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Committee on Science, Space, and Technology
James Webb Space Telescope

Introduction

Chairman Smith, Ranking Member Johnson, and Members of the Committee, thank you for the opportunity to appear before you today on behalf of the women and men of Northrop Grumman supporting the National Aeronautics and Space Administration's (NASA) James Webb Space Telescope. My name is Wes Bush and I am the Chairman and Chief Executive Officer of Northrop Grumman Corporation.

Northrop Grumman is fully committed to Webb's success, including the completion of the remaining test and integration activities to enable launch within the revised budget and schedule. We worked closely with the Independent Review Board (IRB), and support NASA's revised plan based on the IRB's recommendations. As the IRB concluded, we have confidence that the telescope will meet its mission objectives. While we are proud of the technological accomplishments that we have achieved that will enable Webb to perform its important mission, we recognize that we have contributed to the telescope's delays. We are currently implementing the recommendations of the IRB report as well as continually applying lessons learned from Webb and other programs to reduce programmatic risk and cost while ensuring Webb is launched at the earliest possible date. Mission success is our top priority.

The Webb telescope is in its final phase of development – testing and integration. The mission has come a long way, but this didn't happen in isolation. We are honored to be part of the industry team developing this historic telescope.

Under NASA's leadership at Headquarters and the Goddard Space Flight Center, and with the significant contributions of NASA's Johnson Space Center, Marshall Space Flight Center, and the Jet Propulsion Laboratory, as well as their international partners, our nationwide industry team has overcome immense engineering and technological challenges in our efforts to develop the world's most powerful space telescope. The project also has benefited from the substantial contributions of the Space Telescope Science Institute (STScI), which serves as the Science and Operations Center for the mission and will ultimately manage Webb's data and operations. Ball Aerospace, Harris, the former Orbital ATK-- now Northrop Grumman Innovation Systems, Nexolve, and Raytheon have each made significant contributions to the Webb program.

We appreciate our close working relationship with Administrator Bridenstine and the NASA team. We also appreciate the diligent leadership of Mr. Tom Young on the IRB — his technical knowledge and program management experience will help ensure that we continue to take every step possible to appropriately reduce risk. The entire IRB is to be commended for their diligent and thorough review of the program.

Science

The IRB stated. "JWST is an observatory with significant complexity, risk and first time events necessary to accomplish established science requirements," and it was exactly right. NASA's James Webb Space Telescope is the largest and most complex astronomical science telescope ever built, and once launched, will be the world's premier infrared space instrument. Webb will build upon the legacy of NASA's Great Observatories, including the iconic Hubble Space Telescope.

Webb provides the essential next step in the search for life in space. NASA has built incredible survey telescopes like the Kepler Spacecraft and Transiting Exoplanet Survey Satellite (TESS) that see exoplanets, but in order to actually find signs of life, we must look even closer. That is exactly what Webb will do. Webb doesn't just stretch Hubble, it is a true leap ahead in technology and capability:

- Massive segmented mirrors and adaptable optics, that carefully unfold in space, provide a far more powerful eye than was previously possible to peer 13.5 billion years back to the creation of the first stars and galaxies;

- A deployable sunshield and sensitive instruments that operate at cryogenic temperatures to detect even the faintest light in the infrared, making it 100 times more powerful than Hubble; and
- An orbit 1 million miles from Earth that provides a cold and stable point to look across the universe.

Webb is a vital step forward as we seek to deepen our knowledge of the universe.

As the decadal survey stated, what we now call the James Webb Space Telescope is the top astrophysics priority. Webb will have four primary scientific missions: search for light from the first stars and galaxies that formed the universe; uncover the formation and evolution of galaxies; characterize the formation of stars and planetary systems; and study the origins of life. As a general-purpose observatory, one of the most exciting things about the James Webb Space Telescope is that it will help us answer questions we have not even thought to ask.

If Hubble's history is any indication, Webb's unique capabilities will change the way we view the universe. Like Hubble, Webb will reaffirm and solidify U.S. leadership in space, inspire the next generation of scientists and engineers, and transform our understanding of the origins of the universe. Webb's unique capabilities promise to be just as transformative for the next generation of astronomers and innovators.

