it has been focused on implementing many different initiatives to see which ones will have the most impact. NOAA officials stated that further prioritization among mitigation activities was not warranted because the activities were fully funded and were not dependent on the completion of other activities. We disagree. There are dependencies among projects that would benefit from prioritization. While it makes sense to investigate multiple mitigation options, unless NOAA assesses the activities that have the most promise and accelerates those activities, it may not be sufficiently prepared to mitigate near-term data gaps.

The GOES-R Program Has Made Development Progress, but Faces Schedule Risks and a Potential Coverage Gap, and Challenges Remain in Mitigation Planning

After spending 10 years and just over $5 billion, the GOES-R program has completed important steps in developing its first satellite, and has entered the integration and test phase of development for the satellite. While the GOES-R program is making progress, it has experienced recent and continuing schedule delays.

As we have previously reported, problems experienced during the integration and test phase often lead to cost and schedule growth.[18] In

[17]Office of Management and Budget, *Capital Programming Guide: Supplement to Circular A-11, Part 7, Preparation, Submission, and Execution of the Budget* (Washington, D.C.: July 2014).
[18]See, for example, GAO, *NASA: Assessments of Selected Large-Scale Projects*, GAO-11-239SP (Washington, D.C.: March 2011) and *NASA: Assessments of Selected Large-Scale Projects*, GAO-12-207SP (Washington, D.C.: March 2012).

2013, we reported that technical issues on both the flight and ground projects had the potential to cause further delays to the program schedule. By the time of our latest report, in December 2014, these and all other major milestones have been further delayed by 5 to 8 months. The GOES-R program cited multiple reasons for these recent delays, including challenges in completing software deliverables and completing communication testing for the spacecraft. In addition to these intermediate delays, NOAA moved the launch commitment date of the first GOES-R satellite to March 2016.

Further, the program's actions to mitigate schedule delays introduce some risks, and could therefore increase the amount of the delay. For example, the program attempted to mitigate delays by performing system development while concurrently working on detailed planning. In addition, the program has responded to prior delays by eliminating selected repetitive tests and moving to a 24-hour-a-day, 7-day-a-week spacecraft integration testing schedule. We have previously reported that overlapping planning and development activities and compressing test schedules are activities that increase the risk of further delays because there would be little time to resolve any issues that arise.[19]

A key element of a successful test phase is appropriately identifying and handling any defects or anomalies that are discovered during testing. While the GOES-R program has sound defect management policies in place and is actively performing defect management activities, there are several areas in which defect management policies and practices are inconsistent. Among the shortfalls are a number of cross-cutting themes, including in performing and recording information pertinent to individual defects, and in reporting and tracking defect information.

The GOES-R program has also not efficiently closed defects on selected components. Specifically, data for the GOES ground system shows that 500 defects remained open as of September 2014. Defect data for the spacecraft show that it is also taking an increasing amount of time to close hardware-related defects. Until the program addresses shortfalls in defect management and reduces the number of open defects, it may not have a complete picture of remaining issues and faces an increased risk of further delays to the GOES-R launch date.

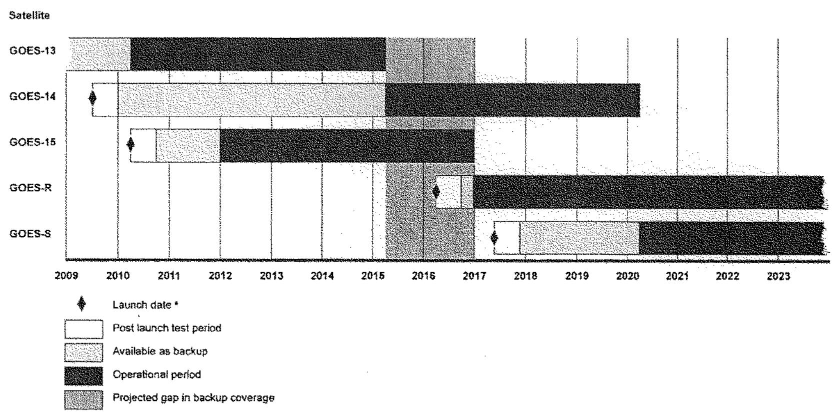
[19]GAO, *Office of Personnel Management: Improvements Needed to Ensure Successful Retirement System Modernization*, GAO-08-345 (Washington, D.C.: Jan. 31, 2008) and *2000 Census: New Data Capture System Progress and Risks*, GAO/AIMD-00-61 (Washington, D.C.: Feb. 4, 2000).

The program is now reaching a point where additional delays in starting the end-to-end testing could begin to adversely affect its schedule. As of August 2014, program officials could not rule out the possibility of further delays in the committed launch date.

GOES-R Faces a Gap in Backup Satellite Coverage

GOES satellite data are considered a mission-essential function because of their criticality to weather observations and forecasts. Because of the importance of GOES satellite data, NOAA's policy is to have two operational satellites and one backup satellite in orbit at all times. However, NOAA is facing a period of up to 17 months when it will not have a backup satellite in orbit. Specifically, in April 2015, NOAA expects to retire one of its operational satellites (GOES-13) and to move its backup satellite (GOES-14) into operation. Thus, the agency will have only two operational satellites in orbit—and no backup satellite—until GOES-R is launched and completes an estimated 6-month post-launch test period. Figure 5 shows the potential gap in backup coverage, based on the launch and decommission dates of GOES satellites.

Figure 5: Potential Gap in Geostationary Operational Environmental Satellite Coverage, as of April 2014



Source: GAO analysis of NOAA data. | GAO-15-386T

During the time when no backup satellite would be available, there is a greater risk that NOAA would need to either rely on older satellites that are beyond their expected operational lives and may not be fully functional, rely on a foreign satellite, or operate with only a single operational satellite. Due in part to the risks mentioned above, NOAA is also facing an increased risk of further delays to the March 2016 GOES-R launch date. Any delay to the GOES-R launch date would extend the time without a backup to more than 17 months.

The GOES-R Satellite Contingency Plan Shows Improvement, but Continues to Lack Details in Key Areas

Government and industry best practices call for the development of contingency plans to maintain an organization's essential functions—such as GOES satellite data—in the case of an adverse event.[20] In September 2013, we reported on weaknesses in the contingency plans for NOAA's geostationary satellites.[21] NOAA has improved its plan to mitigate gaps in satellite coverage. In February 2014, NOAA released a new satellite contingency plan in response to these recommendations. This plan improved upon many, but not all, of the best practices. Specifically, the plan improved in six areas and stayed the same in four areas.

GOES-R program officials stated that it is not feasible to include strategies to prevent delays in launch of the first GOES-R satellite in the contingency plan, because such strategies are not static. While actively managing the program to avoid a delay is critical, it is also important that NOAA management and the GOES-R program consider and document feasible alternatives for avoiding or limiting such a launch delay. Until NOAA addresses the remaining shortfalls in its GOES-R gap mitigation plan, the agency cannot be assured that it is exploring all alternatives or that it is able to effectively prepare to receive GOES information in the event of a failure.

Implementation of Recommendations Should Help Mitigate Program Risks

Both the JPSS and GOES-R programs continue to carry risks of future launch delays and potential gaps in satellite coverage; implementing the recommendations in our December 2014 reports should help mitigate those risks. In the JPSS report released in December, we recommended, among other things, that NOAA

- update the JPSS program's assessment of potential polar satellite data gaps to include more accurate assumptions about launch dates and the length of the data calibration period, as well as key risks such as the potential effect of space debris on JPSS and other polar satellites expected lifetimes;

[20] See GAO, *Year 2000 Computing Crisis: Business Continuity and Contingency Planning*, GAO/AIMD-10.1.19 (Washington, D.C.: August 1998); National Institute of Standards and Technology, *Contingency Planning Guide for Federal Information Systems*, NIST 800-34 (Gaithersburg, Md.: May 2010); Software Engineering Institute, *CMMI® for Acquisition, Version 1.3* (Pittsburgh, Pa.: November 2010).

[21] GAO-13-597.

- revise its existing contingency plan to address shortfalls noted in the 2014 report, such as identifying DOD's and Japan's plans to continue weather satellite observations, including recovery time objectives for key products, completing the contingency plan with selected strategies, and establishing a schedule with meaningful timelines and linkages among mitigation activities; and
- investigate ways to prioritize mitigation projects with the greatest potential benefit to weather forecasting in the event of a gap in JPSS satellite data.

In the GOES report released in December, we recommended that NOAA, among other things,

- add information to the GOES satellite contingency plan on steps planned or underway to mitigate potential launch delays.

For both reports, NOAA agreed with our recommendations and identified steps it plans to take to implement them. Specifically, with regard to the JPSS report, NOAA stated that it will make the necessary changes to its gap mitigation report and establish a process to prioritize mitigation projects. With regard to the GOES report, NOAA stated that it would add information to the GOES satellite contingency plan on steps planned or underway to mitigate potential launch delays.

In summary, NOAA has made progress on both the JPSS and GOES-R programs, but key challenges remain before the new satellites are launched and operational, and it is important that the agency take action to ensure that potential near-term gaps in satellite data are minimized or mitigated.

On the JPSS program, NOAA has recently completed significant development activities and is working to launch its next polar-orbiting environmental satellite as soon as possible. However, the program continues to face increasing costs and schedule delays on key components. Further, the program's estimate of a 3-month potential gap in satellite data may be overly optimistic because it was based on inconsistent and unproven assumptions and did not account for key risks. NOAA has made improvements to its polar satellite gap contingency plan, but has experienced delays in executing key mitigation activities, and has not prioritized or accelerated activities most likely to address a gap.

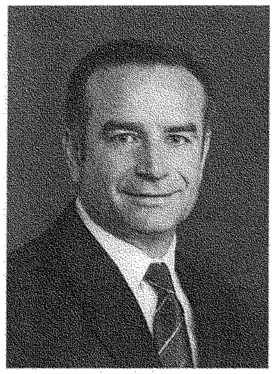
On the GOES-R program, progress in moving through integration and testing has been accompanied by challenges in maintaining its schedule on major milestones and controlling costs for key components. Further schedule delays could affect the committed launch date of the first GOES satellite. NOAA could experience a gap in satellite data coverage if GOES-R is delayed further and one of the two remaining operational satellites experiences a problem. NOAA has made improvements to its geostationary satellite contingency plan, but the plan still does not sufficiently address mitigation options for a launch delay.

Faced with an anticipated gap in the polar satellite program and a potential gap in backup coverage on the geostationary satellite program, NOAA has taken steps to study alternatives, establish mitigation plans, and improve its satellite contingency plans. However, these plans do not yet sufficiently address options to mitigate such gaps. Until NOAA prioritizes mitigation activities with the greatest potential to reduce the impact of gaps in weather forecasting, it may not be sufficiently prepared to mitigate them.

Chairman Bridenstine, Chairman Loudermilk, and Members of the Subcommittees, this completes my prepared statement. I would be pleased to respond to any questions that you may have at this time.

GAO Contacts and Staff Acknowledgments

If you have any questions on matters discussed in this testimony, please contact David A. Powner at (202) 512-9286 or at pownerd@gao.gov. Other key contributors include Colleen Phillips (assistant director), Alexander Anderegg, Christopher Businsky, Shaun Byrnes, Kara Lovett Epperson, Rebecca Eyler, Nancy Glover, Franklin Jackson, Nicole Jarvis, Joshua Leiling, James MacAulay, Lee McCracken, Karl Seifert, Kate Sharkey, and Shawn Ward.



David A. Powner

Experience
Over twenty years' experience in information technology issues in both public and private sectors.

Education
Business Administration
University of Denver

Senior Executive Fellows Program
Harvard University
John F. Kennedy School of Government

Director, IT Management Issues
U.S. Government Accountability Office

Dave is currently responsible for a large segment of GAO's information technology (IT) work that focuses on systems development and acquisition, IT governance, and IT reform initiatives.

In the private sector, Dave has held several executive-level positions in the telecommunications industry, including overseeing IT and financial internal audits, and software development associated with digital subscriber lines.

At GAO, Dave has led teams reviewing major IT modernization efforts at Cheyenne Mountain Air Force Station, the National Weather Service, the Federal Aviation Administration, and the Internal Revenue Service. He also has led GAO's work on health IT, weather satellite acquisitions, and cyber critical infrastructure protection. These reviews covered many information technology areas including software development maturity, information security, IT human capital, and enterprise architecture.

Dave has testified before Congress more than 70 times over the past several years and has received several GAO awards including its client service award. In 2008 and again in 2012, he received Federal Computer Week's Federal 100 award.

Chairman BRIDENSTINE. Thank you, Mr. Powner.

I now recognize Dr. Volz for five minutes to present his testimony.

TESTIMONY OF DR. STEPHEN VOLZ, ASSISTANT ADMINISTRATOR, NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICES, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Dr. VOLZ. Good morning, Chairmen Bridenstine and Loudermilk, Ranking Members Bonamici and Beyer, and Members of the Committee, I am pleased to be here today along with my colleagues from NOAA, John Murphy and Sandy MacDonald. All of us share a desire to ensure that the JPSS and GOES–R series programs are successful and support the Nation's weather enterprise.

We appreciate that Congress is supportive of NOAA's programs in the Fiscal Year 2015 appropriations bill. With these resources, NOAA will continue to provide environmental intelligence that is timely, accurate, actionable, reliable space-based information that citizens, communities and businesses need to stay safe and to operate efficiently.

Funding stability is essential for NOAA to maintain our operational readiness and to continue our progress in our critical research programs. For the NOAA satellite portfolio, we will provide continuous satellite data for current operations while maintaining essential satellite development to ensure the continuity of service to our customers and users into the future.

Every day, decisions are made by citizens and individuals and businesses based on the weather forecast, and we understand and appreciate it is our responsibility to operate the satellites that provide those data that go into the weather forecast. Our current operational geostationary and polar orbiting satellites provide on a 24–7 basis the space-based weather data required to support the weather enterprise of both the National Weather Service and the private weather industry. Research like in Sandy MacDonald's organization and in academia use these satellite data to develop products that can help the weather forecasters in John Murphy's organization produce those improved forecasts. And just yesterday, working together, NOAA, NASA and the Air Force launched the Deep Space Climate Observatory, or DSCOVR satellite on a SpaceX rocket from Cape Canaveral and it is now on its way to its observation point a million miles away from the Earth.

DSCOVR is a NOAA-operated follow-on to NASA's Advanced Composition Explorer, or ACE satellite, and as our buoy in space for geomagnetic storm warnings, the DSCOVR satellite will provide critical in situ data of these approaching solar storms in NOAA's Space Weather Prediction Center, or SWPC, and SWPC and the NWS provides the alerts, forecasts and warnings to commercial users, customers such as the aviation industry, telecommunications, operators of the electrical grid system, all of whom could be significantly affected by such events.

Turning to the GOES–R series and JPSS satellites that are the focus of this meeting, I am pleased to report that these programs are making excellent progress towards their launch dates. About this time next year, we will be preparing GOES–R at Cape Canaveral for its launch in March of 2016. GOES–R, the first in a series of four satellites with significant enhanced capabilities over the current GOES satellites, will continue NOAA's satellite provisions of 24/7 constant monitoring of the Atlantic Ocean, the continental United States, Hawaii, California and the Pacific Ocean for weather. Through ongoing work at the GOES–R proving ground, we are providing simulated GOES–R data to users now so that they will be ready for the real data flow immediately after launch and instrument commission in 2016.

NOAA announced recently that GOES–R satellite will be placed into operational service immediately following its initial onboard checkout period, again to ensure these measurements are made available to the Federal and public users immediately.

Moving to JPSS, by March 2017 the second satellite in the JPSS program, JPSS–1, will be launched. The launch of JPSS–1 will continue the numerical—the gains in numerical weather prediction modeling that we have benefited from since the Suomi NPP satellite was launched four years ago. The high-resolution sounders on Suomi NPP, ATMS and CriS, have provided immediate benefits to the quality of the NWS weather prediction models and ultimately the weather forecasts we all depend on.

In addition, the VIIRS imager on Suomi NPP has brought much improved observations of sea ice in the Alaskan and Arctic waters. The NWS and the U.S. Coast Guard are using blended products from VIIRS and commercially purchased synthetic aperture radar data to better map the ice and warn boats to avoid water where sea ice hazards exist.

The joint NASA–NOAA JPSS team has completed the procurement activities for the JPSS–2 instruments to accelerate the launch date for that mission. NESDIS is also advancing the development of the ground system for the COSMIC–2 radio occultation mission. This mission, which will be launched in 2016 in partnership with the U.S. Air Force and the National Space Organization of Taiwan, will provide thousands of critical radio occultation sightings per day and making a significant contribution to the NWS weather models.

In their reports, Mr. Powner and his staff have provided a number of observations along with specific recommendations from their most recent reviews of the GOES–R and JPSS programs. We value the dialog with the GAO as well as with other independent reviewers. As I have noted from my years with NASA, preparing for review is more benefit sometimes than actually the review itself. We concur with their assessments about the importance of these missions and need to stay vigilant and focused on mission success as indicated in the recommendations, and we folded those recommendations into our implementation plans moving forward.

In conclusion, these important programs, GOES–R and JPSS, have benefited from the best experience of NOAA, NASA and our aerospace partners and are making strong and consistent progress towards launch. Data from the satellites will support the complex process of developing the weather forecast in a three to seven seven day period. We believe these satellite programs have potential for success and to be able to provide the information needed for decision-making.

Thank you, and I look forward to answering questions.

[The prepared statement of Dr. Volz follows:]

WRITTEN STATEMENT BY
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ASSISTANT ADMINISTRATOR
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U.S. DEPARTMENT OF COMMERCE

HEARING TITLED
BRIDGING THE GAP: AN UPDATE ON THE NATION'S WEATHER SATELLITE PROGRAMS

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

February 12, 2015

Chairmen Bridenstine and Loudermilk, Ranking Members, and Members of the Committee, I am Dr. Stephen Volz, the Assistant Administrator of NOAA's National Environmental Satellite, Data, and Information Service (NESDIS). Thank you for the opportunity to join Mr. David Powner from the Government Accountability Office (GAO), and Mr. Steven Clarke from the National Aeronautics and Space Administration (NASA) at today's hearing.

My testimony today will focus on the recent GAO reviews of NOAA's Joint Polar Satellite System (JPSS) and Geostationary Operational Environmental Satellite-R (GOES-R) Series Programs, and on the progress that NOAA is making to develop the Nation's next generation geostationary and polar-orbiting satellite systems. We are confident that with NASA, as our acquisition agent, and with our industry and academic partners, we can meet our development milestones in order to deliver the essential data that these satellites provide to the nation's weather enterprise. These programs are being developed using proven acquisition processes for large aerospace missions and NOAA is confident based on the successes that the GOES-R Series and JPSS Programs have achieved to-date is based on implementing these processes.

Meeting the Nation's Space-based Operational Weather Data Requirements
NOAA's mission to provide science, service, and stewardship to the Nation is fundamentally dependent on observations of our environment. These observations are the backbone of NOAA's predictive capabilities, of which NOAA satellites provide the majority of data required. NOAA ensures that operational weather, ocean, climate, and space weather information are available 24 hours-a-day, seven days-a-week to address our nation's critical civil and military needs for timely and accurate forecasts and warnings of solar storms, extreme weather, and environmental phenomena, such as hurricanes, tornadoes, thunderstorms, winter storms, floods, wildfires, volcanic ash, fog, and sea ice.

NESDIS has managed the operation of polar-orbiting operational environmental satellites since 1966 and geostationary operational environmental satellites since 1974. Over the decades, these systems have supported weather and environmental monitoring programs that are relied upon by users in the United States (U.S.) and around the world. Satellites provide more than 95 percent of the data assimilated into NOAA's National Weather Service (NWS) numerical weather prediction models (NWP). These NWP models are used to forecast the weather seven or more days ahead, and, in particular, the NWP models are essential to forecasting the development of extreme weather events, including hurricanes and blizzards. Of those satellite observations, more than 80 percent are from polar-orbiting satellites, including the NOAA/NASA Suomi National Polar-orbiting Partnership (Suomi NPP) satellite, which is the primary satellite for weather observations in the afternoon orbit. Older secondary satellites, such as NOAA's Polar-orbiting Operational Environmental Satellite (POES) and NASA's Earth Observing Satellites (EOS), supplement Suomi NPP. NOAA's NWP models also rely on data from the European Metop satellites that fly in the mid-morning orbit.

GOES satellites, along with ground-based Doppler Radar, provide near real-time situational awareness, which is vital for "nowcasting" and short-term operational weather forecasting. This capability is especially important for tracking hurricanes and severe weather warnings and forecasts, where a few hours or even minutes matter. GOES satellites also provide some of the data that are used by the NWS Space Weather Prediction Center, the center responsible for issuing space weather forecasts, assessments, and warnings.

The American public depends on accurate, reliable, and timely weather information from NWS upon which to base their actions and decisions to protect themselves, their families, and their property. The growing private weather sector, which delivers specialized weather information, also relies on full, open, and timely receipt of NOAA's data and information. NOAA's satellites are an integral part of the nation's observational infrastructure that supports these NWS and private sector forecasting capabilities.

Data Accessibility

The primary requirement for NOAA's satellite systems is to provide the observations necessary to meet NOAA's environmental monitoring mission and support the needs of the nation's weather enterprise. Satellite data continuity is critical to many activities, including: the operational requirements of NOAA and other weather forecasting agencies around the world; research that enhances weather prediction capabilities; and the commercial weather sector's products and services. NOAA leverages data through a variety of means to augment and enhance data from its geostationary and polar-orbiting systems with other data sources. Much of these data are ingested into the NWS NWP models, or are used by forecast meteorologists to develop blended products that enhance their services to the public. To access additional non-NOAA data, NOAA:

- Leverages data from research satellites, such as NASA EOS and the Advanced Composition Explorer (ACE);
- Uses data from Department of Defense satellites, such as the Defense Meteorological Satellite Program;

- Purchases data from the commercial sector, such as ground-based lightning data and space-based Synthetic Aperture Radar data;
- Implements international agreements to ingest data from partner organizations, such as EUMETSAT) Metop satellites, Taiwan's Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) data, and Japanese Aerospace Exploration Agency's Global Climate Observing Mission – Water1 (GCOM-W1) data);
- Jointly procures satellite systems through domestic partnerships, such as refurbishment of the Deep Space Climate Observatory (DSCOVR), and international partnerships, such as Jason-3 and COSMIC-2; and
- Collaborates with other Federal agencies as well as Canadian, French, and European partners to fly the Argos-Data Collection System and the Satellite-assisted Search and Rescue (SARSAT) instruments.

Over the coming five years, NOAA and its partners will launch a number of missions that will provide continuity and enhanced capability of some of these important data streams. The DSCOVR satellite will provide solar winds data to support the NWS Space Weather Prediction Center mission. Later this year, the Jason-3 satellite will be launched, followed by the first set of COSMIC-2 satellites and GOES-R in FY 2016, and JPSS-1 in FY 2017. NOAA will ensure that its domestic and international users have access to all the relevant data needed to develop weather forecasts and warnings.

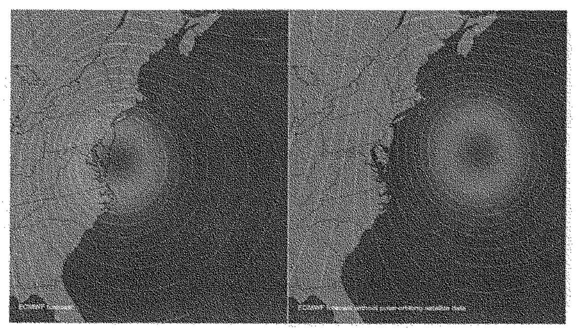


Figure 1. European Centre for Medium-Range Weather Forecasts (ECMWF) forecasts showing the progress of Hurricane Sandy with (left) and without (right) the use of polar satellite data

Downstream Benefits of NOAA's Satellite Data for Weather Forecasts and Warnings

As previously stated, the observations provided by NOAA's satellites are the backbone to NOAA's operational mission of protecting lives and property, along with many other downstream benefits to this information. The U.S. Forest Service, the U.S. Department of Homeland Security, the U.S. Department of Defense, and the Federal Aviation Administration are examples of the many agencies that rely on NOAA's three day and beyond forecasts in advance of severe weather to perform a wide variety of mission needs such as: determine forest fire trajectories, where evacuations should occur, what kinds of relief supplies can be prepositioned, and what travel delays to expect.

