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FROM HERE TO MARS

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED THIRTEENTH CONGRESS

SECOND SESSION

APRIL 9, 2014

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ONE HUNDRED THIRTEENTH CONGRESS

SECOND SESSION

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FROM HERE TO MARS

WEDNESDAY, APRIL 9, 2014

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 10:04 a.m. in room SR–253, Russell Senate Office Building, Hon. Bill Nelson, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Senator NELSON. Good morning.

Thank you all for coming. We have held, in this committee, a number of hearings on space exploration. We've highlighted how the technologies developed benefit our lives here on Earth. We've discussed the potential dangers of near-Earth objects. We've heard about the growing commercial space industry. We've explored how NASA's efforts will eventually allow us to put an American on Mars. We even heard last year, via downlink, from the ISS about some of the amazing work that is going on up there. And all of that means that we have plenty of chances to share the excitement about the space program.

But, look. It's an empty dais. And it'll just be Senator Rubio and me when he arrives. And he's filling in for Senator Cruz who understandably is in Texas today for the memorial service at the Army base there.

So we need to generate some excitement, again, among the American people. And, of course, things give us a problem. Now we have the tensions with Russia. Is it going to impact the space program?

As we've seen before, the exploration of space has been the one area in times of geopolitical conflict that we can rise above that. So NASA's success is not only a product of tremendous investments in technology, but also in international cooperation. And I believe that we need to continue that tradition.

Geopolitics may or may not affect the nation's exploration mission. It certainly affected it back at the dawn of the Space Race, because of the launch of Sputnik. NASA was designed, in part, to demonstrate to the world the power of the American way of life.

NASA's 1958 Organic Act signed by the grandfather of Susan Eisenhower, President Eisenhower, stated that U.S. space activities should contribute to international cooperation. When Secretary of Defense McNamara and NASA Administrator Jim Webb proposed

a lunar mission to the Kennedy administration in 1961, they argued that "Our attainments (in space) are a major element in the international competition between the Soviet system and our own."

And yet, NASA was a vehicle for working with the Soviets in the midst of the Cold War with all of the ICBMs pointed at each other with nuclear weapons. In 1975, we had Apollo-Soyuz, the first link-up between a Soviet and U.S. spacecraft, which President Nixon viewed as important in pursuing détente. General Tom Stafford, the leader of that mission, with General Alexei Leonov, they rendezvoused a Soviet space craft and an American space craft. They docked and they lived together in space for 9 days.

And you talk about a role model for international cooperation. Look at the friendship today between Tom Stafford and Alexei Leonov. And General Stafford testified here. He called it "The shining light during the Cold War Era in our relationship with the Soviet Union." That's what Tom said here.

And so, today, the ISS, a stunning example of engineering and cooperation, combines the contributions of 15 partner nations and the famous NASA-Mars Curiosity Rover carries instruments provided by France, Canada, Germany, Russia and Spain. So our leadership in space is a result of decades of strategic investment. If we want to maintain that position, then the investments that we're making today have got to be strategic.

And yet, we're in an era of limited budgets. The space arena now includes new players like China, India, and the private sector.

So as we look to the future, there are a few questions that I would like to propose. What do we get out of our investment in being pioneers in space? Number two, how will each mission such as the Asteroid Redirect Mission, help meet our space exploration goals and benefit American interests? And Bill Gerstenmaier is going to speak to that. Number three, when and how will we cooperate with international and commercial partners? And which partners will we exclude, and why?

Following so many decades of advancement in space and given the high cost and amazing benefits of exploration, there's no room for rash actions but only for very careful decisionmaking. Those leading exploration efforts will realize it is a truth: those that lead will realize the economic scientific and political benefits.

And so, it's my pleasure to introduce today's witnesses. Bill Gerstenmaier, NASA Associate Administrator for Human Exploration and Operations. Susan Eisenhower, President of the Eisenhower Group, author of *Partners in Space,* which details U.S.-Soviet cooperation. She will discuss lessons learned. Dr. Leroy Chiao, Special Advisor for Human Space Flight to the Space Foundation, former Commander of the ISS and a former member of the Augustine Commission. He will discuss the advantages and complications associated with international cooperation. Jeffrey Manber, Managing Director of NanoRacks and the author of *Selling Peace,* a book about work with the Russian space program. He will address the potential for commercial involvement and expiration Beyond Low-Earth Orbit.

Mr. Gerstenmaier.

STATEMENT OF WILLIAM H. GERSTENMAIER, ASSOCIATE ADMINISTRATOR, HUMAN EXPLORATION AND OPERATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. GERSTENMAIER. Thank you, Mr. Chairman. And thanks for the opportunity to participate in this hearing entitled "From Here to Mars."