Technology

From a technical standpoint, Webb is an incredible engineering feat that pushes the limits of existing technology and represents a significant step forward for the nation's space program. The team has constructed a telescope with a large 21-foot primary mirror and a sunshield roughly the size of a tennis court (40 feet by 70 feet). In the simplest terms, the larger the telescope, the more powerful it is. However, this telescope is so large that it cannot easily fit in a rocket. As a result, we had to design and build Webb like a piece of origami - with 18 hexagonal mirrors and a massive sunshield that can fold. After launch, Webb will slowly unpack itself in space as it progresses towards its operating location, 1 million miles from Earth, in an incredibly harsh environment. This is no easy task. The optical mirror, which faces away from the sun, will operate at a temperature of minus 388 degrees Fahrenheit while on the other side of the sunshield it will be +185 degrees Fahrenheit – a temperature swing of nearly 600 degrees. Building a telescope that can operate in such a harsh environment beyond the reach of satellite servicing requires extensive testing to ensure that it will operate as planned. While NASA was able to repair and refurbish Hubble, which is in low Earth orbit about three hundred and fifty miles above the Earth's surface, Webb's operational location means this team only has one chance to get Webb right.

Webb is so complex and advanced that many thought it was an impossible task. In fact, at least ten innovative new technologies had to be invented to make this mission a reality. Some of these innovations have already spawned "spinoff" technologies that have proven useful in other fields such as medicine, science, aerospace, and commercial applications.

For example, to accurately measure the shape of Webb's mirrors during manufacturing, significant new improvements had to be made in the area of wave-front-sensing technology. The resulting measurement device is called a Scanning Shack-Hartmann Sensor. This Webb-inspired sensor improvement has enabled eye doctors to get much more detailed information about the shape of a patient's eye in seconds rather than hours. In fact, at least four different patents have been issued as a result of innovations driven by the Webb telescope program. According to Dr. Dan Neal of Abbott Medical Optics Inc., "The Webb telescope program has enabled a number of improvements in measurement technology for measurement of human eyes, diagnosis of ocular diseases and has potentially improved surgery."

Additionally, laser interferometers designed to precisely measure each of Webb's mirrors to ensure that they effectively act as one large optic has led to commercial applications. One of the toughest challenges for Webb engineers was to find a way to test mirrors and composite structures at the incredibly cold temperature that Webb will experience in space. With desired precisions of nanometers, vibration is a constant problem. To solve that problem, 4D Technology Corporation of Tucson, Arizona developed several new types of high-speed test devices that utilize pulsed lasers that essentially "freeze out" the effects of vibration. These have had a wide range of beneficial commercial applications in the astronomy, aerospace, semiconductor and medical industries.

Current Status

I am pleased to report that all of Webb's major hardware components are now located at Northrop Grumman's Space Park facility in Redondo Beach, California where they will undergo final integration and testing. I have included a photo of the elements that make up Webb, all together in the high bay at Space Park. It is a great sight to see – we have worked hard for so many years to reach this point where we are assembling these major parts together and testing it to ensure mission success. The second picture shows the success we have had in building up the major subsystems of the telescope, and the remaining steps still before us.

The optical telescope element and integrated science instrument module, what is called the OTIS, is complete and fully tested. We are now focused on testing the spacecraft element that includes the sunshield. Once we have successfully completed the spacecraft testing, both parts of the telescope will be put together, tested and shipped for launch. As an aside, I would like to invite the Committee to come out to visit so that you can see the hardware up close, meet the amazing engineers and technicians working on the program, and gain a deeper understanding of the program's complexity.

Following the 2011 Casani Report and replan, the Webb program has been on budget and on schedule until the program entered the current integration and test phase. Throughout this time several thousand parts and sub-assemblies were successfully built, tested, and delivered to the next level of assembly.

As I mentioned earlier, Northrop Grumman recognizes that we have contributed to some of the program's challenges. We have taken the appropriate corrective actions. Calculated risks were taken in the development plan for Webb and we are all disappointed that the plan did not go perfectly. As emphasized in the IRB report, we agree that mission success is the top priority and we want Webb to be launched at the lowest cost and earliest date possible. Unlike a few years ago when there were multiple simultaneous activities going on as we worked towards launch, there is only one path of integration and testing now. Consequently, as the IRB highlighted, even small problems at this stage have larger ripple effects throughout the program.

Although we have encountered some issues recently, which I will detail later, it is important to not lose sight of the fact that the purpose of testing is exactly that—to find problems with the program now versus finding them after launch. We need to ensure that we allow the necessary time through final integration and testing to get it absolutely right and ensure that Webb is able to fulfill its potential.