Benefits Provided by NOAA and the External Research Community: One of the downstream benefits to increasing the quantity and resolution of future satellite data is continued improvement of global and regional weather models. NOAA's Office of Oceanic and Atmospheric Research (OAR), NWS, and the Joint Center for Satellite Data Assimilation, which includes NASA, Department of Defense, and NOAA, and NOAA's research partners are working to develop additional ways to use the new sensors on NOAA's satellites, including the Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) that currently fly on Suomi NPP and will fly on JPSS-1 and JPSS-2, and the Advanced Baseline Imager (ABI) that will fly on the GOES-R Series satellites, to improve operational global weather models. We expect these collaborative efforts to improve our forecasts and warnings of extreme events, including hurricanes, floods, winter storms, and severe weather. Improved forecasts and warnings will ensure that emergency managers are better prepared to deal with extreme weather conditions and will ultimately have a positive impact on the economy as private companies make their business decisions based on NOAA data and information products that are provided to the entire weather enterprise. NOAA's full-and-open data policy encourages and supports these activities.

NOAA also works with academic and external research communities to develop and transition proven research results into the operational environment using NOAA's satellite data and the relevant leveraged non-NOAA data to improve operational processes. These partnerships with the external research community are integral to realizing downstream benefits of NOAA's satellite data.

Achieving Downstream Benefits: Using U.S. and international forecast models, we can realize downstream benefits by issuing warnings that extreme weather is approaching three to seven days in advance. This supports decisions made by Federal, State, and local officials that save lives and property.

Superstorm Sandy serves as an excellent example of where U.S. models (and others) were used by NWS forecasters to issue the weather and water forecasts and warnings that were used by government officials to make preparations (e.g., closing New York mass transit and interstate highways), evacuate people to move out of harm's way in vulnerable coastal areas, and prepare for the heavy snow that fell in the Appalachian Mountains of West Virginia and western Maryland. Sometimes as important as warnings can be, not warning for a location can be equally important to emergency managers. Hurricane Arthur, that hit North Carolina July 3-4, 2014, was extremely well forecast by U.S. models, accurately predicting both track and intensity. This excellent forecast and our forecaster confidence in the model predictions allowed emergency managers to evacuate only those areas actually impacted by the storm, and not areas in past years that would have been evacuated as a "precaution" due to uncertainty of the track and intensity. These improved models are a result of improved computing capacity and observations, including satellite data.

Benefits to the Commercial Weather Sector: NOAA provides access to a wide range of products and services to all its users, from its raw satellite data to highly analyzed data products through NWS's dedicated communications networks, the internet, or social media. In fact, NOAA recognizes that these data allow the commercial sector to play its important role to help us more widely disseminate NWS forecasts and warnings, supplement and tailor forecasts for the general public and to develop on their own, specialized value-added products for use by unique industries and sectors. These collaborative partnerships have proven to be a huge benefit to U.S. and international weather communities.

Furthermore, there is active outreach and interaction with the nation's weather community, through NOAA's Technology, Planning and Integration for Observation (TPIO) Program, to document their basic data requirements and to ensure the satellite systems that we are acquiring will deliver the needed data and products. This outreach is supported by the Office of Federal Coordination for Meteorology, NOAA's Cooperative Institutes, and the academic community, along with our federal agency customers and partners that are actively involved in this process. NOAA will continue these activities to ensure that we are capturing the data requirements of our customers and users to ensure their sustained access to this rich and collaborative environment.

Government Accountability Office Reviews

Over the past year, NOAA's JPSS and GOES-R Series Programs were reviewed by the GAO's Information Technology Team. The reviewers were mindful of the devastating impacts to the nation that a gap in satellite data coverage could bring, starting with the likelihood of degraded forecast quality and skill of severe weather events, which could place lives and property at risk. While many specific areas of concern were examined, all reviews urged NOAA to remain focused on maintaining the continuity of our observational capability and improving the robustness of the constellations, and provided NOAA with focused recommendations. We share their concerns and concur with these recommendations and we are working to ensure the GOES-R Series and JPSS satellite developments continue on schedule and within budget.

The GAO was concerned enough to add NOAA's satellite acquisition of the GOES-R Series and JPSS Programs to the 2013 Biennial High Risk List due to the risk of gaps in weather observations. NOAA has been taking steps over recent years to implement the GAO recommendations, through strategic investments made using funding from the *Disaster Relief Appropriations Act of 2013*, organizational realignments, and specific satellite acquisition activities that will make the polar-orbiting and geostationary constellations more robust. We believe that these actions will address many of the root causes that the GAO High Risk report emphasized and realize the goal of delivering satellite data to its customers and users without interruption.

Progress on the GOES-R Series Program

The GOES-R Series Program is NOAA's next-generation geostationary environmental satellite constellation. Geostationary environmental satellites are our observational sentinels in space, providing constant watch for severe weather such as hurricanes, severe thunderstorms, flash floods, and wildland fires in the Western Hemisphere. With two geostationary satellites always in operation (GOES-East and GOES-West) and an on-orbit spare, available as a backup, we are able to track severe weather from the west coast of Africa through most of the Pacific basin. The GOES satellites complement *in situ* observational systems, such as NOAA's Doppler Radar network, NOAA's Hurricane Hunters, and ocean buoys, to provide NWS forecasters with near real-time data used to support operational weather forecasts. Additionally, NOAA maintains a partnership agreement with EUMETSAT, through which each agency provides additional backup to the other in the event of the loss of a satellite.

GOES-R Series Program Content: The GOES-R Series Program content remains unchanged since the Congressional Baseline report was submitted in February 2013. The Program consists of four spacecraft (GOES-R, -S, -T, and -U) and associated instruments and the ground system antennas, mission management, product generation and distribution and enterprise management capabilities. The GOES-R series capabilities will provide GOES continuity and needed enhancements of required weather and space weather data. The enhanced GOES-R series capabilities are the result of the new instrument suite that includes:

- Advanced Baseline Imager (ABI)
- Geostationary Lightning Mapper (GLM)
- Space Environmental In Situ Suite (SEISS)
- Extreme Ultra Violet / X-Ray Irradiance Sensor (EXIS)
- Solar Ultra Violet Imager (SUVI), and
- Magnetometer

GOES-R Series Program Progress: The GOES-R Series Program has made significant progress in its development of both the ground and the flight segments.

Flight segment:

- Delivery and integration of all GOES-R instruments onto the GOES-R spacecraft.
- Pre-environmental testing of the GOES-R satellite and instruments is underway.
- Development of GOES-S, -T, and -U instruments well underway with the GOES-S flight set expected to be completed by this summer.
- Build up and integration of GOES-S spacecraft elements has been started in Denver, Colorado.

Ground segment:

- All Core Ground System equipment has been delivered to operational locations (Wallops, Virginia; Fairmont, West Virginia; and Suitland, Maryland) with completion of verification testing on schedule for spring 2015.
- Completed site acceptance testing for three of four antenna upgrades at NOAA's Satellite Operations Facility in Suitland, Maryland.
- Successfully completed the first Data Operations Exercise with 24-hours of simulated data delivered to NWS.
- Completed first spacecraft to ground system end-to-end test.
- Continued progress on the GOES-R Proving Ground, which is designed to accelerate NWS utilization of data from GOES-R data once on orbit.

GOES-R Series Program Cost: The GOES-R Series Program remains on cost within its life cycle cost of $10.8 billion.

GOES-R Series Schedule: The GOES-R satellite is on track for a March 2016 launch, followed by GOES-S in the third quarter of FY 2017. Work on GOES-T and –U is also ongoing and on schedule to support launches in the third quarter of FY 2019, and first quarter of FY 2025, respectively.

2015 GAO Review of the GOES-R Series Program
NOAA reviewed the GAO's report and concurred with all the recommendations:

1. Investigate and address inconsistencies in monthly earned value data reporting for the GLM and ABI instruments;
2. Address shortfalls in defect management identified in this report, including the lack of clear guidance on defect definitions, what defect metrics should be collected and reported, and how to establish a defect's priority or severity;
3. Reduce the number of unresolved defects on the GOES ground system and spacecraft; and
4. Add information to the GOES satellite contingency plan on steps planned or underway to mitigate potential launch delays, the potential impact of failure scenarios in the plan, and the minimum performance levels expected under such scenarios.

Discussion of the Actions to Date to Address these Recommendations
For the first recommendation, the GOES-R Series Program validates all of the earned value management (EVM) data received and has an underlying process to insure that data calculations are correct and that valid data are being reported. We will identify the root causes of the inconsistencies identified and rectify any process escapements. From a management perspective, we also use other data, such as milestones completed and contractor staffing profiles, to ensure our management oversight is based on an integrated view of many metrics or indicators, including EVM.

With regard to the second recommendation, NOAA acknowledges that there are some differences between the various contractors' defect management software and internal definitions. Allowing the contractors to use their own defect management systems, rather than dictating a common system for all contractors, minimizes program cost and the potential technical risk to the program if those companies were forced to use a unique system for us that was different from the systems they use for their other work. We will review defect definitions, defect metrics, and defect priority/severity management to ensure the best overall defect management controls are in place.

For recommendation three, the GOES-R Series Program is actively working to reduce the number of unresolved defects. As mentioned above, we will revise our processes to ensure maximum effectiveness. Note that all defects are reviewed on a bi-weekly basis. This review, which contains a constraints list, enforces timely closure of the defects in order to facilitate advancing through the Integration and Test phase.

For recommendation four, NOAA is working to update and augment its GOES satellite contingency plan. We expect to have it ready by Summer 2015.

An action plan to incorporate these recommendations into our standard operating procedures is under development. We appreciate the review that the GAO has conducted and NOAA remains confident that the GOES-R Series Program development is occurring in an effective manner and using the appropriate management tools and systems for a large satellite acquisition mission. We recognize this is a complex satellite system, and are actively managing the development risks. With timely receipt of sufficient appropriations in FY 2016 and beyond, we will be able to maintain development schedules and launch these next generation GOES satellites to meet the needs of our customers and users.

Progress on the JPSS Program
NOAA's polar-orbiting operational environmental satellites provide full global coverage for a broad range of weather and environmental applications. Placed in the afternoon orbit, these satellites are crucial for NOAA's operational three to seven day weather forecasts and environmental modeling efforts. In addition to the critical role JPSS sounders play in numerical modelling, the imager – the Visible Infrared Imaging Radiometer Suite (VIIRS) – provides observations of the northern latitudes where geostationary satellites cannot see. VIIRS provides additional critical support to NWS forecasters, including cloud and ice coverage data for watches and warnings in northern latitudes (i.e. Alaska) that cannot be covered by NOAA's geostationary satellites. It also supports many government and private interests in the Arctic region. The Suomi NPP satellite, which was launched in October 2011 with a design life lasting until the first quarter of FY 2017, is NOAA's primary afternoon orbit satellite, its ATMS and CrIS instruments provide operational data to the NOAA's operational numerical weather forecast models. NOAA POES and NASA EOS satellites are currently providing backup coverage for the afternoon orbit. The European Metop satellite constellation (Metop A and Metop B), which flies in the mid-morning orbit, also provides observations that NOAA assimilates into its operational numerical weather prediction models.

JPSS Program Content: The JPSS Program consists of: three satellites, Suomi NPP, JPSS-1 and JPSS-2; associated instruments, the ground system, mission management and operations, product generation and distribution, and management. The JPSS Program is focused to support the weather mission and will fly the following core instruments:

- Advanced Technology Microwave Sounder (ATMS)
- Cross-track Infrared Sounder (CrIS)
- Visible Infrared Imaging Radiometer Suite (VIIRS)
- Ozone Mapping and Profile Suite (OMPS)-Nadir
- Clouds and the Earth's Radiant Energy System (CERES), only on Suomi NPP and JPSS-1 and accommodations for a NASA-provided Radiation Budget Instrument (RBI) on JPSS-2

JPSS Program Progress: Over the past year, the JPSS Program has achieved the following successes in both the flight and ground segments and operations:

Flight segment:

- Made significant progress in developing and integrating the JPSS-1 spacecraft including the integration of two instruments, OMPS and CERES, onto the JPSS-1 spacecraft.
- Initiated development of all instruments for the JPSS-2 mission, which is targeted to launch FY 2022.

Ground segment and operations:

- Continued successful operation of the Suomi NPP satellite, which is exceeding its data availability and data latency requirements.
- Completed the design and development of an upgraded ground segment, which is required to support the launch of JPSS-1 and will improve Suomi NPP operations.
- Continued activities to rebuild robustness in the polar-orbiting constellation to ensure uninterrupted data availability.

JPSS Program Cost: The JPSS Program remains within the life cycle cost of $11.3 billion.

JPSS Schedule: The launch commitment date for the JPSS-1 satellite in the second quarter of FY 2017 remains unchanged since the Congressional Baseline report was submitted in November 2014. With respect to the JPSS-2, all instruments are under contract and an award of the JPSS-2 spacecraft bus is expected in April. The JPSS Program is working towards an accelerated JPSS-2 launch to the fourth quarter of FY 2021, a date earlier than the current launch commitment date of the first quarter of FY 2022.

2015 GAO Review of the JPSS Program
NOAA reviewed the GAO's report and concurred with the recommendations:

1. Track completion dates for all risk mitigation activities;
2. Update the program's assessment of potential polar satellite data gaps to include more accurate assumptions about launch dates and the length of the data calibration period, as well as key risks such as the potential effect of space debris on JPSS and other polar satellites' expected lifetimes;
3. Revise the comprehensive contingency plan for potential satellite data gaps in the polar orbit that is consistent with contingency planning best practices to address the shortfalls such as identifying DOD's and Japan's plans to continue weather satellite observations, including recovery time objectives for key products, completing the contingency plan with selected strategies, identifying opportunities for accelerating calibration and validation of products, providing an assessment of available alternatives based on their costs and potential impacts, establishing a schedule with meaningful timelines and linkages among mitigation activities, and defining completion dates for testing and validating the alternatives;
4. Investigate ways to prioritize mitigation projects with the greatest potential benefit to weather forecasting in the event of a gap in JPSS satellite data and report recommendations to the NOAA program management council; and

5. Ensure that the relevant entities provide monthly and quarterly updates on the progress of all mitigation projects and activities during existing monthly and quarterly management meetings.

We also note the GAO discussion of the threat of space debris on these satellites. Continued cooperation amongst all space agencies is required and expected as all space agency satellites are equally at risk and contribute to the generation of space debris. As noted, the JPSS Program satellites are designed to undertake maneuvers to avoid collisions, and critical components are shielded.

Discussion of NOAA's Actions to Date to Address these JPSS Recommendations
NOAA has already started to implement activities in response to the GAO recommendations.

- For the first recommendation, JPSS is reviewing its risk management processes to further ensure critical steps required to mitigate risks are tracked to completion.
- For recommendation two, the JPSS program conducts an annual assessment of satellite data availability. The 2014 assessment report is being finalized, including accurate assumptions about launch dates and length of the data calibration period. The 2015 assessment was already planned to include the impact of orbital debris.
- For recommendation three, NOAA is also reviewing its gap mitigation plan to identify improvements for the next revision, including addressing the shortfalls identified by GAO.
- For recommendation four, NOAA will establish a process to prioritize mitigation projects.
- For recommendation five, NOAA will assess current reporting and implement improvements to assure progress is reported on all gap mitigation activities at normal monthly and quarterly management meetings.

Preparation and contingency planning for the occurrence of a satellite data gap is essential to good enterprise risk management. The JPSS Program's gap mitigation assessment and plan will be updated and reviewed as needed, and we will fold the GAO recommendations into our standard operating procedures. As noted above, we appreciate the review that the GAO has conducted. NOAA remains confident that JPSS development is occurring in a cost-efficient manner, using the most appropriate management tools and systems for a large and complex satellite acquisition mission, and with resources applied appropriately, to mitigate risks and to maintain the second quarter of FY 2017 launch commitment date for JPSS-1. With sufficient appropriations, as noted above, we will launch these next generation polar-orbiting satellites to meet the needs of our customers and users without interruption.

Activities to Re-build Geostationary and Polar-Orbiting Constellation Robustness.
Over the past four years, NOAA has been strategically working to build and strengthen robustness of the geostationary and polar-orbiting constellations. We have been monitoring the current GOES-N Series operating satellites and ensuring that we maximize our ability to use these satellites to support our 24x7 operational needs. We believe that the progress we are making in the development of the GOES-R satellite will provide enhanced and continued coverage in the geostationary orbit when it is needed as the current GOES satellites are retired. We are on target for a second quarter of FY 2016 launch of GOES-R, with continued development towards launch of GOES-S and –T and –U as planned. Through the GOES-R Proving Ground, we have been working with operational and research meteorologists to

demonstrate the utility of the enhanced products and services that the GOES-R Series satellites will provide, and to ensure a rapid utilization of the GOES-R products when they become available. Funds requested in the President's Budget reflect the amount that is critical for us to maintain the momentum as we make the geostationary orbit more robust and as we retain our "two operational satellites with an on-orbit spare" operational posture.

There are a number of activities underway to re-build robustness in the polar-orbiting constellation. We continue to maximize the ability of the Suomi NPP satellite to meet our current data requirements for use in NWS NWP models. We are making tremendous progress on the development of the JPSS-1 satellite and remain on target for launch in the second quarter of FY 2017. We are ramping up development of the JPSS-2 satellite; the instruments are underway and a decision on the JPSS-2 spacecraft bus contractor will be made shortly. We are also working with our European partner, EUMETSAT, to ensure that Metop-C is successfully launched and will provide data for U.S. and European use in our respective weather forecast operations, and we continue to operate and utilize data from the other legacy satellites in the afternoon orbit, NASA's EOS, and NOAA's POES satellites.

The Joint Center for Satellite Data Assimilation is working to accelerate the optimal use of CrIS, ATMS, and VIIRS data from the Suomi NPP satellite, to be ready for use of JPSS-1 data on "day one" to ensure the JPSS-1 data is ready for use within NOAA's global and regional NWP models as early as possible.

We rely on continued Congressional appropriations support to accomplish these activities to ensure that the national weather enterprise has the space-based data needed to provide early warning to the American public that severe weather is approaching.

Conclusion

The nation's weather satellite programs are proceeding well through this final integrated systems test phase leading to the launch of GOES-R in March 2016 and JPSS-1 no later than March 2017. This progress is only possible with the close coordination between NOAA and NASA. We are confident in the technical expertise of NASA and our aerospace partners, and the proven acquisition processes that have supported the successes of the GOES-R Series and JPSS Programs. Continued funding at the requested level in FY 2016 and beyond is critical for meeting developmental milestones that will allow these programs to meet their launch dates. NOAA has been working steadily to rebuild the robustness of the geostationary and polar-orbiting satellite constellations, while taking maximum advantage of existing orbital assets to provide robustness and redundancy today.

Both the GOES-R Series and JPSS Programs are at critical junctures as they prepare for launches in FY 2016 and FY 2017, respectively. We are grateful for the continued support from Congress over the past five years and appreciate your efforts to bring stability to the appropriations that fund these programs and the missions that supplement and provide enhancements to the NOAA geostationary and polar-orbiting data.

Mr. Powner and his team's recommendations offer us recommendations for continuous improvement as we move forward to develop the operational environmental satellites that are so crucial to protecting American lives and property, and the nation's economic security. We accept their recommendations and will be responsive to them, as noted.

Finally, NOAA values the long-standing interest by the Committee and its staff in NOAA's satellite program. We understand the difficult fiscal environment that we find ourselves in and appreciate the Congressional support to ensure that these critical national programs are supported to the maximum extent possible.

Stephen Volz
Assistant Administrator for Satellite and Information Services

Dr. Stephen Volz is the NOAA Assistant Administrator for Satellite and Information Services. NOAA's Satellite and Information Service is dedicated to providing timely access to global environmental data from satellites and other sources to promote, protect and enhance the Nation's economy, security, environment and quality of life. In this role Dr. Volz leads the acquisition and operation of the nation's civil operational environmental satellite system. He also leads efforts for research and development of products and programs to archive and provide access to a variety of Earth observations via three national data centers.

Dr. Volz is a leader in the international Earth observation community, serving as the NOAA Principal to the Committee on Earth Observation Satellites (CEOS). In this capacity he leads efforts to coordinate global satellite-based observations among international space agency partners to further the development of a Global Earth Observation System of Systems. In addition, Dr. Volz serves as the Co-Chair of the NOAA Observing Systems Council, a group that coordinates observing systems requirements and provides resource recommendations for NOAA's observation platforms. He is also a member of the NOAA Executive Council, NOAA's executive decision-making body.

Dr. Volz previously served as the Associate Director for Flight Programs in the Earth Science Division of NASA's Science Mission Directorate. As the Program Director, Dr. Volz managed all of NASA's Earth Science flight missions and associated activities. Within this flight portfolio, Dr. Volz managed a line of Principle Investigator (PI) led missions in airborne science, small satellites, and instrument missions of opportunity, including the development of the Announcements of Opportunity to solicit the science and mission proposals, along with their subsequent evaluation and selection. Steve managed within the flight program a suite of Distributed Active Archive Centers (DAACs) that process, distribute, and archive all of NASA's Earth science data, as well as the science research data products developed from these and other satellite remote-sensing data. Dr. Volz worked with domestic and international space agencies to actively support and promote partnerships and collaboration to further NASA and the nation's Earth science remote-sensing objectives, and to maximize the beneficial utilization of NASA's Earth science data.

Dr. Volz has 26 years professional experience in aerospace. Prior to serving as the Flight Program Director, Dr. Volz was the Earth Science program executive for a series of Earth Science missions, including EO-3 GIFTS, CloudSat, CALIPSO, and ICESat, and he led the Senior Review for the Earth Science operating missions. Dr. Volz worked in industry at Ball Aerospace and Technologies Corporation from 1997–2002, where he was the Project Manager for the Space Infrared Telescope Facility superfluid helium cryostat and other flight projects. From 1986–1997 Dr. Volz worked for NASA's Goddard Space Flight Center as an instrument manager, an I&T Manager, a systems engineer, and a cryogenic systems engineer on missions and instruments including the Cosmic Background Explorer (COBE), among others.

Dr. Volz is a member of several professional societies, including the American Physical Society (M'82), the American Astronomical Society (M'87), the American Geophysical Union (M'02), and the American Meteorological Society (M'08). He is a senior member of the Institute of Electrical and Electronics Engineers (IEEE), an active member of and participant in the Geoscience and Remote Sensing Society (GRSS), and a member of the GRSS Administration Committee (AdCom) for the period of 2013–2017. He is the recipient of several awards, including the Silver Snoopy Award from NASA's astronaut team in 1994 for his work as the instrument manager and team lead for the Space Shuttle cross bay mounted Superfluid Helium On Orbit Transfer (SHOOT) experiment, the Goddard Space Flight Center John Boeckel Award for Engineering Excellence (1992), and the Ball Corporation Award of Excellence from the Ball Aerospace and Technology Corporation (BATC) in 2001.

Dr. Volz has a doctorate in Experimental Condensed Matter Physics from the University of Illinois at Urbana-Champaign (1986), a master's in Physics from Illinois (1981), and a bachelor's in Physics from the University of Virginia (1980). He has more than 20 publications in peer-reviewed journals.

Dr. Volz is a native-born Washingtonian, and lives in Bethesda with his wife Beth and his two teenage daughters.

Chairman BRIDENSTINE. Thank you for your testimony, Dr. Volz.
Mr. Clarke, you are recognized for five minutes.

TESTIMONY OF MR. STEVEN CLARKE, DIRECTOR, JOINT AGENCY SATELLITE DIVISION, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. CLARKE. Chairmen, Ranking Members and other Members of the Subcommittees, good morning, and thank you for the opportunity to appear today to provide you information regarding NASA's role in and commitment to NOAA's Joint Polar Satellite System (JPSS) and Geostationary Operational Environmental Satellite-R (GOES–R) series programs.

JPSS and GOES–R programs are critical to the nation's weather forecasting system, environmental monitoring and research activities. NASA and NOAA have been partners for more than 40 years in developing the nation's polar and geosynchronous weather satellites.

Following the restructure of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program in 2010, NASA and NOAA returned to the successful partnership for JPSS. A NASA program office for JPSS was created and is staffed with a complement of NASA's civil servants and contractors. NOAA and NASA established joint agency-level program management councils to oversee JPSS and GOES–R and have integrated their decision-making processes to efficiently and effectively manage this cooperative activity.

The NASA and NOAA teams have continually demonstrated a strong working relationship over the last four years, and as Dr. Volz mentioned, I am very pleased and proud the NASA and NOAA team in partnership with the U.S. Air Force and SpaceX in launching the Deep Space Climate Observatory (DSCOVR), which will maintain the Nation's real-time solar wind monitoring capabilities. These measurements are critical to the accuracy and lead time of space weather alerts and forecasts. Once it reaches its destination at the first Sun-Earth Lagrangian point L–1, DSCOVR will help provide timely and accurate warnings of space weather events like the geomagnetic storms caused by changes in solar wind, which have the potential to disrupt nearly every major public infrastructure system, including power grids, telecommunications, aviation and the Global Positioning System (GPS).