I'll briefly describe NASA's approach to human spaceflight that takes humans eventually to Mars. NASA does not see this as a monolithic mission or a classic design reference mission approach. NASA in this constrained and uncertain budget environment is building the infrastructure—that's operations, techniques, international involvements, spacecraft and hardware—that will allow us to make sustained progress toward a human presence on the surface of Mars.

NASA is developing capabilities and systems that will allow a human presence off the Earth and in the solar system. We're going off the Earth while benefiting the inhabitants of the Earth. NASA is making significant progress. Each of our activities are judged through the lens of being critical and used in future Mars-class missions. We are not building a single one-time optimized mission to Mars, but an infrastructure that allows humans to pioneer the solar system.

NASA sees three unique regions in space: Earth-reliant, where the ISS resides today; two, the proving ground, where the Asteroid Redirect Mission will occur in the vicinity of the Moon; and three, Earth-independent, or Mars-ready. These regions for human presence require gradually increasing risk acceptance, hardware reliability, and operational complexity.

NASA believes that its step-wise approach is superior than attempting a Mars-class mission without proper preparation. Just as Mercury and Gemini prepared the way for Apollo, we see ISS, in the Earth-reliant region, and the Asteroid Redirect Mission, a first mission in the proving ground around the Moon, as paving the way for Mars-class missions. We also see a significant opportunity to work with the Science Mission Directorate and international partners on this approach.

The International Global Exploration Roadmap, developed by 12 countries, supports this approach. The roadmap provides a framework to guide countries in their role for human exploration. NASA's current plans are implementing those first key pieces of that roadmap.

The ISS plays a critical role. The ISS not only benefits life on Earth but has a critical role in exploration and pioneering of the solar system. ISS is not only helping to understand how the human body will adapt in the long-duration space flight and allowing us to test high reliability hardware such as life support for Mars-class missions, but it's allowing us to build strong international relationships and experiment with commercial private sector capabilities.

It's clear that international involvement will be critical to any Mars-class mission. Jeff Manber and NanoRacks have shown the direct benefit of utilizing the commercial sector and nongovernmental investments to augment government-sponsored activities. Mars-class missions will drive technology and will require international and commercial involvement.

ISS is the first critical step in exploration. Two other critical components are the Heavy Lift Launch Vehicle, SLS, and Orion. It's clear from all studies that a Heavy Lift Launch Vehicle is needed. When I see Russia and China beginning to talk about the need for a Heavy Lift Launch Vehicle, this reaffirms our analysis.

Orion is making tremendous progress. The avionics testing in Florida completed yesterday for the test mission this fall. Orion is making tremendous progress. Eighty percent of the software and basic avionics that will be used on the test flight this fall are the same that will be planned for future Orion flights. The test this fall also verifies heat shield performance.

SLS tests and manufacturing is well underway in New Orleans. Several barrel sections and domes are complete and a vertical weld assembly is being installed in New Orleans that will allow these sections to be welded into a tank.

Flight hardware for the Exploration Mission 1, an un-crewed test of SLS and Orion, is beginning to be manufactured this year in New Orleans. The European service module for the Exploration Mission 1 is undergoing preliminary design review in Europe. This is tremendous progress and reflects the international involvement lessons learned directly from ISS. There is real hardware in manufacture for the path to Mars.

Last, teams are working on the Asteroid Redirect Mission. Solid trades in analysis and requirements are in work. There are concepts being investigated—one that captures an asteroid and returns it into a distant retrograde orbit around the Moon; and another that removes a boulder from a large, potentially hazardous asteroid and also moves this boulder to an orbit around the Moon.

This mission leverages off of activities that were already in work: asteroid identification, solar electric propulsion, and uses the basic capabilities of SLS and Orion. The solar-electric bus used for this mission will be the bus used for Mars cargo-class missions. This mission allows for significant operations development in the proving ground of space near the Moon.

If international partners or commercial companies have interest in a lunar surface operation, the techniques, lunar gravity assists, et cetera, developed by the Asteroid Redirect Mission, will enable NASA to support their efforts. The Asteroid Redirect Mission will make significant progress toward furthering the knowledge needed for a Mars-class mission.

NASA has a strong approach that extends human presence into the solar system. This approach starts with the International Space Station and a firsthand knowledge gained from the ISS and systems, human health, international, and commercial partnerships.

There's still a lot of work for ISS. The extension of ISS operations to at least 2024 was critical. There's also a lot of work needed to establish Commercial Crew capability to the ISS.

The approach, ISS, SLS, Orion, and the Asteroid Redirect Mission, coupled with commercial and international involvement, is well underway today. We have a sound approach that is sustainable, leading to an eventual human presence on Mars. Human exploration and pioneering are more than a single hardware development activity but are an integrated series of activities all of which are required to take us from here to Mars.

