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Chairman Cruz, Senator Peters, and Members of the Committee, thank you for the opportunity to discuss with you my thoughts on U.S. leadership in space exploration. Our daily lives are inextricably interwoven with space-based assets, including GPS, communications, systems for weather monitoring and prediction, and intelligence and defense. Beyond these applications, our national human spaceflight and space science programs directed by NASA and executed in partnership with industry provide opportunities for discovery, scientific advancement, geopolitical influence, emerging technology, space commerce, and education. In addition, NASA stands at the cusp of a new era of exploration in deep space. For the first time in human history, we are poised to answer some of humanity's biggest questions: "Where did we come from?" "Where are we going?" "Are we alone?"

This hearing is entitled "NASA At the Crossroads". I think of it as "NASA In Transition" – or actually, transitions. By this I do not mean the upcoming Presidential and Congressional transitions – to which I will return – but first, a transition that is reflective of the constant change that is all around us – in technology, manufacturing, business models, science, and regional interests, and the global shifts in governance, geopolitical dynamics, the exercise of power, and changes in international economic strength. NASA's space exploration programs have been impacted by or have impacted every one of these global factors. Against this changing backdrop NASA must plan for what is, ultimately, an optimistic vision of the future. A disruption in programs stemming from abrupt change in space policy derails this process and jeopardizes that future. Our national destiny and our ability to guide it rests on decisions made yesterday, today and tomorrow to sustain and advance a flexible and multifaceted exploration architecture - such as the one currently being put into place - that will assure U.S. leadership in space over the decades ahead.

I am pleased to share these perspectives in my capacity as Executive Director of the Coalition for Deep Space Exploration, which is the "voice" of America's industry working on a range of human exploration and space science missions. The Coalition

represents nearly 50 large and small businesses building these deep space capabilities. I also bring the perspective of a small business owner and entrepreneur, a former human spaceflight operations manager for the International Space Station (ISS) Program (Boeing, a member of the Human Spaceflight Committee at the National Research Council, and a current member of the Executive Committee, Space Studies Board of the National Academies of Sciences, Engineering and Medicine.

The International Space Station

America's architecture in deep space begins near the Earth, in Low Earth Orbit (LEO), where a second transition is taking place. Across 50 years of government investment in space exploration and science, and in collaboration with industry partners, NASA has matured technologies, techniques and capabilities that are being transitioned to the private sector. New transportation systems dedicated to shuttling cargo to the ISS have come on line. Crewed flights will begin in 2017-2018. The transition of space transportation services to industry, under a NASA program where industry partners have benefited from government development funding and technical support, coupled with the availability of the ISS as a research and development platform, has attracted investors interested in establishing commercial enterprises in LEO. The growth of these entrepreneurial interests is laying the groundwork for finally expanding the sphere of human economic activity off the Earth, into LEO. As this happens, NASA can turn its attention more fully to deep space exploration.

Here, too, the ISS plays a crucial role. In addition to its facilitation of science, international collaboration, and commercial activity, the ISS is a mission-critical technology and engineering test bed for deep space systems - for example, the development of a next-generation Environmental Control and Life Support System (ECLSS) needed for deep space habitats. It is also a living laboratory for studying how human beings live, work, thrive and survive in space. Ensuring the fullest utilization possible of the ISS through 2024, with continued study of the feasibility of extension beyond that time, is of paramount importance.

Deep Space Exploration

Since the end of the Shuttle program, NASA human spaceflight has been in yet another transition – from two operational programs (Shuttle and ISS) to one of long-duration operations on the ISS and another engaged in development of deep space exploration systems and the ground infrastructure needed to support them. Though tremendous activity is ongoing, development programs lack the visceral or visual punch of Shuttle launches. Virtually all of the planning and development activity is under the radar, invisible to the public - and to policy makers – until major milestones are reached, such as the successful Exploration Flight Test (EFT-1) of the

Orion spacecraft in December of 2014 and the final test of the five-segment Space Launch System (SLS) boosters last month. On behalf of the companies that I represent here today, I wish to thank the Congress and this committee for your sustained commitment to development of the SLS super-heavy rocket, the Orion crewed exploration spacecraft, ISS crew and cargo transportation, the James Webb Space Telescope (JWST), the start of the deep space habitat development, as well as the ongoing operations of the ISS and the recent triumphs of science missions such as New Horizons (Pluto) and Juno (Jupiter). Such support takes foresight and patience, and I believe the American people will soon begin to see the full range of benefits and tremendous impact of these investments in our future in deep space.