Additionally, in the past four years of our partnership, NASA and NOAA have successfully launched the Suomi National Polar-orbiting Partnership (NPP) mission and the Total Solar Irridiance Calibration Transfer Experiment (TCTE) payload. Suomi NPP celebrated its three-year on-orbit anniversary this past October, providing operational data to NOAA for use in weather forecasting. The satellite was developed to extend the record of key observations from the NASA Earth Observing System series of satellites and to demonstrate spaceflight and ground data-processing technologies for the next generation of operational polar-orbiting meteorological satellites.

The JPSS–1 mission is on track towards the planned second-quarter Fiscal Year 2017 launch. The spacecraft Integration Readiness Review was completed in December and both the Clouds and

Earth Radiant Energy System (CERES) and the Ozone Mapping and Profiler Suite-Nadir (OMPS–N) instruments have been fully integrated with the spacecraft. The Visible Infrared Imaging Radiometer Suite (VIIRS) and Cross-track Infrared Sounder (CrIS) instruments have completed environmental testing and are ready for installation onto the JPSS spacecraft.

The GOES–R series program of four geosynchronous satellites continues to make progress toward launching GOES–R, the first satellite of the series, in the second quarter of Fiscal Year 2016, and manufacturing GOES–S, the second satellite of the series, with a planned launch date in the third quarter of Fiscal Year 2017. Last year, the GOES–R Series Program successfully completed the GOES–R spacecraft Mission Operations Review and System Integration Review, allowing the spacecraft to enter the assembly, integration and test phase.

NASA and NOAA are committed to the JPSS and GOES–R programs, and ensuring the success of these programs is essential to both agencies and the Nation. The NASA and NOAA teams have established strong working relationships and are striving to ensure that weather and environmental monitoring requirements are met on the most efficient schedule without reducing system capabilities. I am confident the NASA/NOAA partnership will successfully develop and deliver the next-generation polar and geosynchronous weather satellites to our Nation.

Mr. Chairmen and Ranking Members, I appreciate the continued support of these Subcommittees and the Congress, and would be pleased to respond to any questions you or the other Members of the Subcommittees may have.

[The prepared statement of Mr. Clarke follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
February 12, 2015

Statement of
Steven W. Clarke
Director, Joint Agency Satellite Division
National Aeronautics and Space Administration
before the
House Subcommittee on Environment
and
House Subcommittee on Oversight
Committee on Science, Space and Technology
United States House of Representatives

Chairmen, Ranking Members, and other Members of the Subcommittees, thank you for the opportunity to appear today to provide you information regarding the NASA role in, and commitment to, the National Oceanic and Atmospheric Administration (NOAA) Joint Polar Satellite System (JPSS) and Geostationary Operational Environmental Satellite-R Series (GOES-R) Programs. The JPSS and GOES-R Programs are critical to the Nation's weather forecasting, environmental monitoring and research activities.

Building on a History of Success

NASA and NOAA have been partners for more than 40 years in developing the Nation's polar and geosynchronous weather satellites. Following the restructure of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) program in 2010, NASA and NOAA returned to this successful partnership for JPSS. A NASA program office for JPSS was created and is staffed with a complement of NASA civil servants and contractors. NOAA and NASA established joint agency-level program management councils to oversee JPSS, and have integrated their decision-making processes to efficiently and effectively manage this cooperative activity.

The NASA and NOAA teams have continually demonstrated a strong working relationship over the last four years, and together have successfully launched the Suomi National Polar-orbiting Partnership (Suomi-NPP) and the Total Solar Irradiance Calibration Transfer Experiment (TCTE).

Recently, NASA and NOAA successfully completed the development of the Deep Space Climate Observatory (DSCOVR), which will maintain the nation's real-time solar wind monitoring capabilities. These measurements are critical to the accuracy and lead time of space weather alerts and forecasts. Once it reaches its destination at the first Sun-Earth Lagrangian point (L1), DSCOVR will help provide timely and accurate warnings of space weather events like the geomagnetic storms caused by changes in solar wind, which have the potential to disrupt nearly every major public infrastructure system, including power grids, telecommunications, aviation and Global Positioning System (GPS).

The JPSS Program is Executing Well

The JPSS Program consists of three polar missions: Suomi-NPP, JPSS-1 and JPSS-2. Having successfully transitioned to the execution and implementation phase, the overall program is executing on the schedule and within the budget established when the program was baselined in July 2013. This progress is a true testament to the evolution and effectiveness of the NOAA and NASA partnership. NASA, as NOAA's acquisition agent, manages all of the JPSS instrument, spacecraft, and major ground system contracts, utilizing expertise from NASA Headquarters and the NASA Goddard Space Flight Center.

Suomi-NPP celebrated its 3-year on-orbit anniversary this past October. The satellite was developed to extend the record of key observations from the NASA Earth Observing System (EOS) series of satellites and to demonstrate space flight and ground data processing technologies for the next generation of operational polar-orbiting meteorological satellites. While the satellite was not originally intended to be used as an operational asset, NOAA is using Suomi-NPP data in its operational weather forecasting models. The satellite is operating well and is producing outstanding data with high availability (~99.99%). The satellite operations transitioned from NASA to NOAA in 2013, and the mission continues to satisfy both NASA and NOAA needs.

The JPSS-1 mission is on track towards the planned 2nd Quarter FY 2017 launch. The spacecraft Integration Readiness Review was completed in December and both the Clouds and Earth Radiant Energy System (CERES) and the Ozone Mapping and Profiler Suite - Nadir (OMPS-N) instruments have been fully integrated with the spacecraft. The VIIRS and Cross-track Infrared Sounder (CrIS) instruments have completed environmental testing and held their pre-ship reviews earlier this month.

All JPSS-2 instruments are under contract and are in various states of build. The spacecraft bus procurement is underway and contract award is planned for April 2015. NASA and NOAA are working to accelerate the JPSS-2 Launch Readiness Date (LRD) from its current baseline of first quarter of Fiscal Year (FY) 2022 in order to reduce the probability of a gap between JPSS-1 and JPSS-2. NASA shares NOAA's strong desire to mitigate any potential data gaps that could adversely affect the Nation's weather forecasting capability. Any potential gap could also impact the continuity of data used by NASA scientists for various research.

The next major milestone for the JPSS Program is the JPSS-1 mission Systems Integration Review, which is currently planned for the end of this month. The objective of the review is to evaluate the readiness of the mission for system assembly, test and launch operations, and will therefore focus on the readiness of the last two instruments. The VIIRS and CrIS instruments are to be delivered for integration with the spacecraft later this month. The remaining instrument, the Advanced Technology Microwave Sounder (ATMS) is undergoing rework and is currently planned for delivery and integration later this summer.

GOES-R Series Program Continues to Make Progress

The GOES-R Series Program of four geosynchronous satellites continues to make progress toward launching GOES-R, the first satellite of the series, in the second quarter of FY 2016 and manufacturing GOES-S, the second satellite of the series, with a planned launch date in the third quarter of FY 2017. Last year, the GOES-R Series Program successfully completed the GOES-R spacecraft Mission Operations Review, System Integration Review, and Key Decision Point-D, allowing the spacecraft to enter the assembly, integration and test phase. All of the instruments have been integrated on the spacecraft, with three of the instruments completing initial baseline testing in preparation for the GOES-R spacecraft environmental test campaign. Good progress continues with the GOES-S spacecraft component and spacecraft structural manufacturing. Three of the six GOES-S instruments, the Advanced Baseline Imager, the Extreme Ultraviolet and X-ray Irradiance Sensor, and the Solar Ultraviolet Imager, have completed environmental testing.

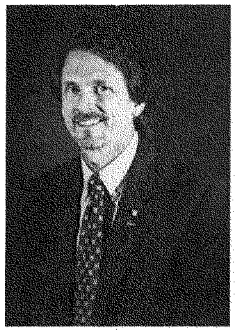
The next major milestones for the GOES-R Series Program are the GOES-R Spacecraft Pre-Environmental Review currently planned for this March and the GOES-S System Integration Review currently planned for the first quarter of FY 2016.

Conclusion

NASA and NOAA are committed to the JPSS and GOES-R programs, and ensuring the success of these programs is essential to both agencies and the Nation. The NASA and NOAA teams have established strong working relationships and are striving to ensure that weather and environmental monitoring requirements are met on the most efficient and predictable schedule without reducing system capabilities. I am confident the NASA/NOAA partnership will successfully develop and deliver the next-generation polar and geosynchronous weather satellites to our Nation.

Mr. Chairmen and Ranking Members, I appreciate the continued support of these Subcommittees and the Congress, and I would be pleased to respond to any questions you or the other Members of the Subcommittees may have.

Steven W. Clarke
Director of the Joint Agency Satellite Division



Steven W. Clarke has been the Director of NASA's Joint Agency Satellite Division (JASD), effective March 9, 2014. He is responsible for managing reimbursable satellite and instrument development activities performed by NASA for partner agencies. The division's portfolio includes the Joint Polar Satellite System (JPSS), GOES-R, DSCOVR, Jason-3, MetOp/POES, and Polar Free Flyer.

Steve recently supported the Deputy Associate Administrator of the Exploration Systems Development (ESD) Division at NASA Headquarters where he was responsible for developing and operating the exploration architecture for human exploration beyond Earth orbit.
After several years as a systems and project engineer in the aerospace industry, Steve joined NASA in 2000 as an integration engineer responsible for NASA's scientific robotic missions. In 2003, he was selected as the Mechanical Branch Chief in the Launch Services Program, Kennedy Space Center, Fla.

He joined the Constellation Ground Operations Project Office when it was established in 2005, assigned as the Chief of the Launch Vehicle Division. Steve was responsible for developing launch vehicle ground processing interface requirements and instilling operability into the launch vehicle design. In 2009, he was selected as the Deputy Director of the Ground Operations Project Office.

Steve has received NASA's Exceptional Achievement Medal for his outstanding leadership in the development of the Ares I launch vehicle in addition to numerous group achievement and performance awards.
He has a BS degree in engineering and a MS degree in engineering management from the University of Central Florida.

Chairman BRIDENSTINE. Thank you, Mr. Clarke.

Members are reminded that the Committee rules limit questioning to five minutes. I will now recognize myself for five minutes of questioning.

Dr. Volz, I have heard some of my colleagues suggest that NASA should be in charge of procuring satellites and NOAA should be in charge of operating weather satellites. Clearly, you have a background that include both NASA and NOAA. What are your thoughts on this?

Dr. VOLZ. Mr. Bridenstine, I think specifically NASA and NOAA are working together and in a very productive relationship now. NASA is the development agency for us. They do the satellite systems engineering, the mission systems engineering, the project management of all of our large satellite systems, but in a close partnership relationship with NOAA. So with NOAA being responsible for the program—overall program from the initiation to the requirements to the decisions based on what performance the satellites are expected and need to provide to the implementation of the data products, the analysis, the user community supporting the mission weather projects and all that. So it is—to separate those, the beginning-to-end responsibility of NOAA as the eventual provider of the weather predictions, the weather forecasts from the actual implementation would be generally a very—would be a poor choice to make.

The partnership now does recognize the skills of both agencies, NASA as a very strong research and development organization with systems engineering and mission development experience and NOAA as the weather service, the weather provider, the agency that knows the requirements and has the community outreach and engagement to provide the weather products into the future.

So such a partnership—a change in the partnership would be to—would adversely affect the performance, I think, of our agency, of NOAA's ability to meets its requirements and deliver the services to the Nation.

Chairman BRIDENSTINE. Is it safe to say that if NOAA is responsible for generating the requirements, they should also be in charge of the budget and maybe not NASA? NASA can do the actual technical innovation but NOAA would be responsible for the budget?

Dr. VOLZ. That is fair to say, sir, but when you actually are implementing a satellite program, it is not a question of just setting a set of requirements, handing it over and coming back when the satellite is delivered. The development, as we have seen in these programs, of satellites takes many years and innumerable trades that are made during the design, development and testing phase which may affect the ultimate performance of the satellite. So it is not a simple question of just setting something and waiting for the delivery. There is an iterative process which involves active engagement between the user community that will use the eventual product coming out of it and the implementers, so that is why the partnership as it is written where NASA is at the table with NOAA through all of those major decision points in the development of the satellite is really critical, and yes, the budget should be on the side of the organization that is responsible for the requirements but the management and the execution requires a very close coordination throughout the development process of the system as well.

Chairman BRIDENSTINE. Got it. Thank you.

Mr. Powner, you mentioned in your testimony that yesterday the GAO released its 2015 High Risk Report. JPSS was included on that report as was GOES. In 2013, when you were before this Committee, you suggested that the likelihood of a satellite data gap was ten out of ten. Do you stand by that assessment today?

Mr. POWNER. I still say there is a very high probability of the gap if you go with the best data, and the best data is NPP lasts until October 2016 and you don't launch until March 17 and you have a six month checkout. Now, there have been a lot of discussions about NPP lasting longer, but if you look at NOAA's budget submission for Fiscal Year 2016, they are still showing a one-year gap based on that data.

So we go with the best data that the experts out there have to say, so I still think it is prudent to go with expected life and not bet that it is going to last longer than what the experts are telling us. Now, if there is new news, that would be good to know, but I think you need to plan accordingly or you are kind of playing with fire.

Chairman BRIDENSTINE. I am down to one minute to go.

Dr. Volz, do you have a comment on that?

Dr. VOLZ. Yes. I think the point that Mr. Powner made, that the plans show the mission life design life as the endpoint of a satellite is an appropriate way to manage a program. You manage a program assuming a design life, and you should be prepared for a gap whether it occurs at any point. We could lose a satellite at any point because of orbital debris or other points. You should have contingencies in place to make sure that you can handle such a loss of any asset in space, a functionally redundant or a reliable system overall.

Now, the actual performance of Suomi NPP, which we update every year based on performance, shows that our expectation is it will last much longer than 2016. That doesn't mean we shouldn't prepare for mitigations for potential gap but we don't expect that to happen but that doesn't mean we don't plan for it.

Chairman BRIDENSTINE. Got it. Okay. So I have got 15 seconds. Suomi NPP, you just mentioned, obviously was not built for an operational capacity but a test capacity yet it is operating right now as an operational satellite. If we knew it had operational capabilities, why was it not originally designed to be an operational satellite?

Dr. VOLZ. Suomi NPP was initially intended to be a test bed development demonstration project, was actually called an NPOESS preparatory project before—that was the NPP—and was intended to give an on-orbit performance demonstration of the key NPOESS, which would have been the NPOESS instruments, those five instruments that are on there now. During the redefinition of the NPOESS program, as Mr. Beyer referenced, in 2007 and 2008, Suomi NPP was already in development, the instruments were being built, and it was determined it would be necessary as an operational—to be used operationally even though it was a research satellite. That doesn't mean that all the efforts didn't go into making the instruments as accurate and careful as we could, the spacecraft built to NASA standards as a very high-quality instrument and spacecraft, but it was not intended from its initial inception to be in operation. It was supposed to be a demonstration. It is—we have many examples where research satellites are being used for operational purposes such as the AIRS instrument on MODIS. It is used operationally but it wasn't designed to be an operational asset to begin with.

Chairman BRIDENSTINE. Thank you, Dr. Volz. I now recognize the Ranking Member, Ms. Bonamici, for five minutes.

Ms. BONAMICI. Thank you very much, Mr. Chairman.

Thank you for your testimony and for defining your acronyms, which in the interest of time, I am not going to do.

So I wanted to really zero in on who is responsible for what. As I understand it, NOAA's mitigation activities really fall into two categories: preventing or limiting a gap, and reducing a gap if or when one does occur. So Dr. Volz, Dr. MacDonald, Mr. Murphy, could you really talk about who at NOAA is responsible for coordinating and managing mitigation activities?

Dr. VOLZ. I will take that first and then I will turn it over to my colleagues.

The preparation for and the activities around preventing a gap and mitigating the impact of a gap is a NOAA responsibility. On a regular basis, we report directly up to the Deputy Under Secretary for Operations on a monthly basis. John can talk about the more frequent meetings on the NWS side of the house. So we have—it is a NOAA responsibility but there are elements that are accomplished within the NESDIS organization, my organization, some within Sandy MacDonald's organization, some within John's as well, but we all integratedly in an integrated fashion report up the chain on a regular basis on how all of these different activities are progressing.

So I am responsible on the NESDIS side for extending satellite life, preparing the ground systems for the next generation, making sure JPSS–1 stays on schedule and is delivered on schedule, and I can let John Murphy talk about the NWS side.

Ms. BONAMICI. That would be terrific, and I want to save time for another couple questions.

Mr. MURPHY. Thank you, ma'am. I just want to thank the Congress actually for Sandy supplemental funds that really enabled us to accelerate a lot of development activity that answered the call for mitigation efforts so things like aircraft data, we are now receiving additional aircraft data as a result of those funds. They are flowing into our system. They are being processed. So that is one example.

Getting back to, you know, the responsibility, since the very beginning of discussions of the mitigation activities, the individual line offices—I am the representative for the Weather Service but I have been meeting with my colleagues in the other line offices in NOAA on a weekly basis to discuss the various projects within the line offices and how they complement and work together with each other and execute, and as Dr. Volz said, we report to our AAs on a monthly basis and up to the Director of Operations on a quarterly basis and report to the Hill as well on a quarterly basis.

Ms. BONAMICI. Terrific. I am going to let Dr. MacDonald take a stab at this.

Dr. MACDONALD. Just quickly. The Sandy supplemental allowed us to work on both the assimilation and the models really effectively, so there are some improvements that we are going to see in the relatively near future that I think will really help with the gap.

Ms. BONAMICI. Terrific. And one of the things that Mr. Powner said in his testimony was, one of the approaches is increasing high-performance computing capacity, and it is my understanding that a lot of the work in that area was from the Sandy supplemental. Are there still needs in increasing high-performance computing capacity that can help mitigate any gap? Dr. Volz?

Dr. VOLZ. I would turn that one over to John from the computing side or from Sandy.

Mr. MURPHY. I will take the first stab and let Sandy back me since he has really got the expertise here, but there is always a need for more computing power. Right now we got a real shot in the arm and a big leap in our operational supercomputing and now there is a need to keep balance between the research computing and the operational computing, and so with all the supercomputing we have right now, we are going from 700 teraflops to 500 petaflops, and I know that doesn't mean anything to anybody other than it is a huge jump in capability, and when you look at that five, that five has to be split between the primary system and the backup system if you have true operational computing so that you never have a down time, so that all went on——

Ms. BONAMICI. I don't mean to cut you off but I wanted to get another question in. I just wanted to get some input on that.

So a constituent of mine in Oregon recently contacted my office and brought to my attention that there is a gap in radar coverage along the Oregon coast. So as Dr. Volz noted in his testimony, radar coverage and satellite data combine to make nowcasting of severe weather events possible. So I am concerned about the hole in radar coverage but it is particularly worrisome when considered alongside a gap in satellite coverage. So any gap in GOES coverage, especially an extended one, could have serious consequences for the safety of my constituents and the health of the economy.

So can you please describe what risk factors are most likely to cause a delay in GOES, and is this gap in radar coverage something that we can address?

Dr. VOLZ. From the GOES satellite point of view, I agree with Mr. Powner that the largest single risk for the successful launch of GOES in March of 2016 is the compressed schedule we have right now. All systems, all instruments have been integrated to the spacecraft. The spacecraft subsystems are all together and we are now entering what we call the acceptance test and launch operations phase, which is very compressed. It is a very aggressive schedule, but the team is working hard and is focused on that. So I think that is the largest risk on the flight side of the house.

We have the amount of reserves that are expected and recommended by NASA guidelines, and we follow the NASA standards because they were the ones who built the spacecraft for us, but we think that is definitely the largest watch item.

Do I think it is a significant risk? I would say no, not in the absolute value. I don't think it is going to—it is so large that I am worried about the March 16 launch date but it is our largest risk and is something the team is focusing their efforts and activities on.

Ms. BONAMICI. Thank you, and I yield back. Thank you, Mr. Chairman.

Chairman BRIDENSTINE. Thank you. I would like to recognize Mr. Loudermilk, Chairman of the Oversight Committee, for five minutes.

Mr. LOUDERMILK. Thank you, Mr. Chairman, and thank you to all the witnesses who have come today. This is enlightening, and I know we have got to find ways to go forward that are much better.

Most of what we have talked about today is the possibility of gaps in extreme weather forecasting and the effects it has had on public safety which is our greatest concern, but there is another side of this as well, and that is the effect it could have on the U.S. economy.

In 1997, I personally experienced that when the Hughes satellite, I believe a communications satellite, spun out of control. Being in the IT services business, we ended up spending almost a month helping industries and businesses reposition their satellite dishes to a backup satellite. I saw that that gap in service cost these industries millions of dollars in down time, in lost productivity. Retailers were not able to connect back to their systems.

This is for anyone on the panel, have we done any estimates on what a gap in this data would do to U.S. economy?

Mr. POWNER. I think one of the best examples if you look back at Superstorm Sandy when there was a post-evaluation of that and you took the polar data out of that forecast, it showed—and that forecast was right on. The location, the intensity and the timing forecast was spot on, and it helped move a lot of people to safe areas and save lives. If you take the polar data out of that forecast, it shows that storm dying 100 miles out at sea, so that is the importance of the polar data in terms of predicting severe storms.

Dr. VOLZ. And I think I would add to that, as Mr. Powner just said, it is the community's reaction to the weather forecast that we provide that allows them to mitigate what might be great big cost increases. For example, the recent snowstorm in New York, the responses in the community—the immediate responders can make choices and decisions which can lessen the impact of the storm's effect on all of us.

So the loss of a complete asset, a complete satellite system, would be very significant, devastating, but the responsibility of our organization is to make sure that loss of any particular element doesn't cause that kind of impact, and that is the benefit of generating a resilient system which is single-fault tolerant, as we say. You can lose any asset and still provide the bulk of the return and the needs that we have, and that is the objective of building a more robust global—I mean geo and low-earth orbit system is that we are fault-tolerant. It is not preventing all of them but we are tolerant to failures in any single system so that we don't have those impacts hitting.

Mr. LOUDERMILK. Besides the extreme weather, you know, basically what we were talking about here was Sandy and other issues, there is weather that we don't consider extreme that can have serious consequences on different industries, such as the construction industry. In modern construction, there is a lot of forecasting done because we have just-in-time delivery of materials. You have of course aviation, maritime transportation as well as state and local governments who are preparing like in Atlanta we experienced snowstorms a couple of years ago. What type of impact would we see in the gap on non-extreme weather forecasting?

Mr. MURPHY. I am unaware of actually a study that has done exactly what you are asking, but as Representative Bonamici said earlier, I think it was, you know, the benefit is $31.5 billion, and there is impacts to not only aviation but to many different societal benefit areas of society, and as you lose confidence in those forecasts, you are less likely to make decisions that reap the benefits. So it is sort of a how bad does it get before you can really quantify the impact.

Mr. LOUDERMILK. Thank you. I have one minute left.

From what we are hearing that Europe and other nations are leading us in their models of weather forecasting, and as I think back, the United States of America has always been the leader in space exploration, in satellites, in technology. Is it possible in the next several years that our U.S. forecasting system could be restored to compete with the European model?

Mr. MURPHY. We are closing the gap. It is very close. You know, we are talking about—the way the world measures the performances on a 500-millibar root mean error doesn't mean anything to us on the surface of the Earth, but that is the standard, and we are—you know, what separates us is a few percent, and so we are very close.

Mr. LOUDERMILK. Where would you rank us as compared to other countries?

Mr. MURPHY. I just looked at the statistics the day before yesterday, and we were number three, not to argue with anybody who said we were number four earlier, but it is that close that it changes pretty routinely given a weather scenario.

Mr. LOUDERMILK. Thank you, Mr. Chairman. I yield back.

Chairman BRIDENSTINE. Thank you. I would like to recognize the Ranking Member on the Oversight Committee, Mr. Beyer.

Mr. BEYER. Thank you, Mr. Chairman.

I would like to start with Dr. Volz with a—and others with a small, then a larger question.

On NPP, the prediction now is the end of 2016. NASA said, "There is an increased likelihood of a collision with space debris at the altitudes at which the JPSS satellites fly." They also talked about NOAA having a rosy view of how long the NPP will last. It is just debris that we are concerned about with the end of NPP?

And then the larger question, especially that Chairman Bridenstine talked earlier about the many different commercial companies getting into launching satellites, what are we going to do about space debris in the larger picture?