Independent Review Board (IRB) Report

Again, Northrop Grumman takes very seriously the trust placed in us to build this incredible telescope and our responsibility to ensure mission success. We fully support the revised program plan that NASA has put forward based on the IRB's findings. Let me take a moment to describe some of the technical and programmatic challenges referenced in the IRB report, as well as the steps taken by Northrop Grumman and NASA to ensure we adhere to the updated program budget and schedule. I think it is important to address several items in this statement:

Propulsion Execution Issues

The spacecraft bus – one of the four major elements of Webb – provides the necessary support functions for the operation of the observatory, and is home to six major subsystems, including the propulsion system. The propulsion system contains the fuel tanks and the rockets that, when directed by the Attitude Control System, are fired to maintain the orbit. Unfortunately, some of the challenges that we have encountered with the propulsion system have been the result of human error and procedures. In June 2016, an incorrect voltage was applied, damaging the pressure transducers that help monitor spacecraft fuel levels. Using a complicated welding process, we installed new pressure transducers on the spacecraft bus before testing and integration could continue. This repair process required many detailed operations to be safely performed, assuring it would not threaten the spacecraft's operations. It was important to take the time to get it right.

In May 2017, during testing of the spacecraft bus, we discovered that several valves in the propulsion system's thruster modules were leaking. After completing all testing it was determined that 8 of the 16 valves did not meet spec and it was decided to remove all valves and refurbish them. We determined that the most likely cause of the leaks was an incorrect solvent used in cleaning procedures several years earlier. While we test, and test again, to identify and determine the root cause of these issues, which we did in this case, it nonetheless resulted in a several month delay to the schedule. In this instance, we simply did not have a clear enough cleaning process in place. As a result, we had to remove, refurbish and reattach the dual thruster modules. Additionally, in the course of our work on the propulsion system, a single thruster component was subjected to overvoltage, which required its replacement.

Although we may face challenges, one thing that I am immensely proud of is the Webb team's ingenuity and relentless pursuit of process improvement. A good example of this is when the Webb team deployed a new approach called induction brazing to reattach the thruster. The new approach was safer and faster than the previous method. In total, the unanticipated propulsion system issues added several months to the delivery and launch timeline. The good news is that the propulsion system is now checked out and ready for upcoming testing. All of these issues have been reviewed by our corrective action board and we have concurrence that everything is back on track.

Sunshield Complications

The detection of infrared light from very distant stars and planets requires the telescope to operate at extremely low temperatures. To shield the system's science instruments and mirrors from the sun's heat, Northrop Grumman developed a deployable sunshield. It is roughly the size of a tennis court (70 feet by 40 feet). The largest part of the entire observatory, it must fit within a rocket fairing 16 feet across. This is no small feat of engineering. This sunshield consists of five layers of aluminum and silicon-coated Kapton, which passively cools instruments to cryogenic temperatures. Each of the five layers are as thin as a human hair and must maintain precise separations upon deployment. In order to make certain the sunshield properly deploys in space, a gauntlet of strenuous tests must occur on the ground. Webb will orbit the sun at Lagrange Point 2, a location that is simply too far from Earth to be serviced, making it essential for us to test, re-test, and test again to ensure that we get it right. The largest driver to the recent schedule delays is that through rigorous testing, we have learned that it simply takes longer than anyone had anticipated to safely fold, stow and deploy the massive and delicate sunshield. We then had to incorporate this additional time throughout each subsequent fold, stow and deployment phase.

The program team was thrilled to complete the first sunshield deployment in October 2017. However, during this process we realized that one of the six membrane tensioning systems experienced a snag. This was quickly mitigated but required a redesign to ensure it will not occur again while on orbit. Further complicating matters, during testing, we also uncovered small tears in several locations where the tension cables attach to the membrane. These were quickly treated with a localized solution but we also discovered a few small tears in the sunshield membrane layers. Due to the size of the sunshield, it had to be elevated off the ground to remediate the issues. Technicians had to slowly maneuver various lifts simultaneously to access the sunshield. The unanticipated challenges of testing the sunshield, as well as the risk reduction activities (inserting membrane retention devices) adopted to prevent additional tearing during space deployment increased the delivery and launch date timeline. The good news is that after multiple reviews by many parties, we have confidence that we have made all the necessary engineering changes to the unfolding mechanism to ensure that the sunshield will deploy without tearing the delicate membrane. Although disappointing, the sunshield obstacles were readily addressable and did not threaten the program's ultimate viability, but they did contribute to further schedule delays.