Looking ahead, we see a continuing need for constancy of purpose, vision, and commitment to pursue steady progress toward America's future in deep space across all of the transitions NASA faces. The long-awaited moment when our solar system is re-opened to human exploration and development will become real in a little more than two years as the first integrated test flight of Orion and SLS, Exploration Mission 1 (EM-1), lifts off in 2018. In 2021, NASA will return American astronauts to deep space as they travel in Orion, powered by the mighty SLS with an Exploration Upper Stage, past the Moon and farther into space than any human being has gone before. These initial flights will open a new era as NASA and its industry partners begin assembling a true deep space infrastructure, with habitats enabling crewed missions in the lunar vicinity, and the development of long distance cargo carriers powered by solar electric propulsion (SEP). Transit of cargo and people between the Earth and cislunar space will commence, inviting participation from current and new international partners and enabling commercial interests in deep space as new capabilities come on line. Eventually, once we have developed sufficient skills and validated our systems, procedures, operations concepts, and technologies, we will push deeper into space, to Mars.

SLS and Orion are being built for decades of use, not just a mission or two. The Orion crew vehicle is capable of sustaining astronauts for up to 1,000 days – a mission to Mars – provided sufficient consumables are available. In addition, there are powerful reasons for the use the super-heavy lift SLS for exploration missions. Future Mars landings, for example, require at least the equivalent mass of the ISS launched from Earth. Assuming NASA is able to incorporate new technologies such as 3D printing and technical approaches to reduce propellant boil off during transit, this mission would require 6 to 7 SLS vehicles with 130 metric ton lift capability. In contrast, considering only the mass requirements, it would take up to 30 launches of smaller, commercially available rockets to conduct a similar mission. The cumulative risk of mission failure from that many launches compared to the number of SLS launches is significantly increased, assuming similar launch probabilities Simply put, the more launches, the higher the overall probability of failure. In the case where the mission is dependent upon the order in which launches occur – as in an assembly sequence – the problem is amplified; failures early in a launch sequence

may disrupt the rest of the sequence until a workaround can be found or a replacement payload developed. As a result of these factors and others, the SLS - and the Orion crew vehicle - are key enablers for America's deep space future.

As EM-1 draws near, the opportunities for human exploration and planetary science mission that these systems will make possible are inspiring the imagination and interests of governments, industry, and the public. There is talk of international lunar science missions, lunar surface operations, concept development of a Mars base camp in orbit, plans for joint science and exploration missions, and proposals for new technologies to enable humans to explore Mars sooner rather than later. Planetary missions, harnessing the unparalleled capability of SLS to cut travel time to outer planets in half, such as the Europa mission, are on the drawing boards. Human missions, making use of the capabilities of the Orion crewed vehicle to carry crewmembers to multiple destinations in the solar system, provide tremendous flexibility over the next 20 years. As we lift our gaze beyond the ISS into deep space – to the Moon, to asteroids, and to Mars, to planetary science missions and deep space telescopes that will not only see all the way back to the Big Bang, but tell us for the first time in human history whether we are alone on the Universe –the realization of these opportunities and more that we cannot yet imagine has never been closer than it is right now.

Political Transition: Preserving the Industrial Base

In my current position, I represent a segment of the U.S. industrial base focused on aerospace, with members that range from large scale systems engineering and development companies with decades of in-space experience - such as our founding members Lockheed Martin, Boeing, Orbital ATK, Aerojet Rocketdyne, and Northrop Grumman - to entrepreneurial startups such as Made In Space, currently testing the potential for using 3D printing in space missions onboard the International Space Station. Our members also include Jacobs Technology, an experienced aerospace company supporting upgrades to the launch and processing capabilities at the Kennedy Space Center; Axiom Space, a commercial space company focused on orbital habitats; Cain Tubular Products, a very small, family-owned company with a 50 year heritage in the space program, and Futuramic, a Detroit company that retooled and rebuilt itself after auto manufacturing left that city into an engineering and manufacturing firm that contributes substantially to NASA's deep space programs.