Dr. VOLZ. Well, related specifically to NPP, I think we are dealing with a communications here and the way that we analyze the expected life, and as Mr. Powner and the GAO have done is they used the design life in their analyses, which is appropriate because that is the way we set up the initial system. Now, as the expected on-orbit life is much longer typically than the design life, once you get into orbit and you see you don't have infant mortalities, the term we call for satellites that die earlier because of something that was built in. Once you get past that, the design life is routinely much longer. So I would not say they expected the lifetime of Suomi NPP will end in 2016. Our analyses show that it is likely to go well past 2020. That doesn't mean it is going to be relied—that we should count on that and then sit back and wait and we don't have to launch anything because we have got ten years or five years. But we do use very careful analysis on on-orbit performance of our satellites and our measurements and the instruments to do accurate and continuous updates on the performance of those satellites.

Regarding the orbital debris, it is a common problem. All satellites in orbit are dealing with the increase in orbital debris. Every time you have a collision, you create more debris. It is something we watch. It is something we monitor. Our spacecraft are monitored daily and operate. We have maneuverable satellites so we move them out of the way when we see orbital debris projections, conjunction analysis, we say, and we have done that in increasing frequency over the last few years as the debris clouds have increased but it is still a very—it is a very diffuse cloud, and we move maybe a dozen times a year to get out of projected debris. We have not been impacted by it—pardon the pun—but we are aware of it, we are monitoring it, and we take active steps to prevent it. Now, as far as orbital debris, removing the debris from space, I don't—I would yield to my NASA colleague here, who probably will not like that but——

Mr. CLARKE. Can I defer back?

Mr. BEYER. Well, let me move on to Dr. MacDonald then.

Mr. CLARKE. Okay.

Mr. BEYER. The data validation, in the literature here that you gave us, you said it took two years to validate the data from NPP, and when you look at the charts on the overlap and the potential gaps, some of that, as I read, is six months to validate the data from some of these new satellites. Why does it take that long when we have so much data validation in the past?

Dr. MACDONALD. Actually, I think that we can go faster, partly because we do have a lot of experience with these sensors like ATMS and CRiS and so on, so we have—with our Joint Center and with our OAR research colleagues, we think we can do better.

Mr. BEYER. Dr. Volz, the Chairman in his opening statement talked about turning to commercial space operations. Does NOAA have any concerns about the use of commercial data to fulfill the requirements of its polar satellite program?

Dr. VOLZ. Regarding the question of commercial space, commercial sources of space data and satellite data, we think that is probably a very capable and open field into the future. We have our backbone system that has been built, I mean, using for many, many years, but the capabilities of the commercial side over the past few years and looking forward in the future are likely to be very significant and are definitely worth evaluating and using.

What we do from the NOAA—what we need to assure from the NOAA side is the data that we get meets certain quality standards, they are accurate, reliable, traceable, and can be validated so that when we use these data in our numerical weather models, we get outputs which we trust. We can't just take the data because you can get bad outputs which could be even worse than no input, than no output. So it is the essential nature of us as NOAA and the NWS, NESDIS needs to make sure that the data that we get are accurate and can be used in the modeling, and we think—and I think looking to the future, we will be using—we will be evaluating and there is a good probability we will be using some commercial data as long as it meets our quality criteria and is consistent with our collaboration approaches of open data to be used with our partners.

Mr. BEYER. And Mr. Clarke, I was initially disappointed that the climate sensors were eliminated from the satellites, you know, the perfect being the enemy of the good enough, but now I read that the Radiation Budget Instrument (RBI) and the Ozone Mapping and Profiler Suites are going to be on the JPSS–2. Can you talk about the current status of these instruments and do you anticipate they will be ready in time to fly with JPSS–2?

Mr. CLARKE. Yes, Mr. Beyer. Those instruments are being developed now. They are in the assembly and initial part of testing, and so those instruments are on schedule to support the JPSS–2 spacecraft. Keep in mind, I think I mentioned in my opening remarks too, CERES is kind of the precursor to RBI, and so those instruments are all set and ready to go and they are installed on JPSS–1. So this is really a continuation from JPSS–1 to build continuity between 1 and 2.

Dr. VOLZ. And if I could comment too, it is another example where the research bases of NASA and the operational bases of NOAA work well together. We provide the platform, JPSS–1 and J–2, and we are—all the operational instruments that we need for the weather forecasting are built into it, but the platform was also designed in Suomi NPP to accommodate the Radiation Budget Instrument, and NASA as the research and development agency took the responsibility of that one. They build that, they meet our specifications, and together we fly on the same platform for a much more efficient approach to making the measurements.

Chairman BRIDENSTINE. Thank you. The gentleman yields back. I recognize the gentleman from Colorado for five minutes——

Mr. PERLMUTTER. She was here first and has a higher rank.

Chairman BRIDENSTINE. The gentlelady from Maryland is recognized for five minutes.

Ms. EDWARDS. Thank you. I have waited six years on this Committee to hear that, and I want to thank our witnesses and obviously our Chairpersons and Ranking Members.

You know, I remember when I first came on to the Committee that it was in the throes, I guess the summer of—I don't know—2008, and it was at a time when there was great consternation about the satellite programs, the management of those, the relationship between NASA and NOAA and DoD, and I think that we have come—we heard from GAO at that time and I think we have come a long way since then, and so I really wanted to be able to salute NASA and NOAA for, you know, after some period of time in fits and starts figuring out the working relationship using the best capabilities of NASA and NOAA to make sure that we could try to get this program back on track.

As the GAO has indicated, you know, we still have some challenges obviously and possibilities for gaps in coverage, and so that remains a concern for the Committee in addition to the predicted cost. I think we started out with the idea that we were going to have six satellites. Now we are at two. And so this has been a really difficult thing.

I want to also acknowledge that today in our audience are a group of students from the University of Maryland in College Park, which is the home to NOAA's Center for Weather and Climate Prediction. The home for NOAA is actually in Suitland, Maryland, right down the street from my office. I spent a lot of time there. I think I did go to observe the NPP launch, and thankfully, rather than just being an experimental platform, it is usable and operational, because I think that helps in the consideration of this discussion.

I guess the question I have actually has to do with the gaps in coverage, and I understand, you know, the imprecision with which one can predict whether there is going to be a gap or not, but I wonder, Dr. Volz, if you could respond to the idea that—of what NOAA's current gap assessment is, and it is also my understanding that NOAA is estimating a longer life expectancy for NPP than before because of its strong performance to date and, you know, so what is your anticipation of the operational period for NPP and what activities are being undertaken to ensure NPP's longevity?

Dr. VOLZ. So thank you, ma'am, for the question. The NPP satellite, as I mentioned earlier, is monitored on a regular basis and we update its performance projections every year. The most recent one shows that we are still operating all primary systems on NPP. All the instruments are functioning well and within specification, some changes, as we note, as you normally do with instruments but the projection is the satellite, barring something we haven't seen, is likely to survive and work past 2020.

As far as the steps we are taking to make sure that that satellite continues to work, we are very carefully looking at all operations that might have life-limiting features on it, which is whether is an instrument operation mode that may burn out degrade the performance over time faster, but with the focus then on making sure that ensuring that the satellite is operating effectively for a long time.

Ms. EDWARDS. And so in hearing that, I mean, if I look at the various scenarios, and I understand the chart that we have has been updated since then, but that would mean that we are falling more in the range of, you know, a scenario one than we are in a scenario three where there would potentially be a much wider gap in coverage if we are making some predictions that NPP has greater lifespan and capacity than we might have thought originally. Is that right?

Dr. VOLZ. I believe that is true. Mr. Powner can comment. I think the point of those scenarios is not “we think, this is going to fail here,” but if it were to fail, what would the gap be, and I think that is the point of preparing for a gap is not that we are trying to project a failure of any individual asset, but if an asset fails at a particular time, what is the impact on the overall constellation, and that is the planning challenge that we have in front of us to make sure that under these different scenarios, which are single fault—one thing can take out a satellite or a launch that JPSS–1, a launch failure could take out a satellite—what is our response to that and how do we mitigate the impact if that were to occur. It doesn’t mean we expect it but it means we have to prepare for it.

Ms. EDWARDS. Thanks, and just in closing, I just want to share with the Chairman and Ranking Members, it is my understanding that in the President’s budget proposal, there is an absolute recognition that we are actually now, with respect to these satellites, really not focused on the development of climate sensors but really focused on weather, and I think that that also represents a change in strategy and direction over the last several years, and with that, I yield.

Chairman BRIDENSTINE. The gentlelady yields back. Without objection, I would like to recognize the gentleman from Colorado.

Mr. PERLMUTTER. Thank you, Mr. Chairman and Ranking Member Bonamici. Thank you for letting me participate today. This is my first of the Science hearings. I sit on the Energy and the Space Committees. I am not on this Committee, but this is of great interest to me.

Like Representative Edwards, I sat on the Rules Committee at the time we were going through the NPOESS saga, and you know, from 2007, 2008, 2009 and 2010, there was a real question how NASA and NOAA were going to work with the Defense Department and how we were going to go forward, and that slowed things down. There is no ifs, ands or buts about it. That is history. We have got to focus on the future. And I appreciate the GAO for identifying and focusing on this subject because one of my quirks is my favorite channel is the Weather Channel, and that is pretty sick actually.

But Mr. Loudermilk hit on a point that is so important in discussing this subject. There is a public safety aspect to this and there is an economic aspect to the services you all provide, and the potential for a gap here, I think may have come from the Bush Administration, the Obama Administration and Congress but we have got to deal with that. We cannot allow for gaps to grow or we need to shrink these things.

And so I would start with you, Mr. Powner. What is the best way as you have analyzed this to deal with this gap and to shrink it if possible?

Mr. POWNER. Well, hopefully NPP does last longer, and we are all hopeful that is the case. What is in your control is the March 17th launch date of J–1. That cannot slip. So we have ATMS as the long pole in the tent and it keeps slipping, and the more that slips, the March 17 launch date will be in jeopardy, and I am not here saying the sky is falling, but the other thing on the October 2016 date—and I keep hearing other dates that it is going to last longer. I would like to see it in writing. There was a NASA assessment that it was going to last three to five years. There is supposed to be a gap assessment from 2014. It hasn't been released yet. The budget still says one year. So if it is 2020, let us put it in writing and say that is where we think it is at.

We have been at this for a long time, Congressman Perlmutter, and the way some sensors were constructed on NPP concerns us, and I think that is why the NASA engineers had the three- to five-year time frame, VIIRS in particular. VIIRS was the—that was a very difficult sensor during the NPOESS days, and there were a lot of shortcuts taken when they constructed VIIRS and put it on NPP. We know that. I visited Raytheon multiple times out in California, and I hear from their engineers about that.

So there are still concerns about that, and I am not here to, you know, say that it is not going to be 2020, but we need to be aware of the facts, and then when we mitigate the gap, we went out and talked to experts including Dr. MacDonald sitting on this panel, and there we identified 40 mitigation alternatives. NOAA's plans have 21 mitigation alternatives. There are four areas that you actually improve the forecast much greater than others. We would like to see a prioritization on those mitigation activities so that we are addressing the most important things as part of the contingency plans.

Mr. PERLMUTTER. All right. So I guess—I appreciate that, and I would ask that we take those mitigation factors and really, you know, exercise them, use them to the best of our advantage.

I think part of where I am coming from is, you know, there was a leadership issue back in the NPOESS days, and I would say to my friends on the Republican side of the aisle—and we take responsibility too—we are coming into a better economy and I would want us to assist you all in budgetary ways so that you can accelerate this so we are—so that we do meet that first launch date, that we can accelerate JPSS–2, that we are moving forward. We—things got stalled, then we had a bad economy, and we have got to get back on track because the potential loss of life and the potential to the economy by missing some of these things is too big.

And so Dr. MacDonald, since we are both Coloradans, I want to give you an opportunity to say whatever it is you want to say, and I will turn the floor over to you.

Dr. MACDONALD. My comment would be as Mr. Powner just said, we are really working hard on many, many ways of improving things, a lot of it because of the Sandy supplemental funding, so I think there has been a positive that has come out of this, and we are excited to see some improvements from those efforts.

Mr. PERLMUTTER. Thank you. Thank you, Mr. Chairman. Thank you for the opportunity to sit today.

Chairman BRIDENSTINE. You bet. The gentleman yields back. We will go into a second round of questions, and you identified ATMS as the critical path for JPSS, and my question is, ATMS is on NPP, correct? Did the requirements change between NPP and JPSS for ATMS?

Dr. VOLZ. No, sir. The requirements did not change. As Mr. Powner—as we said, Suomi NPP was built as a preparatory program under one set of—there was a—one set of contractual arrangements with the vendors. The requirements that NOAA has have not changed. The implementation has—some of the—you often find problems in the development of an instrument, the repeat of processes, et cetera, which may led to a slight change in the implementation and that has led to significant challenges in the ATMS development.

Chairman BRIDENSTINE. Okay. I want to talk about some of the mitigation efforts. The GAO report indicated that one of the best ways that we can mitigate the gap, especially as it relates to the polar satellites, would be GPS–RO, radio occultation from GPS satellites.

My question is, how significant is GPS–RO to the numerical weather models that help us forecast weather? Dr. Volz, I will let you answer that question.

Dr. VOLZ. I will turn that over to John.

Mr. MURPHY. Without a doubt, it is in the top 10. All the studies around the world show that depending on which one you look at, it is number four, five or six. So it is very significant. Radio occultation falls right behind the microwave and IR sounders.

Chairman BRIDENSTINE. And correct me if I am wrong, but the COSMIC–2 program, which is a joint program between the United States and Taiwan, is fully funded for the first six satellites of the COSMIC–2 program. Is that correct?

Dr. VOLZ. That is correct.

Chairman BRIDENSTINE. And how many radio occultations per day would we get from a COSMIC–2 program?

Dr. VOLZ. The COSMIC–2 in whole is 12 satellites, two sets of six, and from a combined set of those 12 you end up on the order of 10,000 occultations a day.

Chairman BRIDENSTINE. And the first six, though, are set to launch by when?

Dr. VOLZ. Next spring, 2016.

Chairman BRIDENSTINE. And how many would we get from those first six?

Dr. VOLZ. About half of that.

Chairman BRIDENSTINE. So 5,000 radio occultations per day?

Dr. VOLZ. Correct.

Chairman BRIDENSTINE. And then as far as what the private sector could provide or augment, is there a limitation on how many radio occultations per day would—at what point do you get diminishing marginal returns from every additional radio occultation?

Dr. VOLZ. It is a unique measurement type which that saturation point is really high. We have looked at studies which go 50,000, 100,000 a day, and there is a rollover but it is not significant. So certainly we are potentially scratching the surface of the value you can get from radio occultations with the 10,000 per day.

Chairman BRIDENSTINE. The Europeans are at 128,000 and they haven't reached saturation. So let us say the private sector commercial satellites, if they were being launched right now, and of course we have got the challenges with testing and validation and calibration and all those things that go into feeding the numerical weather models, if they were able to provide that capability, that would in essence help us augment the data going into the numerical weather models, for example, to predict thunderstorms in my State of Oklahoma. Is that correct?

Dr. VOLZ. That is correct, sir.

Chairman BRIDENSTINE. Right now we don't have an identified limitation on the number of radio occultations. When you said it was in the top 10, if you had, say, maybe 100,000 or a couple hundred thousand radio occultations, would that move it up to maybe number two or number three, or is that a stretch?

Mr. MURPHY. Yes, I think it would come up. That is an interesting aspect that the more you get in—I think we know that 5,000 or 10,000, you get a big improvement and it just goes right on, 20,000 or 30,000, so it would help.

Chairman BRIDENSTINE. So is it safe to say that if there is a gap, that the GAO report is indicating might be more likely than some others might suggest? If the gap does occur and the private sector has the capacity to launch satellites into space that could produce 40,000 or 50,000, is NOAA open to the idea—if those data could be validated and calibrated and fed into the numerical weather model, would NOAA be open to the idea of maybe purchasing that data from the private sector?

Dr. VOLZ. We have been in active communication with a number of the vendors who are proposing to launch and fly these satellites for us, and yes, we have been in agreement that these data could be useful and we would be open to using them as soon as—as long as they meet, as we talked about, the criteria for reliability, dependability and accuracy. So I have had meetings with all of those companies you mentioned up front, and actually we have a planned workshop at the end of April this year to sit down and show how we do our requirements and how they can match their developmental processes to work well with us.

Chairman BRIDENSTINE. And real quick, I am almost out of time, Dr. MacDonald, this might be a question for you. When you talk about hyperspectral and now that is not going to be available on the GOES satellites, how does that impact the weather data models for our Nation?

Dr. MACDONALD. I think hyperspectral is another sensor that has a lot of potential and we are trying to study that with various techniques.

Chairman BRIDENSTINE. We currently have hyperspectral on NPSS, right? Or no, we don't. Do we have hyperspectral in space right now?

Dr. MACDONALD. Yeah, we have interferometers that give us indication of what you can get from a polar orbiter but there is also a geostationary issue that we are trying to learn about.

Dr. VOLZ. That sensor was originally on GOES. It was called HESS, and it was dropped.

Chairman BRIDENSTINE. Okay. And is there—I am out of time, so I am going to turn it over to the Ranking Member for five minutes, but thank you for your testimony.

Ms. BONAMICI. Thank you, Mr. Chairman.

We had some good conversations about how potential gap would affect safety, the economy. I want to talk about how it would affect research.

Dr. MacDonald, can you talk about the importance of satellite data to NOAA's research, comment on the impact that a gap in polar data would have on weather and climate research efforts, and then Mr. Clarke, can you talk about the use of polar satellite data by NASA scientists and what would a lack of continuity—what effect would that have on NASA research?

Dr. MACDONALD. Thank you, Representative Bonamici. It does—we really do depend on the polar orbiters and the satellite sensors. It is our whole Earth look, and with time, we used to—when I started my career, we had little models over little areas and now we can do the whole Earth. So these sensors you have already heard so much about, the interferometers, the microwave. They really are the future, and I think forecasts are going to improve because of it.

So we use one. That is a difficult thing. One area that is important is that we use these for also records of how the—what is happening in climate, so we have lots of in situ sensors and lots of satellites. We try and make up by using continuity from those.

Ms. BONAMICI. Thank you. Mr. Clarke.

Mr. CLARKE. Yes. Thank you. The NASA Earth research community, certainly we collaborate with NOAA and other agencies to be able to obtain data from all types of sources. NASA has plenty of Earth-observing assets on orbit gathering, that kind of information, but it is always good to have additional data to help correlate. So there would be some impact of not getting that data, but we do have other assets to rely on, and if we wanted to get into more detail, I could take the question for the record and then talk with my Earth science colleagues in NASA and provide you more detail.

Ms. BONAMICI. Thank you. I would appreciate that.

Dr. Volz, Mr. Powner talked—expressed some concern, frankly, about the testing schedule for GOES–R. There is some concern that compressing the test schedule increases risks of further delays, there would be little time to resolve any issues that arise. So how long can the GOES program operate on a 24/7 testing schedule, and is there some risk of delaying the launch by operating at sort of an intensive schedule and what are the alternatives, I guess.

Dr. VOLZ. I believe the current plan for the GOES–R is to continue the three-shift operation through maybe the end of March, early April this year at which point we will be getting into the system-level testing, thermal vacuum testing where you are working around the clock anyway. There is no definitive point that at this point it becomes dangerous to go on with three shifts. We have a very capable contractor with Lockheed Martin, who has a lot of resources, so there is no—and like I said, no point where that would be an issue. But I think the launch schedule, however, is still of critical concern, and having—it is a single-point flow for these, and if problems arise, we will have to deal with it with the reserves that we have. We do still have a number of several weeks of unscheduled reserve, which for the purposes of that, which is typical that you see for a project at this point in development schedule.

Ms. BONAMICI. Thank you. And finally, I was curious about the difference between the number of mitigation alternatives. Mr. Powner talked about approximately 40 and NOAA talked about a little more than 20. So what explains the difference, and how are you coordinating to determine which mitigation alternatives rise to the top in terms of priority?

Dr. VOLZ. That is a good question, and I don't have a list of 40 or 20 or the average of those in front of me, and I would be happy to sit down with Mr. Powner and with my team afterwards to reconcile so we don't have that—I don't think we are disagreeing on the things that we need to do but in terms of how we numerate I think is maybe confusing, and I don't have an answer for you. I would be happy to work with him to clear that up.

Ms. BONAMICI. Terrific. I appreciate that. And I yield back the balance of my time. Thank you, Mr. Chairman.

Chairman BRIDENSTINE. Thank you so much. I yield five minutes to the Chairman of the Oversight Subcommittee, Mr. Loudermilk.

Mr. LOUDERMILK. Thank you, Mr. Chairman.

We have talked a lot about lessons learned and going forward, and our focus has been on getting this launch on schedule. But my question, Dr. Volz, is, have we started planning, has NOAA started planning on the next generation of weather satellites?

Dr. VOLZ. Yes, sir, we have, and it takes a long time to bring a new system online, which is part of the reason we are having difficulties over the past with both the GOES and the JPSS programs. Both programs were significant steps up in technology from the legacy missions that preceded those, so we recognize that you don't start five years before; you start ten and twelve years before. And part of our planning right now is doing the architecture studies and the analyses of what measurements we need in the 2030 time frame, what the capabilities are now and projected to be in the next few years, and we have been doing those for the last year and we expect to do those in the coming year, for the next two or three years so that in about two to three years we can lay out a plan which specifically identifies the next generation including, as we mentioned earlier, the changes in the—the landscape of commercial sources, launch vehicles and data-processing capabilities, which are all part of the next generation. We are starting the analysis now.

Mr. LOUDERMILK. What changes, if any, have you made to avoid the issues that we have faced with the cost overruns, gaps, future delays? What kind of changes have you made?

Dr. VOLZ. I think one of the major elements from my perspective is a rationalization of the requirements and the capabilities, and a critical part of doing the architecture up front is not to start with a shopping list of too many requirements and then figure out how much it costs but to do that in an iterative real-time process, look at the requirements, look at the implementation costs.

The other part, which was mentioned in Mr. Bridenstine's first question about the relationship between the partners doing the implementation is absolutely critical, so the NPOESS history was, it was—there was a difficult relationship between the three agencies, which almost guaranteed you would have a problem between requirements and application and implementation, and making sure that you have the right sharing of responsibilities and very clear delineation of responsibilities is essential as you go forward with the planning and going forward.

Mr. LOUDERMILK. Thank you. I want to shift back to our current subject that we are on, and it is the launch of this satellite. We have mentioned mitigation alternatives. Has NOAA done a cost-benefit analysis to determine which ones are likely to be most effective and worthy of investment?

Dr. VOLZ. We are investing in the ones that we think are the highest probability. I can't point to a specific cost-benefit analysis by individual elements but the ones we are extending the lifetime of Suomi NPP, enhancing the data process and capabilities with the supercomputing capabilities and advocating and moving forward with the radio occultation measurements are examples of places where we think there is the most return on investment and the capability, availability of the technical capability to go forward.

Mr. LOUDERMILK. Mr. Powner, do you have any thoughts on this?

Mr. POWNER. Yeah, this is at the heart of some of our recommendations. Not only do you want to focus on the priority mitigation activities but you want to focus on the cost, so there was a huge discussion here about use of commercial data. Commercial data could really help augment our forecast today but what is the cost? So you have to factor in costs on all these mitigation activities. It is, what is the benefit and what is the cost and then you weigh those two, and that is what you end up pursuing. We would like to see more of that going forward.

Mr. LOUDERMILK. Thank you. One last question. Does NOAA have any statutory limitations which would allow you to procure weather data from private space-based observing systems?

Dr. VOLZ. I don't know of any, sir, but I have been with NOAA for three months, so I can imagine there are people behind me who are saying don't answer that question until you are clear, so I will be happy to take that. I don't believe there are but I will take that for the record and get back to you.

Mr. LOUDERMILK. Okay. I would appreciate it. I yield back.

Chairman BRIDENSTINE. I would like to thank the gentleman, and I would like to recognize the Ranking Member of the Subcommittee on Oversight, Mr. Beyer.

Mr. BEYER. Thank you, Mr. Chairman.

Dr. Volz, when this hearing started at 10 o'clock, my biggest concern was about the gap in the weather prediction from three months to eighteen months, but listening to the testimony, it seems that NOAA's expectation of the NPP satellite could well go to 2020 and beyond. Is there any reason not to follow up on Mr. Powner's suggestion that NOAA actually put these expectations in writing? And does that then change the mitigation plans that we would otherwise make?

Dr. VOLZ. To the first question, no, I think if we haven't—I have seen a draft report on the updated prediction and reliability of Suomi NPP, and I don't see any reason why that shouldn't be public. I think we will—and I wrote a note down when Mr. Powner was saying that that says let us get this written down and get it released. I think it to everybody's interest to see that.

