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Chairman Babin, and Members of the Committee, thank you for the opportunity to discuss NASA's Deep Space Exploration efforts on this, the 31st anniversary of astronaut Kathy Sullivan's space walk. On this day in 1984, Dr. Sullivan – current NOAA Administrator - became the first US woman ever to see the Earth from that unique vantage point. I thank you for your support of our Nation's space exploration efforts.

It is an honor for me to represent Purdue, a public land grant university, educating the next generation of explorers. I find the students of today to be part of a curious, passionate and dedicated generation. I see this everyday with the students and my three children. These young voters are ready to build and create a better future for all of us.

And, as a former NASA team member, I want to express my utmost respect for the NASA / Industry team's accomplishments in the current environment. This team is working on a scale larger than Apollo with a constrained budget. Much like today's students, their enthusiasm and dedication to the mission is evident every day and sets the leadership example.

The National Aeronautics and Space Administration Act of 2010 clearly provides the goals and objectives for future space exploration, including the use of the International Space Station for human exploration research, testing and, "enabling an expanded commercial presence in, and access to, low-Earth orbit...", also development of the Space Launch System, Orion, launch support infrastructure, and a balance of human and robotic missions. These are the key elements needed to continue this Nation's space exploration enterprise.

In the 2014 “Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration” from the National Research Council, it is recommended that NASA:

1. “Commit to design, maintain, and pursue the extension of human presence beyond low earth orbit...”
2. “Maintain long term focus on Mars as the “horizon goal” for human space exploration...”
3. “Establish and implement the pathway approach...”
4. “Vigorously pursue opportunities for international and commercial collaboration...”
5. “Engage in planning that includes mission requirements and a systems architecture...”

These recommendations from diverse perspectives should serve as the basis for an overall strategy and plan of human exploration, a plan that Congress and the Administration should adequately fund.

I believe we are at a critical juncture in our exploration efforts. As we continue missions to extend our presence further into the solar system and beyond, we must build the foundational capabilities for humans to go onward. We must effectively utilize humanity’s principal technological achievement, the International Space Station, as an exploration test bed and valuable research facility, and we must seed the initial phases of commercial space travel.

Future generations, as well as today’s societies, are dependent on the development and exploration investments being made today. Think for a moment what it would be like if all cell phone service ceased, satellite weather imagery ended or, medical research on health and aging, happening right now in zero-g, was stopped. Investments in space projects provide us with the capability to continue the human quest for discovery. They let us apply those discoveries here on Earth, enriching private industry with new technologies, new markets, and valuable opportunities.

There is no doubt that among all of the important priorities that this Nation and others need to address, space exploration is valuable, yet its costs need to appropriately fit within funding constraints. It is also clear to me that long-term sustainability of exploration is at least partially dependent upon increasing the space economy and fostering commercial opportunities.

Given the budget instability and continuous policy debates, the NASA / Industry team is making great progress. The team is dedicated to building all systems as safely as possible, as soon as possible, and as cost efficiently as possible.

The Space Launch System, its Orion capsule, and their support infrastructure together create the needed foundation for US expansion beyond Earth's boundaries. Each of the Programs is making significant progress, despite substantial fiscal obstacles. The team is diligently working to build this powerful launch vehicle, and its spacecraft, to reach Mars and eventually, go beyond. The Space Launch System has successfully passed its Critical Design Review, the milestone that approves the final drawings and manufacturing processes for the entire system, along with engine tests, booster tests, and structures that were flight-tested last December. The Orion capsule completed its first flight test last December, and is proceeding to systems testing. Orion's European Service Module is on track for the first flight. Launch infrastructure is on schedule - the retooling of Vertical Assembly Building has begun, along with the launch support structure being outfitted.

Keeping these critical Programs on schedule is essential for 2 reasons. (1) The U.S. needs to continue to maintain our global leadership in space. We must leave this legacy of leadership for the next generation. (2) Schedule equals cost. Maintaining funding stability, and therefore schedule, is essential to minimizing the cost of these Programs. These Programs are significant resource investments in terms of people and money. It is imperative that we diligently work to develop and operate the SLS and Orion as cost efficiently as possible. NASA's leadership, plans, and management implementation reflects the need for cost efficiency, with reduced insight / oversight, reduced management / integration overhead, all while carefully maintaining and improving crew safety over previous systems. For example, NASA has reduced, by almost an order of magnitude, the systems integration funding requirements, as compared to previous human spaceflight programs. NASA is applying the lessons learned from its project and programs such as DC-X/XA. NASA is also working to integrate the latest in technology, such as advanced manufacturing, to reduce costs while maintaining or improving performance and safety.

This team is being asked to develop hardware to go further into space than ever before, with new levels of reliability and safety, all on a flat line budget. Each year the budget policy debates, continuing resolutions, and late year appropriations result in endless, multiple planning scenarios. This is in addition to the challenges of technically complex programs.

Budget stability is THE major issue in executing these programs. All players in the appropriations process have a stake in maintaining budget stability. NASA and their

industry partners are being asked to develop unprecedented, critical capabilities within a contentious, constrained, and ever changing budget environment. How can they resolve complex technical issues, hold schedule, and predict flight dates with pin point accuracy if their budget is constantly in flux?