Our membership is rich with capabilities, innovation, technologies, and dedication to programs that they see as the "the tip of the spear" of United States achievement and leadership in the 21st century and beyond. The U.S. space industrial base is key to enabling our national security, civil and commercial space programs, with skill sets that overlap all three of these domains. The supply chain for human space exploration alone - SLS, Orion, and Exploration Ground Systems - is distributed

across all 50 states and is made up of hundreds of companies, ranging from large contractors with thousands of employees to hundreds of small, privately owned businesses. This large and diverse industrial base ensures the kind of competition that drives technological innovation and ensures American competitiveness.

Small businesses, in particular, bring technical innovation, creativity, expertise and rapid adoption of new approaches to the American deep space enterprise. Space exploration is exacting and technically challenging, requiring years to build workforce expertise. Large companies may have some flexibility to adjust to fluctuations in program funding; however smaller businesses often do not. As a business owner and entrepreneur I can attest to the vulnerability of small firms. It is not unusual for such businesses to have an operating window of only 90 to 120 days before cash flow becomes critical. Major changes in space policy and direction, such as happened between 2009-2011, inevitably result in shuttered offices, empty factory floors, and the ruination of many businesses. Yet, with consistency of policy and contracts, these same firms are the ones most likely to generate new inventions and patents. They also represent the vast majority of new company startups, drive most job creation in the U.S., and exemplify the enterprising spirit that powers our economy and our nation. NASA's SLS and Orion programs have sustained hundreds of companies in this sector, enabling innovation, new technology, new production methods, and the achievement of entrepreneurial dreams. In return, these companies have provided critical components needed to lead the way back into deep space.

The Rationale for a Government-Led Space Exploration Program

Recently, an argument for transition from government to private sector programs for deep space exploration has been put forth. This is not a good idea. In its most common form it reduces the entire value of NASA's human space exploration programs to an economic equation. It disregards the intangible and incalculable benefits that have been conferred on the nation by a government-led program: Collaboration between governments, the free return of scientific, engineering and technical data to all citizens, the establishment of a pre-eminent national presence in deep space (with implications for national security), preservation of the aerospace industrial base, and national aspiration and pride stemming from collective, extraordinary achievements. It is true that these benefits are impossible to assess by economic means. But the counterargument is too narrow in scope, focused on the cost of a launch vehicle, the cost of a crew capsule, the cost of operations, and the cost of a mission. In a time of downward pressures on discretionary accounts, cost is certainly an important factor. But it is clear that a robust human space exploration and science program has returned benefits to the nation that go far beyond a simple cost equation or Return on Investment (ROI) calculation.

It may be worth pointing out that none of the opportunities before us now – in LEO or in deep space - would have been possible without government programs in human exploration and science over the past decades. To continue building upon the progress we have made, the bilateral, bicameral support that has characterized these programs must continue. To those who would ask, "what has the money bought us?", we can answer: America is the only nation on Earth to have visited every planet in our solar system. America is the only nation on Earth that has leveraged 50 years of investment in human space exploration into the private sector, where it has disrupted industries and opened the door to entrepreneurial interests in space. America is the only nation on Earth striving as a matter of policy to expand the sphere of human economic influence beyond the Earth. America is the only nation on Earth bold enough to envision and then build a deep space transportation and infrastructure system for the solar system. America is the only nation that has successfully led an international coalition to build and operate a multi-decade space station. And soon, America will be the only nation capable of transporting astronauts to the Moon and beyond.

The Coalition I represent endorses full funding for NASA's ISS cargo and crew transportation services and includes members who participate in both. We also support government-led programs pushing human presence into the solar system over distances and at a scale for which no business case exists. This is not an "either/or" scenario; rather it is a case-in-point for the evolving roles of government and private industry in the American space program. The funding for SLS, Orion, JWST and other systems also pays for facilities, refinement of engineering expertise and technique, development of new technologies, stimulation of commerce, a rich international collaboration, and educational opportunities, among other core NASA functions. Our national space program enjoys – and must sometimes negotiate among - a wide range of stakeholders. NASA's challenging and diverse portfolio represents an attempt at consensus and compromise among those stakeholders that has been painstakingly developed on a bilateral, bicameral basis across the 2005, 2008, and 2010 NASA Authorization Acts in which this committee has played a significant role. Looking back across a decade characterized by transition, progress, and opportunity, it is evident that this course has been a wise, measured, and effective one.