As far as the second, I don't think it is going to change our approach. Knowing or believing that the satellite will last longer than the worst-case scenario doesn't mean the worst-case scenario might still occur, and we need to do the mitigation activities in any case so that we have a resilient system that is accommodatable to major failures which can occur outside of our best estimates.

Mr. BEYER. And Dr. Volz, the President's budget request includes $380 million for a polar follow-on program in order to achieve robustness in the polar weather constellation. Can you please describe the kinds of activities that you would take on as part of this polar follow-on request and how they would actually improve robustness?

Dr. VOLZ. Yes, sir. Thank you. The polar follow-on is—the current program of record, which is JPSS, is two satellites, as we have identified, one launching in 2017 and the next scheduled to launch in 2021 which, by the way, was accelerated per additional funding to bring that in a few months so it is a quicker return. But a robust program requires that you have redundant or a capable system up there in case of a single-point failure. The polar follow-on establishes the baseline to deliver the next two, JPPS–3 and JPPS–4, along the same lines using the same vendors, the same demonstrated and proven instruments and approaches so that we can have that ready as soon as—in the event of a JPSS–2 failure on launch, just like we talked about J–1. So the same logic applies in the extension.

What it also does by starting it in 2017 or 2016, as requested in the President's budget, it allows us to buy those instruments now from the instrument vendors and most of our funds go to the industry because the U.S. industry builds these instruments for us, allows those instruments to get under contract while we have the production line, the expertise and the intelligence of the community there to build those instruments effectively and efficiently. Having those JPSS–3 instruments built and ready during the late part of this decade is a natural mitigation for if I have a problem with a JPPS–2 instrument so I can switch and plug in and I can switch out, and that also accelerates or provides more reliable delivery of the J–2 satellite. So having this suite allows you then to ensure that you have the regular cadence of missions available when you do.

Mr. BEYER. And Mr. Clarke, you had kindly deferred when Dr. Volz had tossed you the space debris question. Please tell me that someone at NASA is thinking big picture about vacuuming up the space debris and what is going to look like in the years to come.

Mr. CLARKE. Well, I would have to take that for the record for the future plans. That may be discussed in other areas within NASA that I am not privy to, but I can take that for the record.

I will tell you, though, that for all of our spacecraft that are in development now, we do look at those on a case-by-case basis based on the updated probability in these orbital debris models. We also look at the probability and where these spacecraft are going, and implement changes if we need to protect in certain areas on these spacecraft during development. So NASA is just as concerned with on-orbit debris and so we continue to look at it.

Mr. BEYER. Thank you very much. Mr. Chair, I yield back.

Chairman BRIDENSTINE. Thank you so much. I would like to recognize, without objection, the gentlelady from Maryland, Ms. Edwards.

Ms. EDWARDS. You are so kind, Mr. Chairman. Thank you very much.

I wanted to get back to the ATMS issues, and I wanted to hear from Mr. Clarke, because there were some comments about ATMS being on a critical path, and I am wondering what your, you know, take is on the status of ATMS, and I am a little bit curious that if ATMS is integrated in NPP and we are not—maybe we have seen some of the problems that we are, you know, experiencing with JPSS development, but if that is true, is it an integration problem with JPSS rather than an instrument problem? And give us an idea of the kinds of things that you are concerned about there.

Mr. CLARKE. Well, ATMS is a complex instrument just like the rest of the instruments that are part of that suite, and the one that is operating on NPP is doing well, but again, these are complex instruments. They don't—I don't want to—how do I put—they don't come off a production line like many end items. They are not stamped copies, so to speak. They are very detailed, intricate instruments, and the ATMS that we are working on now was manufactured in the early part of that NPOESS phase and then turned over as part of the hardware afterwards, and so we have found issues with that particular when we started going through testing, and due to the complexity, we are working through those challenges. It is not unlike other development programs where we have had very complex instruments and we have had to go in and resolve issues.

The benefit of this, particularly the JPSS program, with these instruments, we have been able to work through how to integrate those instruments and when, and to preserve the schedule for JPSS, and that is what we have done. We have worked with our contractors and with NOAA and looked at mitigation options of how to keep that on track, the overall spacecraft project, which we have done, while we are working through the ATMS issues, and we feel like we are beginning to get a handle on the issues with ATMS, and I feel confident we are going to resolve those problems. But it is not unlike other programs where we may have one particular area experience a challenge or an issue, and we will work through it and find ways to continue to stay on track with the schedule like we are doing now.

Ms. EDWARDS. Thank you very much, because I didn't want us to leave here just thinking while you have got, you know, ATMS, NPP, just plop it up and, you know, set it into JPSS and so what is the problem, and so I appreciate your comments, and with that, I yield the balance of my time.

Chairman BRIDENSTINE. The gentlelady yields back. We will go into a final—or actually the gentleman from Colorado is back. You are recognized for five minutes.

Mr. PERLMUTTER. Thanks, Mr. Chair.

Just as a beginning to this, a prelude, you mentioned, Dr. Volz, about a suite, you know, sort of assembly, production. I think, Mr. Clarke, you talked about production lines. Some of these things are very intricate but some things can be built sort of not in an assembly-line mode but certainly you can prepare and you can have teams of contractors in place.

So first question I have for you, Dr. Volz, is, if by some circumstances the Congress were to appropriate more money to try to accelerate and to have an assembly line of one, two, three and four, can NOAA absorb that. Can NOAA deal with that? Can we acceleration the production schedule and the launch schedule?

Dr. VOLZ. Okay. That is a very good question, and I think the nature of block buys, is often the term used. If you buy a bunch of them at once, do you get some efficiencies and economies and a better-performing system? And in fact, that is the reason for the polar follow-on proposal in the Fiscal Year 2016 budget, which allows us to buy the third and fourth variations of these instruments as contract options with the same vendors so they can do exactly that. They can optimize the development schedule so the subsystems are integrated and brought forward on a regular and reliable place.

Now, the question of accelerating is a different challenge because some of these things are process-intensive and it takes, you know, a few weeks for this, a few weeks for that, so adding more money——

Mr. PERLMUTTER. And I appreciate that. I am just a lawyer. You guys are the scientists, you are the engineers, you are the technicians. But I guess I come from a spot where, you know, President Kennedy said we are going to be on the moon, you know, nine, ten years from now, and everybody going wow, how in the heck are we going to do it. You guys all figured it out. So I don't doubt that if we want to send somebody to Mars we can get going on it. If we want to get these satellites built, you can do it. We need to provide you with the resources obviously, and you know, I am going to be pushing for that kind of thing.

Mr. Powner, are the teams in place? I mean, because of the upheaval and kind of the delays here and there between NPOESS and JPSS and to a degree GOES. Are the teams in place if we wanted to move this thing forward? Do we have the vendors? Do we have—you know, somebody mentioned Lockheed or Ball or whomever. Do we have those vendors in place?

Mr. POWNER. Yeah, we currently have vendors in place. We have a very solid team on the government side. I think the collaboration between NASA and NOAA far better than we have ever seen, nothing like we had on NPOESS.

I do think you have raised a really key question, though, about building clones down the road when you start looking at J–3 and J–4. There is a fundamental question about how much do we advance the sensors and improve versus just building a clone and continuing the status quo, and I think that is a tough call, especially when you start looking at continuity of operations, but that is why this follow-on program is so important.

Mr. PERLMUTTER. Dr. MacDonald, do you have anything to add, since you are from Colorado?

Dr. MACDONALD. No, but thank you for asking.

Mr. PERLMUTTER. I yield back, Mr. Chair. Thank you very much.

Chairman BRIDENSTINE. Thank you. Anybody from Oklahoma, by the way?

Mr. CLARKE. Does my spouse's family count?

Chairman BRIDENSTINE. You are my preferred testifier.

Mr. CLARKE. Thank you, and she thanks you.

Chairman BRIDENSTINE. So we will go into a final round here without objection, and I will recognize myself for five minutes.

I was just reading your testimony, Dr. Volz, and you indicate that currently NOAA purchases data from the commercial sector such as ground-based lightning data and space-based synthetic aperture radar data. Is this true, and in what quantities and how much do we spend on that as an organization, if you know offhand?

Dr. VOLZ. I don't know the dollar value. We can get that to you, and I am happy to do that.

As far as how it is used, the synthetic aperture radar data is a key element of our ice mapping and Arctic forecast measurements that are done with our National Ice Center combined with VIIRS Day/Night Band imagery. The local lightning data is used by the National Weather Service. I don't know again the cost for that but it is a regular input, and John Murphy may want to address that in more specific detail.

Chairman BRIDENSTINE. And just as an example, if we were to have a model where we were to purchase data from the private sector whether it is GPS–RO or hyperspectral, would these models be good ways to go that we are already doing it? Could we not do it in other space-related activities?

Dr. VOLZ. I think as far as the actual getting under contract, they would work fine. The distinction that I would make between these particular examples and some of the GPS–RO and our global modeling examples is, when we take data and use it as part of our global numerical weather prediction models, we are also—we are ingesting along with data from European satellites, the Japanese satellites and our other partners. We have a longstanding relationship with all of our partners who share these models that we all share each other's data, and that makes all of our models better and makes all of our predictions more accurate, and it is the best environment for this collaborative engagement.

If we were to purchase data, we would bring that into that environment so we want to make sure that the data are readily transferrable and usable by all of our partners, and that is one of the key elements, that it is free and open data as far as our numerical weather predictions, and I don't think for local data around an airport or something like that, that is not an issue for that because we don't share that. It is not of interest to our international partners.

Chairman BRIDENSTINE. Okay. So the SAR—but the SAR data would not be local, right?

Dr. VOLZ. SAR data is an agreement with Canada, the Canadian government and their satellite data system there, and it is for—it is a mutual benefit. Both Canada and the United States are using those data, and we share the outputs both in Alaska and the Arctic, and I believe in the Great Lakes region as well, again, on a collaborative basis with—it still is local but it is local across a particular boundary with a specific agreement.

Chairman BRIDENSTINE. And the lightning data is what you would suggest is probably more localized data——

Dr. VOLZ. Yes.

Chairman BRIDENSTINE. —that our international partners are not interested in?

Dr. VOLZ. Correct, sir, and John, if you want to add?

Mr. MURPHY. Just add that we procure mesonet data, lightning data, aircraft data. We are in the process of exploring other data sources, data buys, and as Dr. Volz said, typically the providers don't want to share their data openly but it is a local—more of a local effect.

Chairman BRIDENSTINE. Got it. I saw in the President's budget request there is $380 million for the JPSS follow-on, and I want to be really clear, I support JPSS, I support GOES. I come from Oklahoma. We have thunderstorms and tornados where, you know, in May of 2013 we had 24 of the folks from my state get killed, $2 billion worth of damage. It was a big, big deal, and of course, that is why I took such an interest in this to begin with. So I don't want to see anything happen to JPSS or the GOES programs that feed our numerical weather models. I want to be really clear about that.

But I think we need to move to a day where we have a different kind of space-based architecture that is resilient, that is disaggregated. I know we have been talking about NPP. It was launched as a test satellite, and I know it came from the NPOESS program, but it is not shielded, and because of that, it is susceptible to the space debris that we have had conversations about here. But if we were to disaggregate and move to a different kind of space-based model where we took advantage of commercial technologies that could be launched, I think we could move to a day—and we have done it in the Department of Defense as it relates to communications. We have done it in the Department of Defense as it relates to imagery and other kinds of remote sensing. If we could go that direction on the weather side of things, I think we would have more resilience, we would mitigate data gaps, and we could move to a day where we move from JPSS–2 to JPSS–3.

Maybe we are not having a hearing about a gap that is coming and instead we are saying okay, we have got everything we need, how do we focus NOAA on doing the things that the private sector cannot do, and I think that is the direction ultimately where we can go, and the private sector, of course, my opinion is, you will get greater innovation, lower cost, more competition, all these kind of benefits that we have seen NASA take advantage of as well.

So I guess my ultimate question is, when you think about that $380 million from the President's budget request, is there any openness to maybe using a portion of that money to create a pilot approach where we could purchase from the private sector data for NOAA rather than focusing on, you know, buying another—and again, JPSS–3, if it is necessary, I am all for it, but I want to be clear, if there is an opportunity to take a portion of that money and use it to purchase data from the private sector, is that something that you are open to?

Dr. VOLZ. Well, sir, I think you identified the—the targeted funds in the polar follow-on are really essential to getting the instruments under contract, and I think of the 380, approximately 80-plus percent of that is going directly to our commercial space industry, which is building these instruments.

I do agree with you entirely in the principle that we need to be—we need to have a constellation which has both backbones, government-supplied solutions, and complemented by other alternative approaches, and in the future as the capabilities get stronger is likely to be more—is going to be more prevalent.

I think we have to be very careful of the risks to the user, the end user, which is if we get commercial approach which doesn't work out, we cannot let that compromise our ability to provide the weather forecast, and I know you are very sensitive to that as well.

So as far as the $380 million in the polar follow-on, that is very carefully targeted to making sure we have that backbone system capable through the end of the next decade so that we have the opportunity to try these alternative flexible approaches without jeopardizing our critical basic performance that the Nation expects.

Chairman BRIDENSTINE. I am out of time. I would like to recognize the gentleman from Virginia for five minutes.

Mr. BEYER. Thank you, Mr. Chairman.

Dr. Volz, in the notes that we had, it said that three offices within NOAA have primary responsibility for implementing the mitigation plan—NESDIS, OAR and the National Weather Service—but the NOAA office appears to be in charge of the mitigation activities. Is this accurate? Is there someone who should be the central decider and implementer——

Dr. VOLZ. As I said——

Mr. BEYER. —coordinator?

Dr. VOLZ. As I mentioned earlier on in the presentation here, there are many tasks, whether it is 21 or 40, in terms of the mitigation. There are a number of different tasks which have different disciplinary requirements, whether it is the Weather Service, Oceans Research or NES for satellite management and development, and those tasks are developed down to those different line offices. We each—we coordinate across the organization, and yes, there is a single person in charge, and that is the Under Secretary for Operations that we report to on a regular basis, and we report to the Secretary as well on a —the Under Secretary as well.

So it is coordinated and reported up through the chain of command but the individual activities are delegated down to their Centers of Excellence where the expertise is.

Mr. BEYER. That sounds great.

Mr. Murphy, if the NPP satellite was lost tomorrow, hit with debris, what would be the status of your gap mitigation plans now?

Mr. MURPHY. As I said earlier, the aircraft data is flowing. We have several other projects that are not matured yet. We have improved data assimilation, which will be completed first quarter of 2016, and we have some improved modeling capabilities that are also coming in early in 2016. So really, all we have completed thus far as far as gap mitigation has been the studies to demonstrate the impact and the aircraft data which was—it is not—none of the mitigation steps that I have seen anywhere completely mitigate the loss of the satellite.

I would remind you that we do have legacy satellites up there, the earlier NOAA satellites and the earlier science missions at this time, so it wouldn't be like we would lose all the satellites if it went out right now.

Dr. VOLZ. Yeah, and if I could comment on that too, I am glad John mentioned it. The POES satellites that were launched and are still flying, two of them in that same orbit, have been and still are operating. Now, they are older and they could fail as well, but if you had a—if the Suomi NPP went down, those would still be there.

What you will lose is that leap forward that I mentioned before, that Suomi NPP is much more capable than previous ones, but the backbone, we have infrared sounding and we have microwave radiometry out of those satellites, which would still be part and are used by the models and predictions.

Mr. BEYER. Mr. Powner, do you a reaction to this?

Mr. POWNER. Yeah, I think clearly what we heard on the mitigation activities, there were four areas, and one was—four primary areas that are the priorities, and one is extending the life of the existing POES satellites along with using the midmorning European satellites, and that actually came from folks sitting at this table, so we had them prioritize what the improvements in the forecast would be, that radio occultation, commercial aircraft, the high computing capacity as well as the improvements in the models. Those are the priority areas.

Mr. BEYER. Mr. Chairman, I yield back the balance of my time.

Mr. PERLMUTTER. Mr. Chairman?

Chairman BRIDENSTINE. Yes.

Mr. PERLMUTTER. Rumor has it, Mr. Powner, you are from Colorado?

Mr. POWNER. Yes, I am.

Mr. PERLMUTTER. All right. I am so glad I asked you questions. I yield back.

Chairman BRIDENSTINE. All right. I would like to recognize the gentleman from Texas, Dr. Babin, for five minutes.

Mr. BABIN. Thank you, Mr. Chairman.

Dr. Volz, in April of 2013, NOAA removed funding for three years of operations at the end of JPSS missions to keep the lifecycle cost of the program around $11 billion, two-part question. Even though JPSS–2 will be operational through 2028, operations, I see, are only funded through 2025. Is this a gimmick to hide the true cost of the program?

Dr. VOLZ. I can't speak to that specifically, sir. I will definitely go back and check and see what the funding—how the fundings are distributed. We certainly will operate the satellite as long as it is functioning and operating effectively.

Mr. BABIN. Okay. Are you anticipating no funding for a fully operational satellite program or are you anticipating that we will find more money after the satellite is airborne?

Dr. VOLZ. You are talking about post-2025, sir?

Mr. BABIN. Yes.

Dr. VOLZ. Well, the polar follow-on proposal that we have, which is to build the J–3 and J–4 instruments, includes in it the operational—in the long run. It is outside of this budget cycle particularly. It includes the operation and maintenance costs for these polar satellite constellation to the 2038 is the expected lifetime of those satellites as well. Whatever satellites are in orbit, we will be operating within those budgets as defined in our program.

Mr. BABIN. Okay. Thank you. And then one other question for Mr. Clarke. Where did the space debris come from that has led to the degradation of our polar orbiting satellites?

Dr. VOLZ. Well, sir, I can't comment in detail since I am not very—I don't have a lot of insight into it, but I do know the latest model using data from the last ten years, shuttle data particularly, that helped update those models. As far as—that is probably the level of detail I know. I can take that for the record and go back and get some more information for you if you would like.

Mr. BABIN. Okay. And then Mr. Powner, how important is improving NOAA's supercomputing capabilities to mitigating a data gap?

Mr. POWNER. It is clearly one of the top priorities.

I would also like to address the space debris that you just mentioned. Clearly, there has been an increase in space debris but there has also been some unfortunate incidents that contributed to the space debris. In 2009, there was an iridium satellite that hit a Kosmos satellite that increased the space debris and then also unfortunately in 2007, there was a Chinese military operation where they shot a satellite as part of their military ops, and that contributed to space debris. So those events in 2007 and 2009 clearly contributed to the space debris issue.

Mr. BABIN. Absolutely. Thank you.

Dr. Alexander MacDonald and Mr. Murphy, where does our supercomputing capacity rank relative to the rest of the world?

Dr. MACDONALD. I think that in—if we talk about our operational computing, it has been behind for quite some time. However, it was recently announced that we are going to get a major upgrade to our operational computing. I think it is actually five petaflops this fall, and I think that puts us on a par with the others, and I want to say that that is a big part of the mitigation, that is, we think with that additional computing, it is going to help us a lot in our predictions and help for the gap.

Mr. BABIN. Okay. One other thing. Should NOAA be placing a higher priority on this?

Dr. VOLZ. It has been a top priority. So, I have problems with all this discussion of priorities about these mitigation efforts because every mitigation step that I know has been a top priority for us.

Mr. BABIN. Okay. Thank you.

One thing else. I am sorry. Do you feel budgetary pressures elsewhere in NOAA's budget prevent you from having access to the best resources?

Dr. VOLZ. I am not sure if that is directed to all of us, sir. I don't believe we have pressures that limit us from doing the right thing and making the right choices.

Mr. BABIN. Okay. Thank you. That is all. I yield back the rest of my time.

Chairman BRIDENSTINE. Okay. We are coming to the end here, and Dr. Babin, your question about the operations piece of this where we are funding a technology that is, JPSS–2 specifically, which will last through 2028, and the operations side of it is only funded through 2025 in order to hold the cost of the program down to $11.3 billion. That is something that we will need to have addressed as we are at the end of this hearing. Maybe we can get that for the record.

And then also lastly, before we close out, I would just like to— Dr. Volz, I asked the question. I just want to get it on the record. If you are open, whether it comes from the $380 million for JPSS–3 or some other place, are you open to a pilot approach where NOAA would fund a certain amount of money to buy private satellite data, whether it is JPSS or GPS–RO or hyperspectral, to purchase it from the private sector for the purposes of resiliency and disaggregation?

Dr. VOLZ. I think we are open to buying appropriate data with the quality and the validation capabilities that meet our needs, and using that as an input into our numerical weather models, and we are happy to work with vendors to define a process by which we can validate the quality of their data sets and the reliability of them.

Chairman BRIDENSTINE. Could NOAA be an anchor tenant for that project?

Dr. VOLZ. I am not sure that I would call it an anchor tenant because the question is, do we invest in their development costs on the premise that the outcome will be something we can use, and that is a higher-risk approach than I would prefer to take from the NOAA side.

I am not in the—I don't think it should be appropriate for us to develop a commercial capability that we might use in the future. I am happy to look at their data. I am happy to work with them on the way that they are developing their approaches in an open forum, and if it meets criteria, I am happy to buy it and use it.

Chairman BRIDENSTINE. Would you have had that same position on the NPOESS program had you been at NOAA back when that started?

Dr. VOLZ. Oh, boy. I am not going to answer that one, sir. I am sorry.

Chairman BRIDENSTINE. Well, I appreciate your testimony. I thank the witnesses for their testimony and the Members for their great questions.

The record will remain open for two weeks for additional comments and written questions from Members. The witnesses are excused and this hearing is adjourned. Thank you so much.

[Whereupon, at 11:53 a.m., the Subcommittees were adjourned.]

Appendix I

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. David Powner

QUESTIONS FOR THE RECORD

U.S. House of Representatives, Committee on Science, Space, and Technology Subcommittees on Oversight and Environment Joint Hearing

"Bridging the Gap: America's Weather Satellites and Weather Forecasting"

Thursday, February 12, 2015

Mr. David Powner

Director, Information Technology Management Issues, Government Accountability Office

Questions submitted by Rep. Jim Bridenstine, Chairman, Subcommittee on Environment

1. What are the best alternatives among the gap mitigation strategies, from a feasibility and cost/benefit perspective, and why? Has NOAA started work on any of these alternatives?

While the National Oceanic and Atmospheric Administration (NOAA) has not assessed its gap mitigation alternatives from a cost/benefit perspective, we recently reported[1] that several alternatives represent the best known options for reducing the impact of a gap:

- **Extending use of existing satellites.** Extending legacy satellites, continuing to obtain data from European midmorning satellites, and ensuring legacy and European satellites' data quality remains acceptable would be a strong fallback strategy to reduce the impact of a gap. This is because forecasters and their models have been using these data operationally for years. Moreover, these alternatives could be important in the near-term when other options may not be available.
- **Obtaining additional observations.** Obtaining additional observations of radio occultation and commercial aircraft data could provide more significant support during a gap than other data sources. Studies conducted by leading forecast modeling centers have validated that they are among the top contributors for reducing forecast errors.
- **Improving data utilization techniques.** Advancing 4-dimensional data assimilation and the next generation global forecast model could help reduce the impact of a gap because they are expected to make more efficient use of data that are still available and produce improved techniques for evaluating data with each model run.
- **Increasing high-performance computing capacity.** Increasing high-performance computing capacity is the key factor for enabling greater resolution in existing and future models, and it drives the pace of development for assimilation of new or additional data that could further improve NOAA's models.

NOAA has started work on all of these projects. In order to ensure that the most promising alternatives can be put into place as soon as possible, we recommended that NOAA investigate ways to prioritize mitigation projects with the greatest potential benefit to weather forecasting in the event of a gap. The agency agreed with this recommendation and stated that it plans to establish a process to prioritize mitigation projects.

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[1]GAO, *Polar Weather Satellites: NOAA Needs to Prepare for Near-term Data Gaps*, GAO-15-47 (Washington, D.C.: Dec. 16, 2014).

2. How can NOAA determine that appropriate progress is being made on implementing gap mitigation activities?

NOAA can determine if appropriate progress is being made on its gap mitigation activities by implementing sound program oversight and actively monitoring progress on mitigation projects. While NOAA is providing some oversight of its many gap mitigation projects and activities, we recently reported that the agency's oversight efforts are not consistent or comprehensive. [2] Specifically, the National Weather Service is providing required monthly reporting on the status of its gap mitigation projects, while other NOAA offices are not. Until NOAA provides monthly reporting for all gap mitigation projects, the agency's oversight of these projects will be constrained.