I look forward to your questions. Thank you.
[The prepared statement of Mr. Gerstenmaier follows:]

PREPARED STATEMENT OF WILLIAM H. GERSTENMAIER, ASSOCIATE ADMINISTRATOR, HUMAN EXPLORATION AND OPERATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to testify before you on NASA's exploration efforts. Consistent with the NASA Authorization Act of 2010, NASA's space exploration architecture is based on capabilities that will support multiple missions and destinations, enable private access to—and use of—space, and complement and advance other NASA, national, and international objectives and goals. This architecture is intended to be sustainable over the long term and affordable. This endeavor is responsive to changing environments, including on-ramps for new technologies, new approaches, and other space players. We also are tightly coupling the planning of our science and technology portfolios with this strategy.

Our architecture is designed for long-term human exploration of our solar system, including the goal of human missions to Mars. NASA's near-term strategy for exploration has four prongs: using the unique environment of International Space Station (ISS) to conduct the research and technology demonstrations necessary to keep our crews safe and productive on long-duration spaceflights; partnering with commercial entities to develop the capacity to transport cargo and crew affordably to low-Earth orbit (LEO); working in cooperation with other NASA Directorates to better understand exploration destinations and improve our ability to work there; and moving outward to deep space with Orion and the Space Launch System (SLS) to take us there. Orion and the SLS are foundational capabilities for the implementation of our integrated human and robotic exploration strategy. We will then travel beyond LEO to the proving ground of cis-lunar space, where we will expand and test our capabilities in a rendezvous with a redirected asteroid in lunar orbit. These steps will build the foundation for further deep-space exploration. With the technologies and techniques we develop, we will enable expeditions to multiple destinations, ultimately allowing us to pioneer Mars and other destinations as we lay the groundwork for permanent human settlements in the solar system. Conceived in coordination with our international partners, this strategy maintains America's role as the world's leader and foundational partner in space exploration.

The International Space Station: Learning the Fundamentals in LEO

The ISS is an unparalleled asset for the conduct of research and technology development in a unique, microgravity environment. The full focus of ISS is on operations and research to: (1) improve our ability to live and work in space, including enabling human exploration beyond LEO; (2) enable development of a demand-driven commercial transportation and research market in LEO; (3) enable science, engineering research, and technology development in the fields of Earth, space, life (biological and human research), and physical sciences; and (4) derive tangible benefits for citizens on Earth.

NASA's Human Research Program continues to develop biomedical science, technologies, countermeasures, diagnostics, and design tools to keep crews safe and productive on long-duration space missions. The progress in science and technology driven by this research could have broad impacts on Earth as it advances our ability to support long-duration human exploration.

On board the ISS, we are conducting technology demonstrations and development efforts to advance human and robotic exploration beyond LEO and the Station also serves as the foundation for an international exploration partnership. As an example of both the technology demonstration and exploration partnership aspects of the ISS, NASA is preparing for an extended duration, year-long human mission to explore human adaptation to space. The mission, which will involve NASA astronaut Scott Kelly and cosmonaut Mikhail Kornienko of the Russian Federal Space Agency, is slated to launch in March of 2015. The ISS partnership is strong, and the agencies involved continue to work together in the mutual pursuit of peaceful space exploration. Plans remain on track for upcoming launches to the Station and return of astronauts to Earth. Later this year, NASA intends to select from among American companies competing to provide crew transportation to the ISS beginning in 2017. In the meantime, NASA and its partners will continue to work with each other to maintain the Station, where humans have lived continuously for more than 13 years, and we are confident that the agencies will continue to work as closely as they have in the past.

Two U.S. companies—Space Exploration Technologies and Orbital Sciences Corporation—are supporting the ISS under Commercial Resupply Services (CRS) contracts. Purchasing cargo and crew transportation services from U.S. companies allows NASA to focus its efforts on developing the vehicles that will take our astronauts beyond LEO and to multiple deep-space destinations.

Orion and SLS: Traveling Beyond LEO

The dedicated NASA-Industry team, working across the Nation utilizing all of the NASA Centers and our primary industry partners, Lockheed Martin, Boeing, ATK, and Aerojet-Rocketdyne, is making excellent progress toward developing the next capabilities for human and robotic space exploration missions beyond LEO. The flight test milestones driving the schedule include the uncrewed Exploration Flight Test-1 (EFT–1) this December, the first uncrewed launch of Orion and SLS on Exploration Mission-1 (EM–1) in FY 2018, and the first crewed launch of Orion and SLS on Exploration Mission-2 (EM–2) in FY 2021–22. Both Orion and SLS are being designed to enable multiple missions and destinations rather than being optimized for one particular mission or architecture. Early missions will explore cis-lunar space and rendezvous with and return samples from a near-Earth asteroid, as well as demonstrate capabilities to support deep-space human research and exploration in a safe and sustainable manner. SLS will be evolvable to provide progressively greater lift capability, and, with Orion, will enable mankind to successfully navigate the proving ground of deep space, ultimately sending humans to a variety of destinations in the solar system, including Mars.