Going Forward: Essential Elements

A government-led program that opens the frontier beyond Earth for ourselves, our international partners, commerce, and science is crucial if we wish to control our national destiny and lead the way to a future guided by American values and freedoms. For the past decade there has been bipartisan consensus on the path forward for human exploration of deep space, using NASA's new Orion crewed spacecraft powered by the super-heavy Space Launch System (SLS) rocket. In my view, there are some essential elements that should be maintained, and other that

may be considered, in order to ensure that U.S. leadership in deep space human exploration and science continues:

- That to the greatest extent possible, close alignment between the new Administration and Congress should be developed and maintained on space policy, priorities and funding levels that build on the bipartisan consensus reflected in the 2010 NASA Authorization Act and in the annual appropriations adopted over the past six fiscal years. Budget instability has been a tremendous challenge, requiring rework and - across each year of development. For the last several years the President's budget request and Congressional appropriations have been out of sync, forcing NASA and its contractors to work at a slower pace under greater budget pressure for the first part of the year until Congressional appropriations are set at the necessary levels. This draws out the program and drives up costs. Reduction of political uncertainty together with budget stability would significantly reduce costs and clarify planning.

- That a restatement be made that it is the policy of the United States to expand permanent human presence beyond low Earth orbit…and that it shall explore beyond Earth orbit using the national assets developed for such purpose: The super-heavy exploration rocket – the Space Launch System – and the exploration crewed spacecraft, Orion.

- Ensure funding sufficient to complete development of NASA's human exploration systems: SLS (including the Exploration Upper Stage beginning on EM-2), Orion, and Exploration Ground Systems, and maintain the schedule for EM-1 in 2018 and EM-2 in 2021.

- Ensure funding for development of a Deep Space Habitat, with sufficient follow on funding to carry out testing and eventual deployment of that habitat while the International Space Station is still operational, so that there will be no "gap" in human spaceflight missions.

- Enable NASA to fund mission planning using SLS and Orion for EM-3 through EM-10 throughout the 2020's, with funding that permits investments to be made for early development of capabilities important to the successful completion of these missions.

- Provide NASA the authority to negotiate with international partners on contributions to EM-1 through EM-10..

- Extend indemnification for SLS and Orion, extending coverage as provided to the Space Shuttle program in a manner similar to the coverage provided for commercial launch providers under the CSLCA.

- Restate authorization for NASA operations on the International Space Station through 2024, ensuring its use as a critical test bed for deep space exploration, science, and as a catalyst for commercial development of LEO, and encourage continued analysis of extending ISS utilization beyond that time.

- Ensure that cargo and crew transportation services for LEO are fully funded. Focus these programs on supporting NASA's low-Earth orbit activities and missions without sacrificing safety and mission assurance.

- Ensure robust funding for successful planning, execution and completion of space science missions, including completion of the James Webb Space Telescope and Mars Insight mission for 2018 launches, as well as continued execution of missions such as Juno and New Horizons, and development of upcoming planetary missions to Mars, Europa, and other bodies in the solar system.

- Ensure increased funding for Planetary, Astrophysics, and Heliophysics space science accounts.

- Where appropriate due to payload mass or reductions in travel time, make use of SLS to launch space science missions.

- Adopt the highest possible authorization levels drawn from the House and Senate FY 2017 Commerce-Justice-Science Appropriations bills, including a NASA top line of at least $19.5B, with increases in the out years to keep pace with inflation, at a minimum.

Mr. Chairman and Senator Peters, thank you again for the opportunity to address the committee on this important topic today. I encourage you to also review the Coalition's recent white paper, "A Space Exploration Roadmap for the Next Administration," which I respectfully submit for the record. Our members are deeply committed to the success of NASA's human exploration and space science programs, and we couldn't be more excited about the upcoming milestones on the road to returning American astronauts to deep space and exciting scientific discoveries in the years ahead. Thank you for this opportunity to speak, and thank you for your time and attention. I look forward to your questions.