In addition, while responsible officials are providing quarterly progress briefings on some mitigation projects to NOAA's program management council, they have not reported on nine mitigation activities outlined in NOAA's contingency plan. Because of the criticality of efforts to mitigate the potential gap and the need for oversight of these efforts, it is important for NOAA to monitor the progress being made on all activities. We recommended that NOAA ensure that the relevant entities provide monthly and quarterly updates on the progress of all mitigation projects and activities during existing monthly and quarterly management meetings. The agency agreed with our recommendation and stated that each entity with responsibility for mitigation efforts would begin to report this information monthly. We will continue to monitor NOAA's progress in this area.

3. For JPSS, your report focuses on a potential gap in the 2015 to 2017 timeframe. Are there similar concerns about a gap between the first and second JPSS satellites in the early 2020s?

While our recent report[3] focused on the potential near-term gap (between October 2016, when the Suomi-National Polar-orbiting Partnership satellite reaches the end of its expected lifespan, and September 2017, when the first Joint Polar Satellite System (JPSS) satellite is expected to become operational), there is also the potential for a gap between the first and second JPSS satellites in the period from 2018 to 2021.

NOAA acknowledged the potential for this second gap in its most recent contingency plan and is taking steps to mitigate it. In response to a recommendation in a previous GAO report,[4] NOAA established a more comprehensive plan in February 2014 that addressed the possibility ~~for~~ of a gap in the early 2020s. Among other things, the plan listed options such as accelerating launch readiness of JPSS-2 and accelerating other satellite procurements, such as a smaller "gap-filler" satellite. NOAA has also acted upon the first of these options by moving up the launch date of the second JPSS satellite from December 2022 to December 2021. However, if significant issues arise with the operations of the first JPSS satellite prior to the availability of another satellite, then a gap in this timeframe remains possible.

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[2]GAO-15-47.

[3]GAO-15-47.

[4]GAO, *Polar Weather Satellites: NOAA Identified Ways to Mitigate Data Gaps, but Contingency Plans and Schedules Require Further Attention*, GAO-13-676 (Washington, D.C.: Sept. 11, 2013).

a. The President's Fiscal Year 2016 budget request asks for $380 million to begin the next polar follow-on system. Given the program's history of delays and cost overruns, is GAO confident that NOAA can handle the polar satellite program going forward?

While NOAA's recent accomplishments on JPSS development provide increased confidence in its management of the polar satellite program, the JPSS program still faces key challenges. In 2013, we reported that NOAA had made significant progress on both the flight and ground components of JPSS.[5] More recently, we reported that NOAA is continuing to develop JPSS within its cost and schedule baselines, and has completed a major development milestone.[6] Also, collaboration between NOAA and NASA has improved on the JPSS program compared to the previous polar satellite program. However, concerns remain. For instance, JPSS program cost estimates for specific components have recently increased at an unsustainable rate, and key components have encountered major delays in development and testing. Moving forward, we will continue to monitor the agency's progress in managing the polar satellite program.

4. In the future, what factors may increase the risk of further launch delays to the polar orbiting satellite system and the geostationary program?

On the polar-orbiting satellite system, key factors that may increase the risk of further launch delays are cost increases and schedule delays. While the JPSS program is currently within both cost and schedule baselines, we recently reported on concerns in both of these areas.[7] For example, from July 2013 to July 2014, the total program cost estimate has increased by 2 percent, or $222 million. If JPSS costs were to continue to grow at this same rate annually, the program could surpass its cost baseline by 2018 and end up costing $2 billion more than expected by 2025. With regard to schedule, key components, such as the Advanced Technology Microwave Sounder (ATMS) instrument, have encountered milestone delays in development and testing. Since July 2013, the expected delivery of this instrument has slipped by 15 months to June 2015. Because of the technical issues that led to these delays, completing the ATMS instrument has now become the critical path for the entire JPSS-1 mission, and little schedule reserve remains until its expected delivery.

On the geostationary satellite program, GOES-R, continuing milestone delays are the key factor affecting the risk of further launch delays. Since September 2013, all remaining major milestones, which had already experienced significant delays, were delayed an additional 5 to 8 months.[8] Reasons for these delays included technical challenges in delivering software and in completing individual tests. The GOES-R program has also experienced recent issues in developing specific components that increase the potential for further delays, and some schedule mitigation efforts, such as moving to a 24-hour-a-day, 7-day-a-week integration testing schedule for its spacecraft, introduce further schedule risks. The program is now reaching a

[5]GAO-13-676.

[6]GAO-15-47.

[7]GAO-15-47.

[8]GAO, *Geostationary Weather Satellites: Launch Date Nears, but Remaining Schedule Risks Need to be Addressed*, GAO-15-60 (Washington, D.C.: Dec. 16, 2014).

point where additional delays in starting the end-to-end tests could begin to adversely affect its schedule.

Responses by Dr. Stephen Volz

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Subcommittee on Environment
Subcommittee on Oversight

Hearing Questions for the Record
The Honorable Jim Bridenstine (R-OK)

Bridging the Gap: America's Weather Satellites and Weather Forecasting

Dr. Stephen Volz
National Oceanic and Atmospheric Administration

Question 1: Both GAO and NOAA stated at the hearing that multiple alternatives exist for mitigating a polar satellite gap. However, NOAA's Sandy Supplemental project status reports and its Gap Mitigation Plan have different lists of mitigation projects. Does NOAA have an authoritative list of mitigation projects? If not, when does it plan to put one together?

Response 1: Yes, NOAA's Gap Mitigation Plan (February 2014) is a comprehensive plan of all gap mitigation activities currently being pursued by NOAA. This document was provided to the Committee in 2014.

The Sandy Supplemental reports contain all NOAA projects that are funded by the Disaster Relief Appropriations Act of 2013 (P.L. 113-2); only some of these are gap mitigation projects. For example, of the $325 million in Sandy Supplemental funds received by NOAA, $111 million were appropriated into the Weather Satellite Data Gap Mitigation Reserve Fund.

Therefore, Sandy Supplemental reports contain additional, non-gap related projects, commonly referred to as Disaster Preparedness projects, which are not part of NOAA's Gap Mitigation activities and are not included in the Gap Mitigation Plan.

Additionally, there are gap mitigation activities included in the Gap Mitigation Plan that do not use Sandy Supplemental funds and are not included in Sandy Supplemental reports. An update to the 2014 Gap Mitigation Plan will be available shortly and will be shared with the Committee.

Question 2: Which of the mitigation alternatives currently considered by NOAA have the best value from a cost benefit perspective? Does NOAA plan to prioritize work on the alternatives it considers to be the best from this perspective? If so, has NOAA created a prioritized list of the alternatives? If not, why not?

Response 2: An independent Analysis of Alternatives (AoA) was conducted by Riverside Technologies, inc. in 2013 to help NOAA identify and prioritize ideas to mitigate a gap in polar-orbiting data.

The AoA identified 44 distinct alternatives, of which 12 were listed as high merit and recommended for implementation:

- Satellite-Based Observations
  - Assimilation of Feng Yun-3 (China) Data
  - Assimilation of DMSP (USAF) Special Sensor Microwave Imager/Sounder
  - COSMIC-2 and other GNSS Radio Occultation Data
  - Use of Atmospheric Motion Vectors
  - Creation of Pseudo-Soundings from Geostationary Data

- Non-Satellite Observations
  - Increased Use of Observations from Aircraft
  - Targeted Observations for High Impact Events

- Data Assimilation
  - 4-Dimensional Data Assimilation
  - Assimilation of Cloud-Impacted Radiances

- Modeling
  - Blends of Global Models
  - Accelerated Global Model Research to Operations

- High Latitude Operations
  - Direct Readout Imagery from Other Satellites

NOAA concurred with these findings. Funds made available by the Weather Satellite Data Gap Reserve Fund in the Disaster Relief Appropriations (DRA) Act of 2013 allowed NOAA to pursue 11 of the 12 ideas. The one high merit idea not pursued was the assimilation of sounder data from Chinese weather satellites. The value of each idea was studied to determine the contribution to forecast accuracy improvement. This understanding was one element affecting internal prioritization of each alternative.

Question 3: In its most recent report, GAO reported the following mitigation projects as having the greatest potential benefit to weather forecasting in the event of a gap: Extending the use of legacy satellites; obtaining data from European midmorning satellites; obtaining additional observations from commercial aircraft and radio occultation; enhancing forecast models, and increasing high performance computing capacity. What progress is NOAA making in implementing this set of alternatives?

Response 3: NOAA is making excellent progress in implementing all of these alternatives. Detailed progress of these activities can be found in the Quarterly Sandy Supplemental briefings to the NOAA PMC. Progress to date will be spelled out in the 2015 update of the *Mitigation Plan For Potential Afternoon Polar-orbiting Satellite Data Gaps*.

Following is a brief update on how NOAA is pursuing each alternative:

Extend the Use of Legacy Satellites – NOAA will continue operation of the legacy NOAA Polar-orbiting Operational Environmental Satellites (POES) system, i.e., NOAA-19, including maintaining and upgrading the processing system, until the satellites no longer provide functional value. Additionally, a number of actions are being taken to extend the expected functional lifetime of NOAA-19 and the Suomi NPP spacecraft. The JPSS Program has established a dedicated special program systems engineering lead to focus on Suomi NPP life and has developed a plan for assessing and mitigating risk on all the items that typically have the potential to be life limiters such as, batteries, mechanisms, radiation exposure on electronics. The JPSS program continues to conduct special analyses and tests where warranted to help with potential life limiters like bearings as identified in the plan for assessing and mitigating risks to longevity of the spacecraft.

Obtain Data from European Midmorning Satellites – NOAA continues to ingest data from European midmorning (MetOp) satellites through existing international agreements and continues to provide support during the early development of the next generation of European polar-orbiting satellites. The U.S. portion of the MetOp data processing system is maintained and upgraded as part of NOAA's core activities. NOAA is also supporting the MetOp program by funding the testing of NOAA-provided instruments[1] for MetOp-C, the next satellite in the MetOp series.

Obtain Additional Observations from Commercial Aircraft and Radio Occultation – NOAA has obligated Sandy Supplemental funds to increase the use of aircraft observations in data sparse regions and develop advanced techniques for assimilating aircraft data.

NOAA is working with U.S. partners and NSPO (Taiwan) to support the COSMIC-2 constellation of 12 Radio Occultation (RO) spacecraft. The COSMIC-2 constellation will greatly increase the availability of RO data to NOAA. The FY 2016 President's Budget request called for $20 million to allow NOAA to continue RO ground system development and purchase the RO sensors for the polar portion of the COSMIC-2 constellation; this would be part of the U.S. contribution to the joint U.S.-Taiwan program. To date, no commercial entity has launched a system that is providing RO data. However, NOAA continues dialogue with various commercial entities that are developing such systems for launch in the future. In 2014, NOAA issued a Request for Information[2] and received responses from the commercial sector that suggested that while there are no commercial RO data providers operating at present; it is likely that commercial data will be available in the future. In late April 2015, NOAA convened a workshop that will help inform NOAA/NESDIS as it develops a process for assessing commercial solutions. At the workshop, participants heard from and engaged with NOAA/NESDIS leaders on satellite data requirements development, the process for determining how NOAA meets these requirements, how these data are ultimately used, and how NESDIS can and should engage with the commercial sector.

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[1] AHVRR=Advanced High Resolution Radiometer; SEM=Space Environment Monitor; AMSU-A=Advanced Microwave Sounding Unit-A

[2] https://www.fbo.gov/index?s=opportunity&mode=form&id=1758bf35aef1af52b14f52964aa6ebed&tab=core&_cview=1

Enhance Forecast Models - NOAA has pursued this through projects to develop a 4-D Ensemble Variational Numerical Weather Prediction system, advancing use of cloud-impacted radiances, preparing for use of advanced GOES-R data and other hyperspectral infrared data from European satellites, and testing of improved Atmospheric Motion Vectors products.

Increase High-Performance Computing Capacity - NOAA has obligated $42 million of Sandy Supplemental funds to increase operational and research high performance computing (HPC) capacity. NOAA-NESDIS has completed an upgrade of the S4 and JIBB supercomputers. A new research HPC system was delivered to NOAA-OAR and configured in December 2014. It is undergoing testing for acceptance and should be open to all users in Q3 FY2015. The NOAA-NWS operational HPC upgrade is ongoing and on schedule for completion in Q4 FY2015.

Question 4a: Expected delivery of the ATMS instrument on the JPSS-1 satellite has recently been delayed from March to June 2015. How certain is NOAA of a June delivery date?

Response 4a: The June 2015 delivery date for ATMS is no longer feasible. The rework of the Intermediate Frequency (IF) Amplifiers is taking longer than expected, and given the importance of the instrument, the NOAA/NASA team wants to ensure the corrective actions are successful. NOAA will keep the Committee apprised of the situation and will include updates during the Satellite Quarterly briefings.

Question 4b: What is the latest this instrument can be completed before delays would affect the launch date of JPSS-1?

Response 4b: If there is further delay, JPSS has developed a schedule that uses the flexibility available in the integration and test activities to allow an ATMS delivery as late as possible while maintaining a launch commitment date of the second quarter of FY 2017. NOAA will keep the Committee apprised of the situation and will include updates during the Satellite Quarterly briefings.

Question 4c: What is the total cost to NOAA resulting from recent delays to ATMS?

Response 4c: The cost of the delays to ATMS is currently estimated to be $24 million, which can be accommodated by the JPSS-1 program reserves.

Question 5a: During the hearing, Dr. Volz stated that NOAA had done some analysis to determine the date it estimates that the SNPP satellite will stop functioning, and that this date was likely on or after 2020. What is this date, and how was it determined?

Response 5a: The 2014 Suomi NPP satellite probability of success model is based on a specialized model to determine failure rates called "Military Handbook, Reliability Prediction of Electronic Equipment", MIL-HDBK-217. This model was applied at the system level (e.g., spacecraft and instruments) and modeled degradation of system components.

The model output suggests that around the year 2020, the Probability of Success (Ps) for the system components that are required to produce key data products to be below 60 percent. The model output suggests the Ps continues to degrade until the satellite has to be de-orbited due to propellant depletion, which is currently predicted to be no later than 2026.

For program planning purposes, when estimating future on-orbit satellite reliability, NOAA assumes a satellite will not be available if its predicted reliability is below 50-60 percent. These analyses are repeated annually as part of our continuous process to understand and manage our overall program risk. NOAA provides regular operational status updates of Suomi NPP on the internet (http://www.ospo.noaa.gov/Operations/SNPP/status.html)

Question 5b: Did this estimate consider the potential effect of space debris impact on SNPP?

Response 5b: No, this estimate did not consider the potential effect of space debris in the Suomi NPP operational orbit. The JPSS Program has engaged the NASA Orbital Debris group and the micro-meteoroid and orbital debris (MMOD) risk will be added to the Suomi NPP Ps calculations for the 2015 analysis update.

Question 5c: If this estimated date is after the expected JPSS-1 launch date of March 2017 (implying no gap), then why is the gap between SNPP and JPSS-1 estimated to be approximately one year in the FY16 President's Budget?

Response 5c: The fly-out chart provided in the FY 2016 Budget request reflects design life which is five years for Suomi NPP. By design, the flyout charts are based on design life until missions are in their extended lifetime phase. Once a satellite has successfully completed its initial on-orbit checkout, operations usually continue longer than the design life.

Question 5d: Has similar analysis been performed to determine the actual date that NOAA expects GOES-13, GOES-14, and GOES-15 to stop functioning? If so, what are these dates?

Response 5d: NOAA has not conducted similar Probability of Success assessments on its current GOES legacy satellites, but performs appropriate analysis and monitoring of trends in the health and safety of each satellite constellation, including instrument performance and fuel availability. Whenever there is a significant change in a performance trend or in the health and safety status of the mission, NOAA reassesses the minimum criteria necessary to safely decommission each satellite. In accordance with the NESDIS Satellite Decommissioning Policy, the following factors are used to determine when to propose the decommissioning of a GOES satellite:

- The remaining amount of fuel on board sufficient to raise satellite to 300 kilometers (km) above geostationary orbital altitude. (Raising a Geostationary Satellite 300+ km for decommissioning is a standard best practice for limiting orbital debris.)

- Unacceptable degradation of critical redundant spacecraft component.
- Unacceptable degradation of battery capacity such that it can no longer support mission through eclipse season.
- Complete Failure of Imager instrument.
- Unacceptable degradation of ability to control earth pointing attitude through normal operations.

We do not know specific dates for when the GOES-13, -14,-15 satellites may stop functioning, however, the calculated fuel limited lifetime for these satellite are 2021, 2024, and 2025, respectively. The operational status of the GOES satellites is available on the internet:
http://www.ospo.noaa.gov/Operations/GOES/status.html

Question 6: How long has 24x7 testing been in place on GOES-R satellite development, and how long is it likely to occur for the remainder of both GOES-R and GOES-S satellite development?

Response 6: 24/7 operations for electrical testing of the GOES-R satellite started in November 2014. The GOES-R Series Program is planning to have Lockheed-Martin continue 24/7 electrical testing through the completion of GOES-R testing in December 2015. Mechanical testing is not planned to be run 24/7, but is operated as two extended 10 hour shifts per day.

The current plan for GOES-S includes 24/7 operations only for the satellite-level thermal/vacuum testing.

Question 7a: The President's Fiscal Year 2016 budget request asks for $380 million to begin the next polar follow-on system. Please provide the committee with a detailed description of how these funds would be allocated and used to start the Agency's next polar satellite program. Will any of these funds be used for mitigation of the upcoming polar coverage gap?

Response 7a: Approximately 80 percent of the Polar Follow-on (PFO) funds are expected to go to the instrument prime contractors for the development of PFO JPSS-3 and JPSS-4. The funds will be used by the instrument manufacturers to place orders for sub-contracted items and begin sub-assemblies. The balance covers reserves, program and project management, indirect costs and one gap mitigation project.

The gap mitigation project included in the PFO budget request is $10 million for Earth Observing Nanosatellite-Microwave (EON-MW). EON-MW is an advanced technology miniature microwave sounder that will fly on proven CubeSat spacecraft technology in CY 2019. EON-MW approximates the atmospheric profiling capabilities of the ATMS instrument and, if successful, would be available to provide comparable quality of data in the event of a launch or instrument failure on JPSS-1.

All of the funds requested for JPSS, and PFO JPSS-3 and JPSS-4 missions, will be used for reducing the likelihood of a gap in polar coverage to an acceptable level. NOAA has determined that an acceptable programmatic reliability level is to achieve single fault tolerance on orbit (two failures to a gap), and the ability to replace a failed capability quickly with a replacement in the event of failure. This achieves a robust program.

The Administration's strategy to achieve a robust JPSS system program is to:

1. Take all measures to maximize the operational life of Suomi NPP;

2. Maintain current acquisition and development schedules to launch JPSS-1 no later than Q2 FY 2017 and maintain the accelerated launch date for JPSS-2 (currently Q4 of FY 2021); and

3. Implement the PFO activities outlined in the Administration's FY 2016 Budget Request.

The report language received in Explanatory Text that accompanied the FY 2014 Omnibus Appropriations bill provided NOAA the flexibility and the authority to initiate procurement of additional spare instruments and spacecraft as necessary to ensure the continuity of polar observations. NOAA will use these spares to support the accelerated JPSS-2 launch commitment date, or if necessary, use the spare for instruments which could fly on PFO/JPSS-3 or PFO/JPSS-4. The JPSS Program issued a Justification for other than Full and Open Competition (JOFOC) prior to making the decision to sole-source the PFO JPSS-3 and JPSS-4 instruments and has the procurement actions underway to add options to procure these instruments to the JPSS-2 instrument contracts by the beginning of FY 2016. The PFO JPSS-3 and JPSS-4 missions will be copies of JPSS-2 and the instruments are being procured as a simultaneous single contract action block buy addition to the JPSS-2 instrument contracts in order to reduce risk, schedule, and cost for the follow on-missions.

The JPSS program also included options for PFO JPSS-3 and JPSS-4 spacecraft in the JPSS-2 spacecraft competition. The JPSS-2 spacecraft bus contract was awarded on March 23, 2015. These actions will allow JPSS to launch the JPSS-3 mission by 2026 (launch readiness date of Q2 FY 2024) and the JPSS-4 mission by 2031 (launch readiness date Q3 FY 2026).

All of the activities listed above are expected to reduce the likelihood of a gap to an acceptable level (single fault tolerant with microwave and infrared sounders on orbit, with the ability to return to a single fault tolerant sounder posture should a failure occur) by mid-2023 and maintain that posture through the mid-2030's.

Question 7b: What lessons has the agency learned in the development of JPSS and GOES-R to avoid future delays, cost overruns, and/or gaps in weather satellite programs?

Response 7b: The National Polar-orbiting Operational Environmental Satellite System (NPOESS), which was the predecessor to JPSS, represented a failed acquisition approach that has been very difficult and costly to overcome. The approach used by NPOESS was known as Total Systems Performance Responsibility (TSPR), which gave a single integrated system prime contractor responsibility for the total system, flight and ground, and left the Government with limited insight and control. That was coupled with a tri-agency management structure that prevented crisp, timely decision making, and in which routine decisions were made at an interagency level rather than the program manager,. The NPOESS program was also burdened with ineffective requirements control, and incompatible requirements between the agencies. Finally the NPOESS program suffered from optimistic and unsupportable cost estimates, optimistically low estimates of the technical risks for the new instruments, and consequently, inadequate cost and schedule reserves.

JPSS was announced in February 2010, to replace NPOESS. JPSS was hampered in its transition year (CY 2010) by only having access to the Department of Commerce half of the NPOESS budget, and by the year-long FY 2011 Yearlong Continuing Resolution (CR) so both of the first two years of JPSS were only funded to 43 percent of the identified funding requirements.

Due to the lack of stakeholder confidence in the NPOESS components that the JPSS Program inherited, authority was only given to complete, launch and operate Suomi NPP, and proceed with JPSS-1 (made up of the second edition of Suomi NPP instruments), which had already been started under NPOESS in 2007/2008.

The JPSS Program was structured to have:

- A single source of requirements and control by NOAA with streamlined decision making, very disciplined and structured decision making processes for timely decision making at the right levels;
- Management with support of a technical center of excellence (NASA GSFC);
- Adequate cost and schedule reserves (as defined in the NASA Program and Project Management processes);
- Realistic cost estimates (the Independent Cost Estimates (ICE) were within 1 percent of the JPSS program baseline established in July 2013. The ICE was conducted through a very thorough and proven process including many independent reviews following NASA standards);
- Separate contracts for instruments, spacecraft, and ground, managed and controlled by the Government, with Government-led integration, and with appropriate insight and control and thorough flow down of mission assurance requirements.

The success of this approach has been proven with JPSS program performance. The program has been on track since FY 2012 when it received its first appropriation to implement the program requirements.

One other lesson learned critical to success is budget stability. The funding challenges in FY 2010 and FY 2011 caused a two year delay in JPSS-1 and significant cost increases above the $11.9 billion originally proposed at the time of the Administration's decision to restructure the Tri-Agency NPOESS program.

Funding reductions as a result of the FY 2013 sequestration affected the JPSS program, however, the JPSS Program absorbed the increased through program efficiencies and by reducing requirements. Some of these requirement reductions included focusing the JPSS Program as a weather mission and moving climate instruments outside of the JPSS Program portfolio to NASA, and moving the Argos-Data Collection System and SARSAT requirements to a new program area within NESDIS.

The GOES-R Series Program was structured as a NOAA required system, supported by NASA as the technical Center of Excellence. GOES R examined the use of TSPR in its concept development phase but determined to utilize its current approach, as the NPOESS experiences were unfolding. The GOES-R

Series Program also planned and committed to Block buy a series of four integrated spacecraft from the beginning, providing major risk, schedule and cost reductions through block buy of four copies of spacecraft and instrument parts. Significant investments were made early on in risk reduction for the key instruments and these investments were for the most part successful. The GOES-R Series Program did experience two developmental issues that were common with JPSS. First, the requirements represented very ambitious advances compared to existing capabilities, and these resulted in an expensive system and delays in completion of development; and second, the GOES R Series Program suffered from budget instability leaving it with inadequate resources in some years, resulting in life cycle cost increases, schedule slips, and work deferment/scope reductions.

Polar Follow-on (PFO) takes advantage of the successful experience of the GOES-R Series Program and many other satellite acquisition programs by introducing block buys of the PFO/JPSS-3 and PFO/ JPSS-4 instruments, along with structuring the contract for the JPSS-2 spacecraft bus to include two pre-priced options for the JPSS-3 and JPSS-4 spacecraft These features of the PFO approach will reduce the schedule, cost and risk compared to the buy-one-at-a-time approach required of JPSS for Suomi NPP, JPSS-1, and JPSS-2.