Budget stability is driven from 2 basic aspects. First, our Constitutional appropriations process requires an Executive Branch budget proposal and Congressional appropriations for NASA. The very nature of this debate requires the NASA / Industry team to develop a set of Program plans to meet the proposed budget, and then be prepared for significantly modified Congressional appropriations. This debate alone causes the team to develop significant program planning and execution options and is the major component of budget stability.

The second aspect of budget stability is the recent history at the National budget level of continuing resolutions, government shutdowns, brinksmanship of the appropriations process, and tardiness in receiving final appropriations. These all lead to cost and schedule impacts to the Programs, in addition to the continuous debate between the President's Budget Request and Congressional appropriations.

This unpredictable process leads to significant inefficiency. The need to constantly have backup plans for each potential appropriations outcome, different budget planning levels, along with flexible workforce blueprints, all but invites confusion and miscommunication – at all levels, from the Administration to the technician on the manufacturing floor. Let me be clear, I am speaking of inefficiency **externally** imposed on the NASA / Industry team. Yes, appropriations increases are obviously helpful, and have been vital in the Programs' progress to date, but budget stability is key to a well-executed Program.

NASA diligently manages risk, cost and schedule through daily, direct contractor interaction, periodic element / program reviews with detail discussions of technical and programmatic progress, issues, and risks. Reviews are conducted at all levels of the Programs, at the Exploration Systems Division, and Human Exploration and Mission Operations Directorate levels. Technical status and risks are addressed and fed into the budget planning cycles. During my tenure, NASA provided OMB a bi-weekly briefing on the status and issues of the SLS, Orion, and Ground Systems Programs. Similar status briefings were provided upon request to House and Senate staff. All of these steps were utilized along with the Joint Confidence Level analysis.

Joint Confidence Level is a model / risk based approach to assess potential technical and programmatic uncertainties and their possible sensitivities / impacts to the cost and schedule of a project or program. The models analyze project risks, and budget /

schedule uncertainties to develop combined probabilities of success from cost and schedule viewpoints. In the past, NASA has used the 70% Joint Confidence Level as the Agency commitment to Congress as required by Public Law 109-155 (Nunn-McCurdy). In this analysis, NASA uses the President's Budget Request as the budget baseline, and makes assessments assuming higher and lower budget estimates to understand the impact on the schedule. This has proven to be successful in robotic mission program planning and commitment mainly due to specific expected launch dates for science objectives, and therefore a known life cycle of a project or program. NASA has been working to apply this process to human spaceflight programs; however, this is proving difficult due to the longer duration of these programs. Large human spaceflight, single-project Programs, that are long term investments, to be used over multiple decades, have relatively undefined life cycles. These Programs are subject to greater budget planning uncertainty due to overall economic conditions and Presidential / Congressional policy changes. The September 29, 2015 NASA IG report on the NASA JCL Process states "...JCL policy may not be suitable for single-project programs...". This caution should apply to SLS/Orion/Ground Systems use of the JCL process. I must add that during my tenure, the process of analyzing the detail program plans, risks, sensitivities, and uncertainties has resulted in more thorough planning for SLS.

In the most recent announcement of Orion, and the Agency approval of the Key Decision Point – C, it was noted that the new crewed flight date is April 2023. This date is based on model analysis of projected costs, risks and uncertainties, of the detailed program plan, including expected budgets, and calculating a combined 70% probability of success. **This is only an estimate.** NASA openly stated that they continue to work toward the 2021 date.

During my tenure, NASA would continue to work toward an earlier date, what is known as a management agreement, to keep sufficient focus on doing what is needed, minimize unnecessary work, and thereby execute the Program as efficiently as possible. All of this while being very careful to make sure safety and technical decisions are sound. In Orion's case this is the 2021 crewed flight date.

NASA is an Executive Branch Agency that works with and responds to the Office of Management and Budget (OMB). Therefore, NASA communications with the Legislative Branch are coordinated with OMB and the Office of Science and Technology Policy. Budget planning follows a typical process, of bottoms-up development and top down assessment to assure budgets are developed based on program realities, Human Exploration and Operations Mission Directorate priorities, and Agency priorities. Once the Agency has developed a budget request, it is then transmitted to OMB for review and negotiations within National priorities to support

the Presidents Budget Request submittal to Congress. During my tenure, OMB was involved only at the Agency level and not directly in the detailed Program budget prioritization.

In summary, the biggest challenge in developing the Space Launch System, Orion, the launch support infrastructure, and Commercial Crew is budget stability. Managing these Programs efficiently and effectively is the result of the dedicated NASA / Industry team across this country, and the international partners. The team demonstrates every day their ability to deliver. NASA carefully manages the Programs at all levels, recognizes the cost constraints, and most importantly assures the future safety of our space travellers.

The government funded Lewis and Clark expedition helped open the frontier for the commercial development of rail transportation and other opportunities to the West Coast. Today, NASA is opening the frontier of space and helping to build the space economy.

Thank you for your time and attention. I look forward to your questions.