At the end of April 2018, following what appeared to be a successful acoustic testing of the spacecraft element, visual inspection revealed that a small fraction of the sunshield membrane fastening hardware that hold the retraction springs loosened during testing. During assembly that was performed several years back, engineering needed to deviate from the standard process because the original fasteners were sharp and tearing the covers. The redesigned fasteners did not threaten the membrane, but they were not as secure as the previous fasteners. When exposed to the spacecraft element acoustic testing, some became loose. A design modification is being incorporated to address this finding. This issue added significant time to the program's schedule because of the complexity of the sunshield. Nevertheless, by identifying the issue and fixing it now, we are focused on ensuring the sunshield will work on orbit.

Optical Telescope Element and Integrated Science Instrument Module (OTIS)

OTIS is Webb's science payload. During the vibration testing of OTIS at NASA's Goddard Space Flight Center we concluded that more tests at slower speeds were necessary. Furthermore, although some previous tests had been planned in parallel, it would reduce risk to do them in sequential order instead. I mention these not to point out any mistakes, but rather to note that we need to allow a program of Webb's significance to the scientific community and importance to our nation the necessary time to test to ensure that we get it absolutely right.

Next Steps

As we move closer to the revised launch date, the next few months will be critical. Our immediate focus is the integration and testing of the spacecraft hardware (spacecraft bus and sunshield). The spacecraft elements then must successfully undergo acoustics, vibration, and thermal vacuum testing followed by post-environmental deployment and stow tests. Next we must integrate the completed OTIS and spacecraft elements before putting the full observatory through the final testing phase. After the electrical, acoustics, vibration and deployment tests are concluded, Webb will be prepared and shipped to the launch site in French Guiana, to complete its final site processing. Although important work remains, we are in a vastly different position than during the 2011 replan. All the hardware is complete. All the inventing is complete. The technical and engineering feats of creating the unique pieces of Webb are behind us. With all the hardware done, the once wide range of activities (and program variables) has now narrowed to a single path in integration and testing. However, every little deviation has larger impacts throughout the program as each piece is brought together for the first time. While risks remain, we believe we have an appropriately risk-managed program plan defined that is executable.

Corrective Actions

Building a one-of-a-kind scientific instrument is extremely challenging. Northrop Grumman is focused on mission success and supports the NASA defined plan based upon the IRB. We are implementing the recommendations.

The women and men of Northrop Grumman are doing Webb's final testing and integration, and we are proud of their commitment to Webb's mission. We recognize we have had some human errors, which for a one-of-a kind program of this complexity are to be expected. As the IRB identified, "Human errors must be minimized; however, they cannot be totally eliminated." In order to minimize the occurrence and impact of "human mistakes" as the IRB identified them, we are implementing these specific improvements:

Processes – assure they are well defined, current, accurate, implementable and not subject to interpretation.

Northrop Grumman stood down operations and performed an independent set of process reviews, which included feedback from those performing the processes. This resulted in rewrites of a number of procedures that were found to create the potential for errors. To further enhance robustness in I&T procedures, Northrop Grumman will be incorporating cross-program independent reviews of the table top and pre-task briefing processes.

Personnel certification – assure people capable of performing the task at hand.

In addition to formal training and certification for employees interfacing with the spacecraft hardware and the associated integration and test equipment, we are making certain that operations that are especially critical also require individual performers to have previously demonstrated expertise and prior successful execution of the specific type of critical process task. So, for example, a certified I&T mechanical technician would require an additional level of experience verification before working on the tasks associated with the sunshield membranes.

Discipline – assure individual accountability and follow the process, call a halt if the process appears questionable.

All employees supporting JWST are aware of their individual responsibilities to assure mission success through all of their actions, including thorough, careful and precise compliance with the defined processes. This is an ongoing part of the discussions with the teams. A core part of that responsibility is to speak up if the employee sees, or even suspects, that there may be something that is not correct, or that may lead to a problem. A process is in place to recognize and reward performers who say ‘Stop’. Additionally, we have brought in leadership from outside the program to meet with the various performing organizations (home-rooms of personnel assigned to work on JWST) to solicit feedback and to work with the program to incorporate that feedback into actions designed to enhance mission success.