In summary, both the GOES-R Series and JPSS programs included significant performance enhancements over then existing capabilities to meet growing observational requirements, and were challenged by technical issues and budget instability. The GOES-R Series program, however, was structured through most of its history to more closely follow acquisition best practices. NPOESS did not follow best practices, and thus JPSS inherited many challenges, which have been overcome in the five years since the announcement. The final piece to complete the best practices and long-term polar weather satellite system health is implementation of PFO starting in FY 2016.

The list of lessons learned are:

- Ensure budget stability by establishing and maintaining confidence of stakeholders with effective communication, successful fulfillment of commitments, and adequate long-term planning
- Start the programs with adequate lead time, and appropriate balancing of cost, risk and schedule
- Link requirements and budget under control of the agency with the mission enables appropriate balance of performance and cost to be handled by that single agency
- Execute the acquisition with the support of a technical Center of Excellence
- Follow proven rigorous program and project management processes that delegate authority appropriately to the right levels and provide for well controlled execution at all levels
- Provide the Government with adequate insight and control
- Plan with adequate cost and schedule margin and realistic cost estimates
- Appropriately leverage competition and simultaneous/block buy of multiple copies

Question 8: When does NOAA plan to make final, viable decisions on the set of contingency strategies it will implement to deal with the possibility of a gap in the afternoon polar orbit? Further, without timely decisions by the agency, what are some of the "windows of opportunity" that NOAA would lose out on as possible mitigation options?

Response 8: NOAA's Gap Mitigation Plan lays out all the actions NOAA is and may take to mitigate the impact of a gap in the afternoon polar orbit. This plan is dynamic and is updated on an as needed basis to incorporate changing circumstances such as budget decisions and the availability of mitigating data sources. The most recent version of this plan was released in February 2014, and currently being updated.

Question 9: Other federal agencies, from the National Geospatial Intelligence Agency to DHS to NASA to the Farm Services Agency, routinely purchase commercial data for their requirements, oftentimes at lower cost than in-house collection methods. Why is NOAA not following these successful models?

Response 9: NOAA has a strong record of purchasing commercial data when it is available, affordable, and meets NOAA's requirements. NOAA continually analyzes the use of commercial data as long as NOAA is confident it is accurate, reliable, and can be validated. Because NOAA and NASA work together and with other countries in developing global numerical weather prediction models, the data must be readily transferable to and usable by all those countries.

For local and regional applications, NOAA already purchases some commercial data, including lightning data and Synthetic Aperture Radar (SAR) satellite data. Table 1 below includes additional examples of commercial purchases. Note that prior to any NOAA Commercial Data Buy, NOAA/NESDIS will actively negotiate modifications to the basic commercial entity business model proposed in order to achieve a more 'optimum business model' satisfactory to both the commercial entity and NOAA. This will include contract negotiations regarding data rights, data distribution and data reuse.

NOAA conducted a workshop with the commercial sector on April 28, with interested companies and discussed steps toward creating an effective working relationship.

Table 1: Examples of Data Buys

1. **Terrestrial Lightning Data:**

Data Type: lightning data from the U.S. National Lightning Data Network

Commercial Partner: Vaisala and Earth Networks

Mission Need: National Weather Service offices use this data to support severe weather warnings.

Data sharing policy: NOAA does not openly share the commercial data purchased through this arrangement. However, as this data is used at a regional scale, it does not impact the global numerical weather prediction and therefore does not have a significant impact on our partnerships

2. **Aircraft Observations:**

Data Type: Global observations of temperature, wind and moisture

Mission Need: Support operational analyses and forecasts for aviation, severe convective weather, and other general applications

Commercial Partner: Airline industry collects and distributes the data

Business Model: Observations of temperature and wind are derived from avionics systems onboard the aircraft and are communicated to ground using radio (over land) or satellite (over water). NOAA pays the communications costs and the commercial airlines pay for the sensor and avionics maintenance. Observations from the Water Vapor Sensing System ("WVSS") are derived from special sensors mounted on the aircraft. NOAA pays the airlines for the sensors and their installation and maintenance (usually over a one year up-front cost), and also pays the communication costs as on ongoing obligation.

Data sharing policy: NOAA cannot re-distribute the raw data within 48 hours to other commercial entities. NOAA can share end products derived from the data.

3. **Synthetic Aperture Data (SAR):**

Data Type: high-resolution SAR imagery

Mission Need: Support ice detection and monitoring for the National Ice Center (NIC) and the NWS Alaska Region.

Commercial Partner: Commercial sources in Canada (RADARSAT)

Business Model: NOAA data buy contract with MacDonald, Dettwiler and Associates Ltd (MDA) Geospatial Services, Inc. at commercial rates.

Federal Partners: NIC (MOU partners, NOAA, U.S. Navy, and U.S. Coast Guard) is considered a single user

Data sharing policy: NOAA is not permitted to redistribute raw imagery. Images incorporating format changes and annotation and carrying the MDA copyright logo can be distributed to NOAA, Navy, Coast Guard, NSF and vessels operating in support of these agencies' ice operations. Image Data products which are generated using Radarsat-2 data as one data input, and including MDA logo, may be made available on

NOAA's public website. These data are used for local and regional applications and do not affect data needs for global numerical weather prediction models.

4. SeaWiFS (Sea-Viewing Wide Field-of-view Sensor) ocean color data:

Data Type: Ocean color data

Mission Need: Support Harmful Algal Bloom and water quality assessments

Commercial Partner: GeoEye Inc. SeaWiFS is no longer providing useful data.

Business Model: NOAA had a contract for the direct purchase of real-time data. GeoEye primarily developed and operated the end-to-end satellite system that produced the data.

Federal Partners: NASA had an agreement with GeoEye Inc. to obtain archived data

Data sharing policy: Varied by use. For operational users, purchased data could not be shared outside of NOAA. For approved researchers, data sharing was permitted among the collaborators.

5. Aerial and satellite data for mapping, charting, and coastal change assessment:

Data Type: High resolution imagery over the U.S. and territories

Mission Need: This data supports navigation products, various habitat and benthic mapping, hazardous weather impacts, oil spill detection, trust resources monitoring, and coastal change analysis.

Commercial Partner: Digital Globe provides a Government-wide license for this data.

Business Model: Since 2000, NOAA's Ocean Service has managed an Indefinite Delivery, Indefinite Quantity geospatial services contract that has been used to procure geospatial data and related services (data processing, derived products, etc.) including procurement of aerial and satellite data (lidar, IfSAR, digital multi-spectral and hyper-spectral imaging, and imagery).

Federal Partners: DoD/National Geospatial Intelligence Agency acquires commercial data and shares (at no cost) with NOAA.

Data sharing policy: Data rights vary dependent upon conditions of the individual task orders but for the most part are free of licensing restrictions and publically accessible. These data are used for local and regional applications and do not affect data needs for global numerical weather prediction models.
6. <u>National Mesonet Data</u> **Data Type:** Observations of wind, temperature, and moisture in the lowest few thousand feet of the atmosphere, plus solar radiation, soil moisture, and soil temperature, over the 50 states **Mission Need:** These data fill gaps in NOAA/NWS's own observing systems, enabling improved warning and forecast operations for weather features that might otherwise not be detected by NWS's own systems. **Commercial Partner:** A consortium of 23 observing networks ("mesonets") operated by state, local, and private sector entities, currently overseen by Global Science and Technology, Inc. **Data Sharing Policy:** Most of the data are restricted to "NOAA only" use. On a case-by-case basis, data from some networks may be redistributed to other NOAA/NWS partners in government, academia, and the private sector.

Question 10: Since the President's FY2016 budget request transfers responsibility for developing climate instruments and climate satellites from NOAA to NASA, will NOAA funds that were meant to pay for such instruments and satellites stay within NOAA for use in gap mitigation efforts? Or will those funds be transferred to NASA to offset the cost of their development? What effect would such development have on NASA's budget? Please provide the Committee with a funding breakout of how this arrangement would look.

Response 10: The FY 2016 President's Budget does not propose to transfer funding between the agencies for climate satellite development. Funding is requested in NASA's budget to cover NASA's responsibilities for TSIS-1 and a future ocean altimetry satellite mission. There are no remaining funds for TSIS-1 in the NOAA budget beyond the FY 2015 appropriated amount of $7.3 million.

In the FY 2015 budget, there were no funds in NOAA's budget for development of the follow-on Jason missions beyond Jason-3, so there were no funds to transfer. NOAA will continue with the launch and operations of the Jason-3 satellite, currently scheduled for launch on July 22, 2015, and will continue to fund Jason-2 operations.

See page ES-36 of NASA's FY 2016 congressional budget justification for funding information on TSIS-1 and an Altimetry Follow-on mission. NASA's FY16 Budget provides $52 million on TSIS-1 and an Altimetry Follow-on mission.

Question 11: Are there any limitations on NOAA for beta testing commercial weather data against proprietary NOAA weather data? If not, is NOAA open to such testing?

Response 11: Assuming mutually agreed to terms are arrived at, and subject to the availability of appropriated funds, there is no reason that NOAA could not evaluate data for its impact on its operational numerical weather models if the data are made available to us for such an evaluation. We would conduct the evaluation in a development environment to ensure there are no operational problems. If commercially available product (e.g., GPS RO) is made available and evaluated for its operational usefulness, NOAA would undertake a cost-benefit analysis to determine if the data meet our quality requirements and if there is a business case that can be made to supplement and/or replace data to which we already have or have access. Please note that these evaluations can be very expensive and can take many years to complete.

Question 12: Does NOAA have any statutory limitations which would allow you to procure weather data from private space-based observing systems?

Response 12: NOAA has all the statutory authority it requires in order to procure data from commercial offerors. To meet mission requirements, NOAA engages in data buys and exchanges in accordance with the requirements of the Federal Acquisition Regulation, applicable appropriation laws, and U.S. Government policy.

Material requested for the record on page 66, line 1484, by Representative Bonamici during the February 12, 2015, hearing at which Mr. Steven Clarke testified.

Many global scientists—especially NASA's Earth Science Research community—use data from polar and geostationary satellites from NOAA and USGS as well as from NASA to conduct studies in a broad range of Earth Science disciplines. Data from this carefully coordinated and continuously observing suite of satellites offer key insights into the Earth system's evolution over a variety of time scales. Thus, they are routinely used to study terrestrial productivity; fire distributions; sea and land surface temperature; sea-level rise, polar sea ice distributions; changes in the polar region's effect on the global climate; ocean productivity; atmospheric temperature, moisture, aerosol, cloud, and ozone distributions.

There are two chief concerns with potential gaps in polar and geostationary satellite coverage relative to their use by NASA scientists in their research activities. First, our ability to identify trends in the earth system would be hindered. Second, if a gap arises that is not covered by alternative means (e.g., international partner satellites), we may miss important observable events.

Having a multi-instrument/multi-platform architecture in place is crucial to give researchers reasonable confidence their observations are indeed trends being observed as opposed to one-off issues with a single instrument or instruments with gaps (e.g., instrument degradation, inter-instrument calibration issues, etc.). The current system is well-calibrated and overlapping. Plainly put: gaps in the observing system or data continuity translate into less confidence in the results of the research.

To develop many of its long-term Earth system studies, NASA uses data from Terra (launched in 1999), Aqua (2002), Aura (2004), and most recently, the Suomi-National Polar Orbiting Partnership (S-NPP) satellite (2011). The Joint Polar Satellite System (first launch in 2017) will occupy a similar "afternoon orbit" of Aqua, Aura, and S-NPP and thus provide complementary measurements and continuity of data for that coverage.

A system without gaps means naturally occurring and anthropogenic events are likely to be observed, providing needed information on the particular events—something useful to forecasters, managers and researchers—and ensuring the statistics of such events can be well-documented. For example, geostationary satellites' temporal sampling capture the statistics of extreme meteorological events that might be 'missed' by the polar-orbiting satellites that only observe at a limited set of local times. Our ability to better understand this distribution and any potential changes in the future would be hampered without consistent observations.

Material requested for the record on page 74, line 1698, by Representative Beyer during the February 12, 2015, hearing at which Mr. Steven Clarke testified.

NASA has a robust strategy addressing orbital debris that encompasses executing a long-standing program to monitor, predict, and protect our assets, to the best of our ability, and developing new technologies that enhance our capability to operate safely in space. Our technology development includes ongoing projects and consideration of new technology development activities, such as advanced ground-based and in-situ debris measurement capabilities, innovative multi-purpose spacecraft impact protection shielding material, and low maturity orbital debris remediation capabilities. As no single agency or country can solve the orbital debris issue alone, NASA has worked with other countries and international organizations to develop mitigation strategies and standards that reduce the generation of new orbital debris.

Currently, only a small fraction of orbital debris is routinely tracked. The U.S. Space Surveillance Network (SSN) maintains a catalog of objects larger than 5-10 cm at low-Earth orbit altitudes. The Department of Defense Joint Space Operations Center provides potential collision ("conjunction") warnings for operational spacecraft with these tracked objects. For objects smaller than those tracked by SSN, NASA statistically measures the orbital debris environment using radars, optical telescopes, and examination of returned spacecraft surfaces. Data from these sources is analyzed by NASA's Orbital Debris Program Office (ODPO), as a part of NASA's Safety and Mission Assurance Program, for inclusion in the ODPO's environmental models that are used to define and predict risk to Agency spacecraft.[1] Such models were recently used to assess the risk to the Joint Polar Satellite System 1 (JPSS-1) spacecraft and instruments. Because the models indicated a significant increase in orbital debris density in JPSS orbits, the program is now actively assessing the need for additional hardware protection at added cost.

While knowledge of existing debris is important, NASA and other federal agencies actively seek to prevent the proliferation of these objects via cost-effective mitigation measures. NASA was the first agency to recognize the growing issue of orbital debris more than 30 years ago. NASA developed the world's first orbital debris mitigation guidelines for the Agency in 1995. Based on those guidelines, NASA led the effort to develop the U.S. Government Orbital Debris Mitigation Standard Practices which were approved in 2001. These mitigation guidelines and standard practices are largely aimed at reducing the generation of orbital debris in the near- and far-term. As NASA is not a regulatory agency, it works with other USG departments and agencies, such as the Federal Aviation Administration (FAA) and Federal Communications Commission (FCC), in developing effective orbital debris rules.

Internationally, NASA was the founding member of the Inter-Agency Space Debris Coordination Committee (IADC) which was established in 1993. The IADC, currently consisting of 13 major

[1] The orbital debris population, particularly at low-altitude orbits, where the International Space Station flies, changes rapidly with such parameters as solar flux levels and debris generation events. If the debris population is not periodically re-measured, the risk uncertainties would reach unacceptable levels, requiring the addition of costly shielding, or other countermeasures to spacecraft.

international space agencies, is recognized as the international technical authority on orbital debris. NASA led the development of the IADC Space Debris Mitigation Guidelines in 2002, building on the U.S. practices issued the year before. NASA was instrumental in the development of the United Nations' (UN) Committee on the Peaceful Uses of Outer Space (COPUOS) Space Debris Mitigation Guidelines, which were endorsed by the UN General Assembly in 2007. NASA continues to actively work with the international space community to promote the awareness of the orbital debris problem and the importance of the implementation of the orbital debris mitigation guidelines.

The National Space Policy directs the pursuit by the Department of Defense and NASA on research and development of technologies and techniques to mitigate and remove on-orbit debris, reduce hazards, and increase understanding of the current and future debris environment. With regards to removal of on-orbit debris, NASA is currently focusing upon technology development as opposed to operational deployment.

To address spacecraft protection and orbital debris remediation, NASA is funding a number of technology development projects that improve inspection and detection of defects in various aerospace materials and structures, improve material strength (minimizing the damage of orbital debris), provide self-healing of composites at locations that may be hard to access for manual repair, and improve NASA's ability to repair in-space assets through in-space robotic servicing. NASA is also funding a Small Business Innovation Research project to advance the capability of ground-test facilities and navigation systems by performing an end-to-end simulation of an approach and capture of multiple rocket bodies.

NASA has identified several promising new technology candidates in the draft 2015 NASA Technology Roadmaps. These candidates will be evaluated and prioritized as part of NASA's Strategic Technology Investment Plan development.

In addition, in June 2014, NASA issued guidance to address technology development efforts, expanding the focus to include orbital debris remediation (ODR). Over three decades, NASA and other Government partners have studied the orbital debris environment and continue to assess various options to mitigate and remediate the problem. The removal of large debris objects from Earth orbit will be needed to control the hazardous debris population in the long-term. NASA has compiled past research and studies related to ODR and will be holding an internal Technical Interchange Meeting to evaluate different approaches. The results of this interchange will further expand the list of technical development candidates. The new technology candidates will focus on technology readiness level (TRL) 1-4 concepts that exclusively address detectable human-made objects.

The remediation of the near-Earth space environment will necessarily involve not only a multi-agency approach, but an international effort. The United States is responsible for less than one-third of all cataloged debris, and only 22.9 percent of mass now in low-Earth orbit. Since international treaties prevent a country from removing space objects that do not belong to it, the United States, by itself, cannot solve the orbital debris problem. NASA works with the international partners through the IADC and UN COPUOSNASA, as a member of the USG Delegation, is a leading participant in the UN COPUOS' on-going effort to develop a new set of guidelines for the long-term sustainability of outer space activities, which will include remediation as an element for long-term consideration.

As highlighted in the President's 2010 National Space Policy, the orbital debris problem is creating a major challenge for space situational awareness (SSA) and for the safe operation of U.S. space assets. NASA is taking a number of steps to address this challenge, and will continue to work to better define the orbital debris population for near-term debris impact risk assessments, protect critical space assets, evaluate the far-term sustainability of the environment, and initiate early technology development to reduce the risk in the future.

Responses by Mr. Steven Clarke

U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Subcommittee on Environment
Subcommittee on Oversight

Questions for the Record, Steven Clarke, Director Joint Agency Satellite Division, NASA
The Honorable Jim Bridenstine (R-OK)

Bridging the Gap: America's Weather Satellites and Weather Forecasting

QUESTION 1:

What are NASA's thoughts about NOAA's contingency plan for the polar afternoon orbit? Are you comfortable with the reduced satellites and instruments? Is this the best plan that budgets can afford, and does it meet the needs of the nation and of those who rely on weather data?

ANSWER 1:

NOAA's concerns regarding the risk of a gap in the ability to provide timely and accurate weather forecasts are clear and have been communicated to NASA. As the acquisition agent for our NOAA partners, NASA continues to meet the needs of the nation in providing cost-effective solutions for providing critical weather data to the user community. NASA continues to look for ways to accelerate the JPSS-2 launch date to mitigate the risk of a data gap.

QUESTION 2:

What lessons did NASA learn from the failure of the NPOESS program, and what is being done to avoid making the same mistakes as in the past?

ANSWER 2:

The NPOESS program tri-Agency partnership created a highly complex and demanding program management environment with conflicting Agency requirements that drove significant increases in cost and delayed the execution of the program.

In response to the lack of success of the NPOESS program, the Administration dismantled the program and gave responsibility for developing a polar-orbiting weather satellite in the morning orbit to the Department of Defense and responsibility for developing a polar-orbiting weather satellite in the afternoon orbit to NOAA. The 2010 National Space Policy stated that NOAA would "primarily utilize NASA as the acquisition agent" for its satellites.

The primary lesson from the NPOESS program is that cross-Agency roles and responsibilities must be clearly defined, documented, implemented and adhered to for a successful inter-Agency partnership to achieve mission success. To embrace this primary lesson, NASA established the Joint Agency Satellite Division (JASD) within the Science Mission Directorate (SMD) in April 2010 to manage reimbursable satellite and instrument development performed by NASA to meet the NOAA requirements.

The primary focus of JASD is to efficiently manage the acquisition, development, launch and on-orbit checkout of NOAA's operational satellite projects using NASA's rigorous program/project management and systems engineering processes. These same processes are used to ensure mission success on NASA research missions. Key Decision Point reviews are co-chaired by NASA and NOAA, and the reimbursable nature of JASD projects gives the partner agency the final decision authority for the projects. JASD also provides early support to NOAA in its planning for multi-satellite operational missions, leading to better-managed and more cost-effective acquisitions.

U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Subcommittee on Environment
Subcommittee on Oversight

Questions for the Record, Steven Clarke, Director Joint Agency Satellite Division, NASA
The Honorable Don Beyer (D-VA)

Bridging the Gap: America's Weather Satellites and Weather Forecasting

QUESTION: According to a report by the Government Accountability Office, entitled *Polar Weather Satellites: NOAA Needs To Prepare for Near-term Data Gaps,* "Space debris experts from NASA's Orbital Debris Program Office believe that the danger of collisions to satellites at altitudes similar to JPSS is compounded by estimates that the amount of space debris will increase as worldwide spacecraft launch rates increase and collisions between debris particles create more debris. In particular, experts are concerned about increases in space debris that is larger than 2 centimeters for which shielding options are limited and less than 5 centimeters for which collision avoidance maneuvers cannot be conducted because the debris are not actively tracked and cataloged." Can you please describe NASA's long-term strategy for dealing with increased amounts of space debris?

ANSWER: NASA has a robust strategy addressing orbital debris that encompasses executing a long-standing program to monitor, predict, and protect our assets, to the best of our ability, and developing new technologies that enhance our capability to operate safely in space. As no single agency or country can solve the orbital debris issue alone, NASA has worked with other countries and international organizations to develop mitigation strategies and standards that reduce the generation of new orbital debris. Our technology development includes ongoing projects and consideration of new technology development activities, such as advanced ground-based and in-situ debris measurement capabilities, innovative multi-purpose spacecraft impact protection shielding material, and low maturity technology development efforts related to orbital debris remediation.

Currently, only a small fraction of orbital debris is routinely tracked. The U.S. Space Surveillance Network (SSN) maintains a catalog of objects larger than 5-10 cm at low-Earth orbit altitudes. The Department of Defense Joint Space Operations Center provides potential collision ("conjunction") warnings for operational spacecraft with these tracked objects. For objects smaller than those tracked by SSN, NASA statistically measures the orbital debris environment using radars, optical telescopes, and examination of returned spacecraft surfaces. Data from these sources is analyzed by NASA's Orbital Debris Program Office (ODPO), as a part of NASA's Safety and Mission Assurance Program, for inclusion in the ODPO's environmental models that are used to define and predict risk to Agency spacecraft.[1] Such models were recently used to assess the risk to the Joint Polar Satellite System 1 (JPSS-1) spacecraft and instruments. Because the models indicated a significant increase in orbital debris density in JPSS orbits, the program is now actively assessing the need for additional hardware protection at added cost.

While knowledge of existing debris is important, NASA and other federal agencies actively seek to prevent the proliferation of these objects through cost-effective mitigation measures. NASA was the first agency to recognize the growing issue of orbital debris more than 30 years ago. NASA developed the world's first orbital debris mitigation guidelines for the Agency in 1995. Based on those guidelines, NASA led the effort to develop the U.S. Government Orbital Debris Mitigation Standard Practices which were approved in 2001. These mitigation guidelines and standard practices are largely aimed at reducing the generation of orbital debris in the near- and far-term. As NASA is not a regulatory agency, it works with other USG departments and agencies, such as the Federal Aviation Administration (FAA) and Federal Communications Commission (FCC), in developing effective orbital debris rules.

Internationally, NASA was the founding member of the Inter-Agency Space Debris Coordination Committee (IADC) which was established in 1993. The IADC, currently consisting of 13 major international space agencies, is recognized as the international technical authority on orbital debris. NASA led the development of the IADC Space Debris Mitigation Guidelines in 2002, building on the U.S. practices issued the year before. NASA was instrumental in the development of the United Nations' (UN) Committee on the Peaceful Uses of Outer Space (COPUOS) Space Debris Mitigation Guidelines, which were endorsed by the UN General Assembly in 2007. NASA continues to actively work with the international space community to promote the awareness of the orbital debris problem and the importance of the

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implementation of the orbital debris mitigation guidelines.

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To address spacecraft protection, NASA is funding a number of technology development projects that improve inspection and detection of defects in various aerospace materials and structures, improve material strength (minimizing the damage of orbital debris), provide self-healing of composites at locations that may be hard to access for manual repair, and improve NASA's ability to repair in-space assets through in-space robotic servicing. To address orbital debris remediation (ODR), i.e., the removal of space debris from operational orbits, NASA is also funding a Small Business Innovation Research project that is performing an end-to-end simulation of an approach and capture of multiple rocket bodies.

NASA has identified several promising new technology candidates in the draft 2015 NASA Technology Roadmaps. These candidates will be evaluated and prioritized as part of NASA's Strategic Technology Investment Plan development.