Failure-proof “safety net” – testing, independent analysis, inspection.

We have taken steps to enhance the “safety net” around the program activities. Two organizations, in particular, have specific authorities and accountability for independent action. The Mission Assurance organization is independent of the program, and has full authority to stop any process it deems to be unacceptable. Members of the Mission Assurance team are assigned to be present with the technicians and engineers at all times when integration and test efforts are underway. The Engineering organization has the responsibility to conduct independent analyses to ensure that the right talent is reviewing critical decisions and that any concerns are immediately addressed. Just as we are focused on the training and capabilities of the team members assigned to the program, we also are assigning Mission Assurance and Engineering representatives in whom we have confidence in providing this “safety-net” process.

As the IRB recommended, NASA is undertaking a design audit aimed at identifying potential embedded risks, such as the fasteners previously mentioned. Northrop Grumman is supporting that audit. This activity will look at the pedigree of all the hardware and seek to identify other areas where lower level testing was deferred in order to identify possible additional challenges. We have also added more senior technical and management resources in engineering and leadership to ensure the Webb team can effectively meet the revised schedule demands. Many of the steps we are taking to integrate and test Webb hardware have simply never been done before. We are committed to providing the necessary training and resources to achieve mission success. We are undertaking additional reviews, strengthening communication across our team and ensuring that the people, process and tools are in place for Webb to fulfill its scientific promise.

There is frequent, in-depth dialogue between NASA’s Science and Mission Directorate’s front office and Northrop Grumman senior management. In addition, NASA has decided to place additional Integration and Testing personnel and senior project management residents at Northrop Grumman, a crucial step. All of us at Northrop Grumman recognize our responsibility and the trust that you and the American people have placed in us to complete this important mission.

NASA's new launch schedule includes a 9-month schedule reserve. Given our current view of the remaining risks, we believe this provides adequate contingencies to achieve a successful launch in March 2021. Since the beginning of development, the Webb team has solved a wide array of difficult engineering and technical challenges. Most of the complex issues are now behind us: we have completed the construction of the spacecraft, the OTIS, and the sunshield. All those components are now ready for integration and final testing.

When I speak with the Webb team, everyone is laser focused on delivering a system that we are confident will perform its mission. The team also understands the importance of delivering the telescope to the launch site at the earliest date possible with the lowest cost, while not in any way jeopardizing mission success. We are all eager to see Webb's successful launch and activation and the amazing scientific discoveries it will yield for decades to come.

As of today, we are employing more than 400 engineers, technicians and support staff for integration and testing at our Space Park facility in Redondo Beach, California. To reach this point in the program, we have partnered with 511 suppliers across 39 states to complete the work to date. The reach of Webb is truly worldwide, harnessing the best technical expertise around the globe to fulfill this unprecedented engineering and science endeavor.

Conclusion

While we are incredibly proud of the technical achievements on the Webb program to date, we recognize that we have contributed to the schedule delays. At every level, from our technicians to our corporate leadership, Northrop Grumman is fully committed to mission success. I want to assure the Committee that we have worked with NASA to develop a high confidence plan for completion of the program. This revised plan has the benefit of additional testing, enhanced experiences and numerous internal NASA, Northrop Grumman and independent reviews. We have learned from the recent challenges of the integration and test phase of the program. We have implemented the necessary corrective actions and put the people, processes and tools in place to better manage the remaining risks on the program.

Let me take a brief moment to specifically address the brilliant women and men across the James Webb Space Telescope program at NASA and in industry. Thank you for your hard work and dedication. Although we have had challenges, what you have already achieved on this program is absolutely incredible and deserves to be recognized. Your continued diligence, creativity and commitment to getting it right will ensure that Webb is a success.

This Committee's decades long, bipartisan support is essential to keeping the program on track. As difficult as this path has been, we should all take great pride in the incredible scientific contributions that Webb will deliver; the technological advances it will enable; and the millions of young girls and boys who will be inspired by its discoveries. Importantly, it will serve to advance our nation's leadership in physics. Again, we would be honored to have Members of the Committee visit the telescope's integration and test facility in Space Park before it is placed on a ship, travels through the Panama Canal, and is launched from French Guiana on its path to astounding scientific discoveries. We look forward to continuing to work closely with NASA, Congress, and our industry and international partners as we work towards making Webb the successful program that I have no doubt it will be.