In June 2014, NASA issued guidance regarding developing technologies, but not operational capabilities, related to removal of orbital debris. Over three decades, NASA and other Government partners have studied the orbital debris environment and continue to assess various options to mitigate and remediate the problem. The removal of large debris objects from Earth orbit will be needed to control the hazardous debris population in the long-term. To date, there is not established practice for space debris removal that can satisfy technical, economic, and safety considerations. NASA has compiled past research and studies related to ODR and will be holding an internal Technical Interchange Meeting to evaluate different approaches. The results of this interchange will further expand the list of technical development candidates. The new technology candidates will focus on technology readiness level (TRL) 1-4 concepts that exclusively address detectable human-made objects.

The remediation of the near-Earth space environment will necessarily involve not only a multi-agency approach, but an international effort. The United States is responsible for less than one-third of all cataloged debris, and only 22.9 percent of mass now in low-Earth orbit. Since international treaties prevent a country from removing space objects that do not belong to it, the United States, by itself, cannot solve the orbital debris problem. NASA works with the international partners through the IADC and UN COPUOS. NASA, as a member of the USG Delegation, is a leading participant in the UN COPUOS' on-going effort to develop a new set of guidelines for the long-term sustainability of outer space activities, which may include remediation as an element for long-term consideration.

As highlighted in the President's 2010 National Space Policy, the orbital debris problem is creating a major challenge for space situational awareness (SSA) and for the safe operation of U.S. space assets. NASA is taking a number of steps to address this challenge, and will continue to work to better define the orbital debris population for near-term debris impact risk assessments, protect critical space assets, evaluate the far-term sustainability of the environment, and initiate early technology development to reduce the risk in the future.

U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Subcommittee on Environment
Subcommittee on Oversight

Questions for the Record, Steven Clarke,
Director Joint Agency Satellite Division, NASA
The Honorable Suzanne Bonamici (D-OR)

Bridging the Gap: America's Weather Satellites and Weather Forecasting

QUESTION: When we discuss the potential problems resulting from a gap in data from our polar or geostationary satellites we are often focused on how such a gap will degrade our weather forecasting capabilities-- putting lives and property at greater risk. However, a gap in data will likely also have serious negative consequences to our research capabilities. In your written testimony, you state that "any potential gap could also impact the continuity of data used by NASA scientists for various research." Can you please elaborate on the use of polar and geostationary satellite data by NASA scientists and how a lack of continuity in such data could have a deleterious effect on NASA's research?

ANSWER: Many global scientists—especially NASA's Earth Science Research community—use data from polar and geostationary satellites from NOAA and USGS as well as from NASA to conduct studies in a broad range of Earth Science disciplines. Data from this carefully coordinated and continuously observing suite of satellites offer key insights into the Earth system's evolution over a variety of time scales. Thus, they are routinely used to study terrestrial productivity; fire distributions; sea and land surface temperature; sea-level rise, polar sea ice distributions; changes in the polar region's effect on the global climate; ocean productivity; atmospheric temperature, moisture, aerosol, cloud, and ozone distributions.

There are two chief concerns with potential gaps in polar and geostationary satellite coverage relative to their use by NASA scientists in their research activities. First, our ability to identify trends in the earth system would be hindered. Second, if a gap arises that is not covered by alternative means (e.g., international partner satellites), we may miss important observable events.

Having a multi-instrument/multi-platform architecture in place is crucial to give researchers reasonable confidence their observations are indeed trends being observed as opposed to one-off issues with a single instrument or instruments with gaps (e.g., instrument degradation, inter-instrument calibration issues, etc.). The current system is well-calibrated and overlapping. Plainly put: gaps in the observing system or data continuity translate into less confidence in the results of the research.

To develop many of its long-term Earth system studies, NASA uses data from Terra (launched in 1999), Aqua (2002), Aura (2004), and most recently, the Suomi-National Polar Orbiting Partnership (S-NPP) satellite (2011). The Joint Polar Satellite System (first launch in 2017) will occupy a similar "afternoon orbit" of Aqua, Aura, and S-NPP and thus provide complementary measurements and continuity of data for that coverage.

A system without gaps means naturally occurring and anthropogenic events are likely to be observed, providing needed information on the particular events—something useful to forecasters, managers and researchers—and ensuring the statistics of such events can be well-documented. For example, geostationary satellites' temporal sampling capture the statistics of extreme meteorological events that might be 'missed' by the polar-orbiting satellites that only observe at a limited set of local times. Our ability to better understand this distribution and any potential changes in the future would be hampered without consistent observations.

Responses by Dr. Alexander MacDonald

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Subcommittee on Environment
Subcommittee on Oversight

Hearing Questions for the Record
The Honorable Jim Bridenstine (R-OK)

Bridging the Gap: America's Weather Satellites and Weather Forecasting

Dr. Alexander MacDonald
National Oceanic and Atmospheric Administration

QUESTION #1:
What types of weather events cause the most loss of life in this country?

a. **Are polar-orbiting satellites the best approach to improve forecasting for these events?**
b. **Could you speak to the status and outlook of using computer modeling to assist in weather prediction?**
c. **What is the potential and what is needed to make modeling more useful to forecasters?**
d. **How much does modeling cost relative to that of other observing systems?**
e. **Where would you rank U.S. forecasting capabilities compared to other countries?**

RESPONSE:
What types of weather events cause the most loss of life in this country?
Fatalities due to weather events can be divided into two categories. The first category is "Weather-Direct" fatalities, which includes those fatalities caused by hurricanes, tornadoes, floods, and other specific weather events. The second category is "Weather-Related" fatalities, in which weather events were a factor, such as heat waves and air quality. During the last 10 years, for Weather-Direct fatalities, the average annual death tolls were highest for hurricanes, tornadoes, and heat, at 108, 109, and 123 fatalities, respectively.[1] The goal of the National Oceanic and Atmospheric Administration's (NOAA) Weather-Ready Nation initiative is to save more lives and livelihoods by increasing this country's weather-readiness through preparation to protect, mitigate, respond to, and recover from all types of weather-related disasters.

a. **Are polar-orbiting satellites the best approach to improve forecasting for these events?**

   Different satellites have different strengths to improve forecasting for life-threatening weather events. Polar-orbiting satellites are part of the solution to improving weather forecasting.

[1] The U.S. Natural Hazard Statistics provide statistical information on fatalities, injuries and damages caused by weather related hazards. These statistics are compiled by the Office of Services and the National Climatic Data Center from information contained in Storm Data, a report comprising data from NWS forecast offices in the 50 states, Puerto Rico, Guam and the Virgin Islands. *http://www.nws.noaa.gov/os/hazstats.shtml*

Observations from satellites and other sources, computer modeling, and research about our Earth system are all necessary components for weather prediction. On short range time scales, forecasts and warnings of weather events are dependent on geostationary satellites and ground-based observing systems over land with rapid refresh rates, such as the Doppler radar and radiosonde networks. NOAA's polar-orbiting operational environmental satellites have a much slower refresh rate, but provide full global coverage for a broad range of weather and environmental applications. These satellites are crucial for NOAA's operational three-to-seven day weather forecasts and environmental modeling efforts. This information alerts forecasters to atmospheric conditions that could lead to life-threatening events, including hurricanes.

Hurricane track and intensity, snow storms, floods and other predictions are much improved because of a combination of global models and polar-orbiting satellites. For example, as polar-orbiting satellite remote sensors have matured, the ability of the models to use the data has also matured. As an indication of model improvement, hurricane models can currently predict the landfall location of a hurricane to within less than 100 miles three days prior to landfall, whereas in the 1970s the location could only be predicted to within 400 miles – a factor of four improvement. Other observing systems, such as geostationary satellites and in situ systems are also important in global weather prediction, but rank behind polar-orbiters in quantitative tests.

The improvement of sub-seasonal to seasonal predictions has also benefited from the combination of satellite data (e.g., sea surface temperature and ocean topology) and in situ ocean observations, such as moored buoys and the Argo floats. The phenomena that allow the longer term predictability are ocean-driven events, such as the El Niño – Southern Oscillation (ENSO), as well as longer term events, such as the Pacific Decadal Oscillation (PDO).

b. **Could you speak to the status and outlook of using computer modeling to assist in weather prediction?**

The outlook of using advanced computer modeling for improving weather model prediction is excellent, primarily because of two factors. First, the United States has an aggressive research effort to develop a new generation of global computer models for weather prediction. Researchers from NOAA's National Weather Service (NWS) National Centers for Environmental Prediction, Office of Oceanic and Atmospheric Research's (OAR) Earth System Research Laboratory and Geophysical Fluid Dynamics Laboratory, along with the National Science Foundation's (NSF) National Center for Atmospheric Research and the Navy have all worked together on the High Impact Weather Prediction Project (HIWPP) to develop new, improved global models. The second factor in improvement of model skill is the use of a new generation of computers, such as Massively Parallel Fine Grain.

NOAA is making progress toward reaching key milestones in advancing and upgrading our *operational* weather supercomputing capacity. These computers and the weather models they run are the bedrock of all weather forecasts in the United States. NWS upgrades and investments will lead to more accurate forecasts and warnings, especially for extreme weather and water events, for the American public that will rival all other national and international weather enterprises.

Thanks to the support from Congress in the Disaster Relief Appropriations Act of 2013 and in our recent base appropriations, we will increase our high performance computing (HPC) capacity from 776 TeraFLOPs in January 2015 to 2.8 PetaFLOPs (for primary and backup, respectively – for a total of 5.6 PF) by the end of this calendar year 2015. NOAA's environmental computer modeling enterprise underpins many of NOAA's products and services to the Nation. NOAA's current research and development HPC systems, Gaea and Zeus, are part of the critical infrastructure required for NOAA to accomplish its mission. NOAA's HPC system, Zeus, is being recapitalized as part of the Disaster Relief Appropriations Act of 2013. By 2016, NOAA's Research and Development (R&D) HPC system, Gaea, will be at the end of its useful life. There is a requested increase of $9M in the FY 2016 President's budget for recapitalizing this HPC system. This increase would establish a permanent source of funding that would allow NOAA to maintain its scientific leadership and organizational excellence through regular refresh and recapitalization of this R&D HPC resource.

c. **What is the potential and what is needed to make modeling more useful to forecasters?**

The new generation of cloud-resolving global models offers great promise to improve the most crucial short to mid-range weather predictions. The 3-km resolution models being tested now by NOAA and its collaborators in HIWPP have the potential to improve the accuracy of cloud and precipitation prediction. Increasing our ability to predict cloud cover and precipitation is an economically important component of weather forecasts as it will lead to enhanced predictions of phenomena such as hurricane eyewalls, flood causing rains, and the very heavy snowstorms.

Another major opportunity that NOAA is pursuing is called "Warn On Forecast." The FY 2016 Budget requests $4.3 million for Warn On Forecast, an increase of approximately $1.7 million. This program is based on a new generation of super-models that will better predict where tornado producing thunderstorms will appear up to an hour in advance – allowing people to take appropriate action. Our current tornado warnings average 13 minutes of lead time, and these warnings are designed to help the public to take immediate action to seek shelter.

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d. **How much does modeling cost relative to that of other observing systems?**

Observations are essential for any computer model to run effectively. Without observations, computer models cannot function. As observations improve in both number and quality, computer models will also improve, provided sophisticated data assimilation techniques and computing capacity increase to take advantage of the latest model developments. Modeling costs can be divided into two areas, the human capital required to develop more advanced assimilation, physical formulations and dynamic cores, and secondly the costs associated with running operational and research High Performance Computers. NOAA has used its internal councils, such as the NOAA Research Council and the NOAA Observing System Council, to try to understand and propose future investments in a balanced way between modeling and observing systems. In addition to qualitative efforts such as those developed by the NOAA councils, it is now feasible to use system simulations such as Observing System Simulation Experiments (OSSE) and computer benchmarking to determine components of the most effective and efficient future observation and modeling systems.

e. **Where would you rank U.S. forecasting capabilities compared to other countries?**

When considering the full range of U.S. forecasts, the U.S. forecasting capabilities are the benchmark of excellence. The United States experiences the worst combination of hazardous weather anywhere in the world, including hurricanes, tornadoes, flash floods, floods, and winter weather. Forecasting responsibility for these dangerous situations ranges from just a few minutes for tornado warnings, out to more than two weeks for preparing for these events. The United States ranks as a world leader in very short range prediction and warning services. Short range forecasts, including forecasts of less than three days ahead of weather events, are crucial for public safety, and are based on very high resolution, shorter range forecast models and include observations such as radar, satellites, and sophisticated data assimilation techniques. For mid-range forecasts of three days or longer, the United States lagged behind other countries, most notably the European Center for Medium Range Weather Prediction (ECMWF), and the United Kingdom Meteorological Office (UKMO). Limited operational computing resources and the diversity of NOAA's operational forecast mission compared to ECMWF and UKMO are important reasons for why we lagged behind in midrange forecasting skill. For the U.S. forecasting capabilities specifically, great strides have been made to increase computing capacity over the last several years, including $25 million in funding from the Disaster Relief Appropriations Act of 2013, which significantly increased NOAA's capacity and ability to bring proven research model improvements into operational computing. The United States is also investing in a more comprehensive research program for global weather assimilation and modeling, which will be required for world leadership. These upgrades and investments will lead to more accurate forecasts and warnings for the American public, and narrow the gap with other international medium range predictions.

Beyond ranking, it should be noted that NOAA shares its data and leverages other domestic, international, and commercial data to ensure that NOAA and U.S. users have access to all the relevant data they need to develop weather forecasts and warnings that provide their customers and users with confidence in decisions to protect life and property.

QUESTION #2:
What advanced technology systems might offer the greatest increase forecasting capability? In addition, what technologies would offer the best increase while also giving us the most "bang for the buck?"

RESPONSE:
There are many technologies currently being developed and tested by NOAA and its partners that may improve NWS forecasting capabilities. Many of the improvements to weather forecasting capabilities in recent decades can be attributed to the improvement of computer models, with the remainder of improvements attributable to better observations, such as those from advances in satellites and a better understanding of atmospheric processes. When considering overall forecasting, i.e., the forecast from now until day 10, the greatest 'bang for the buck' advanced technology is likely more computing capacity. Increased supercomputing capacity, as supported in the FY 2016 budget, will allow us to develop, test and implement increasingly sophisticated computer model simulations for the environment linking the air, sea, land and space into one holistic environmental model. This is conceptual at this time, but it will garner the greatest increase in NWS forecasting capability in the future. Increasing space-based and in situ observations and the necessary advanced data assimilation techniques are critical for computer model improvements and will further the accuracy in NWS forecasts, and extend the timeframe of useful weather forecasts.

More advanced observation technology systems could also contribute to improved tornado forecasts and hurricane forecasts.

Specific technology to improve tornado forecasting:
NOAA is pursuing two technology areas: observations and high performance computing capacity.

1. **Observations for Tornado Prediction**

   The next step in improved tornado warnings is developing sophisticated computer models that can simulate strong thunderstorm development and identify those particular storms most likely to produce tornadoes. Work at NOAA continues to move in this direction. Near continuous four-dimensional observing of the atmosphere is key to developing and implementing these new predictive capabilities. Observations of water vapor and detailed vertical profiles of temperature and moisture are critical to take tornado warning prediction to the next level. The two technologies below may further address these opportunities:

   a. **Satellite technology:** The satellite technology that is manifested on the GOES-R system that will provide timely information includes the Advanced Baseline Imager (ABI) and Geostationary Lightning Mapper (GLM). The ABI can be thought of as 60 times more capable than the current imager due to its three times greater spectral content to discern cloud properties and the near-storm environment, four times greater spatial resolution to resolve finer detail, and five times greater refresh rate providing more timely indication of evolving and intensifying severe storms on a time-scale of a minute or less. Trends in total lightning that are available with the GLM have shown promise by providing critical information to

NWS forecasters, allowing them to focus on storms 15-20 minutes before these storms produce damaging winds, hail or even tornadoes. These storms exhibit a significant increase in total lightning activity, which can be detected often many minutes before the radar detects the potential for severe weather. Used in combination with radar, visible satellite, and surface observations, we believe total lightning data has great potential to increase lead time for severe thunderstorm storm warnings. GLM will also provide information on lightning strikes over the open ocean, which is important for transoceanic aviation interests. GLM will also provide strike data in remote land areas where in situ lightning detectors are not located and where wildland fires are ignited by lightning strikes. Overall, knowledge of the total lightning activity and its extent will help improve public safety.

b. **Other Observations:** Additional observation capabilities are being developed and tested to address "gaps" in observations in the lower atmosphere, below the national Next-generation Radar (NEXRAD) network coverage and below what satellites can detect. We believe that improved observation and analysis of the information in the lowest levels of the atmosphere may improve our ability to warn and predict tornadoes. Such exploratory technology includes the Multifunction Phased Array Radar (MPAR), which is a joint research and development effort between the Federal Aviation Administration (FAA) and NOAA and can provide full volume rapid, radar scans at less than 1-minute intervals to monitor storm evolution and to feed critical data to the Warn On Forecast modeling systems. Another radar technology to sample the lowest levels of the atmosphere below the radar scan of the NEXRAD network is currently being tested by NOAA and its partners in a study funded by NSF. Research has shown that data from these lower atmospheric sensing radars, such as Collaborative Adaptive Sensing of the Atmosphere (CASA), hold promise for improving our capability to detect and predict thunderstorms and then tornadoes, particularly in areas of relatively poor coverage by NEXRAD. These data would complement the data from satellites and would also feed our high resolution computer model simulations increasing the capacity to Warn On Forecast.

These observing technologies are still in the developmental phase, but they do show promise. Finally, continued support for the National Mesonet is critical to maintain and increase observation density and availability near the surface.

2. **Improved High Performance Computing Technology for Tornado Prediction**

As mentioned above, continued improvements in HPC are needed to support advancements in numerical weather prediction (NWP) model activities in order to take advantage of enhancements in observational capabilities. For tornado forecast improvement, these activities include advanced data assimilation, very fine-scale high resolution NWP ensemble prediction systems, extraction of information with respect to model-simulated severe and tornadic storms, and improved post-processing tools to provide reliable and actionable probabilistic hazard information prior to the development of storms. The prediction process begins many days in advance of potential high-end tornado events to provide a continuous flow of planning information about upcoming tornado risk and uncertainty, leading to more specific hazard information as the event draws near. The increased HPC capacity is needed to adequately assimilate observational data, eventually moving NWS toward a "warn-on-forecast" capability, providing probabilistic information for tornados up to an hour in advance. The increased computer capacity will also prove to be a critical factor as will the four-dimensional displays of key meteorological fields that will produce real-time insights into the total evolutions of the severe storm system before, during, and immediately after the events.

Specific technology to improve hurricane forecasting:

Hurricane prediction has improved markedly over the past 10-20 years. Continued improvement requires technology improvements in two areas – observations HPC capacity and associated model development and implementation.

1. **Observations**

Increased observations of pressure, temperature, humidity and winds speed are needed in and around the eye of hurricanes, especially at lower and middle levels. One source for this information is dropsondes from aircraft, but these measurements are currently limited in both temporal and spatial density, and do not provide the needed horizontal resolution through and around storms. Another newer source of three-dimensional wind information in and around the tropical cyclone is the tail Doppler radar outfitted on all of the "Hurricane Hunter" aircraft. The FY16 Budget also calls for a $5 million investment to conduct research and development of an airborne phased-array radar (APAR) to improve the detection and understanding of severe storms. Finally, important wind and temperature information in and around the hurricanes are provided by the polar orbiting and geostationary (wind vectors) satellites. NOAA has also been evaluating the use of Unmanned Aircraft Systems (UAS) to obtain higher spatial and temporal resolution measurements in and around the core of hurricanes. An experimental UAS system under evaluation, called a Coyote, is being developed to increase the number of dropsonde-like observations by a factor of 10 to 15 – the minimum number needed to make the system cost effective. Additionally, some satellites can provide moisture and humidity measurements remotely outside of the storm, but cannot "see" inside hurricanes like these UASs.

2. **High Performance Computing, Model Development and Implementation**

NOAA's Hurricane Forecast Improvement Project (HFIP) provides a focused effort to develop improved hurricane forecasting capabilities. Substantial research has been done, aided by increased HPC capacity, to operationalize an improved high resolution hurricane forecast model —the Hurricane Weather Research and Forecasting Model. NOAA will continue to improve its hurricane observations and modeling by:

   a. **Better use of observations,** including in situ and remote sensing data, for model initialization and development

b. **Advanced high-resolution ensemble-based data assimilation techniques** for extracting the most useful information from in-situ and remotely sensed observations for use in the global and regional numerical models
c. **Improved modeling algorithms** for better accuracy and capability to model periods of rapid changes in intensity
d. **Improved post processing** of model results for better guidance on hurricane genesis and storm surge

These technological efforts will continue to improve not only the forecast track of the storm, but to also improve our capability to predict hurricane intensity and impact.

QUESTION #3:
What advances in weather forecasting have been driven by NOAA research in the last decades? And what are some of the promising technologies and research areas that we are not pursuing (or not pursuing adequately) due to lack of funding but which could improve severe weather forecasting?

RESPONSE:
There are several major advances in weather forecasting that have been driven by NOAA research in recent decades. The NWS Modernization in the 1990s included two major advances: the national Doppler radar network, which drew largely from the radar development at OAR's National Severe Storms Laboratory and the Advanced Weather Interactive Processing System (AWIPS) that was largely developed at OAR's Forecast Systems Laboratory (now called Earth System Research Laboratory's Global Systems Division (ESRL/GSD)). A few additional examples of NOAA research advancing weather forecasting are:

- The Forecast Systems Laboratory pioneering and developing the use of Massively Parallel Computers for weather and climate prediction. In recent years, ESRL/GSD has led the adaption of weather models to Massively Parallel Fine Grain computers;
- The Joint Center for Satellite Data Assimilation, created and hosted by NOAA, has been working towards making more effective use of satellite observations, which are key to improved medium range weather prediction;
- NWS's Environmental Modeling Center and ESRL's Physical Sciences Division have delivered significant improvements in medium range weather prediction by the development and operational implementation of the Ensemble Kalman Filter assimilation system; and
- The improved understanding and forecasting of hurricane track and intensity has been achieved by NOAA's Atlantic Oceanographic and Meteorological Laboratory.

Recently, NOAA researchers transferred to NWS the advanced hybrid assimilation system, the RAP model, and the revolutionary High-Resolution Rapid Refresh model known as the HRRR. Currently, ESRL is actively engaged in the High Impact Weather Prediction Project and the Research to Operations Project to develop the next generation global weather prediction system. The HRRR model is also fundamental to advancing the Warn On Forecast program.

To look to the future of weather forecasting, revolutionary improvements in weather prediction would come from the continuous, real-time capability to track the physical, chemical, and biological Earth system. Such a prediction system would include all components of the Earth system: air, land, ocean, ice, and space. The suite of instruments becoming available on NOAA's GOES-R and JPSS satellites would enable such a prediction system. This prediction system would need the full suite of global real-time satellite and in situ data, with forward models for chemical and biological constituents, in addition to the physical atmosphere and ocean that already have operational assimilation. In the longer term, space-based observations of clear-air three dimensional wind fields would be an extremely useful addition to observational capabilities. This capability has been proposed, but not demonstrated in space.

Responses by Mr. John Murphy

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
Subcommittee on Environment
Subcommittee on Oversight

Hearing Questions for the Record
The Honorable Jim Bridenstine (R-OK)

Bridging the Gap: America's Weather Satellites and Weather Forecasting

Mr. John Murphy
National Oceanic and Atmospheric Administration

QUESTION #1: What advanced technology systems might offer the greatest increase in NWS forecasting capability? In addition, what technologies would offer the best increase while also giving us the most "bang for the buck?" What specific technology would offer an increase in tornado forecasting? What specific technology would offer an increase in hurricane forecasting?

RESPONSE: There are many technologies currently being developed and tested by NOAA and its partners that may improve NWS forecasting capabilities. Many of the improvements to weather forecasting capabilities in recent decades can be attributed to the improvement of computer models, with the remainder of improvements attributable to better observations, such as those from advances in satellites and a better understanding of atmospheric processes. When considering overall forecasting, i.e., the forecast from now until day 10, the greatest 'bang for the buck' advanced technology is likely more computing capacity. Increased supercomputing capacity, as supported in the FY 2016 budget, will allow us to develop, test and implement increasingly sophisticated computer model simulations for the environment linking the air, sea, land and space into one holistic environmental model. This is conceptual at this time, but it will garner the greatest increase in NWS forecasting capability in the future. Increasing space-based and in situ observations and the necessary advanced data assimilation techniques are critical for computer model improvements and will further the accuracy in NWS forecasts, and extend the timeframe of useful weather forecasts.

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