The Orion spacecraft will be capable of taking humans farther into deep space than ever before, to multiple destinations as needed, and sustaining them in this challenging environment for longer than ever before. The Orion spacecraft includes both crew and service modules, and a Launch Abort System that will provide for crew safety during ascent. Orion can fly a crew of up to four for 21 days; if used in concert with a potential future Habitation Module, Orion will be able to support larger crews on extended-duration missions. Orion has a focused and rigorous stepwise test campaign to validate these capabilities in the challenging deep-space environment.

This year's EFT–1 flight test will serve as a pathfinder to validate innovative approaches to space systems development. The test will demonstrate spacecraft postlanding recovery procedures and the launch vehicle adapter, which will also be used on EM–1 and EM–2. EFT–1 will allow us to test the heat shield at about 85 percent of lunar re-entry velocity, protecting the vehicle from temperatures near 4,000 degrees Fahrenheit. The EFT–1 flight test will significantly reduce or eliminate 10 of the top 16 risk drivers for the first crewed flight (EM–2). The flight test will also demonstrate 47 percent of the design, development, test, and evaluation (DDT&E) required for EM–2, and includes 50 percent of the software needed for the first crewed mission. Not only is EFT–1 testing hardware and software, but it also is testing key processes which will be needed for EM–2.

The SLS is a heavy-lift launch vehicle that will transport Orion, as well as cargo and other systems, with a range of lift capabilities from 70 metric tons, evolving to 105 metric tons and eventually up to 130 metric tons, based on future mission requirements. The evolution of the SLS lift capability fulfills specific, important roles within the exploration architecture, with the 130-metric-ton vehicle supporting full capability asteroid missions and ultimately missions to Mars.

In 2014, NASA will make significant strides in SLS development. The testing of the Booster Qualification Motor-1 (QM–1) will occur this year with a test firing of the motor, and fabrication of the QM–2 motor will be completed. Manufacturing will begin on key components of the SLS vehicle to be used for the EM–1 mission, including Boosters, interim cryogenic propulsion stage (ICPS), and major components of the Core Stage (tanks, engine structure, intertank, and forward skirt), as well as the associated Structural Test Articles (STAs). Additionally, the Vertical Assembly Center at Michoud Assembly Facility will be completed this spring, as well as modifications to the A–1 Test Stand at the Stennis Space Center for testing of the RS–25 Core Stage engines. The SLS Program will conduct the detailed design review (Critical Design Review) for the Booster and Core Stage elements. Definitization of SLS contracts for Core Stages and the ICPS will be completed this year, as well.

The Ground Systems Development and Operations (GSDO) team at Kennedy Space Center (KSC) continues to make significant progress on the necessary Exploration Ground Systems (EGS) infrastructure design, development, and refurbishment to support SLS and Orion. KSC also is providing valuable operations expertise to the SLS and Orion teams to address operational issues in the design in order to help reduce eventual production and operations costs. This is a key aspect of assuring long-term sustainability for deep-space human exploration. In 2014, construc-

tion of new platforms in the Vehicle Assembly Building at KSC will enable SLS and Orion stacking and preflight processing as planned. Refurbishment and upgrades to a crawler-transporter, to accommodate up to the 130-metric-ton version of SLS—a vehicle more powerful than the Saturn V—are being performed to support the FY 2018 EM–1 flight of SLS and Orion.

Orion, SLS, and EGS teams are using the latest in systems and manufacturing technology with the intent of developing the safe, affordable, and sustainable systems this country needs to extend human presence to Mars. For example, the Orion team is using time-triggered Ethernet and is taking advantage of the standards for this technology that are used in the automotive industry. The SLS team has mastered the development of friction-stir welding on large structures to build the SLS Core Stage, culminating in the most advanced and largest friction-stir weld machine in the world. The EGS team has stripped out the old copper cables from Pad 39B and replaced them with the latest in fiber optics. These are three simple examples of how NASA's Exploration Systems are utilizing and advancing the latest in technology.

In developing the Orion, SLS, and EGS, NASA is seeking to build a sustainable National capability for the long-term human exploration of space. By providing more volume and mass for payloads, SLS could enable the simplification of the design and trajectories of future spacecraft. The evolving capabilities of these systems will provide the Nation with flexibility over the long term to achieve a variety of goals. As we move out into the solar system to establish footholds in a variety of locations, having such flexibility will be important, as future missions can be built on what our astronauts and robotic probes learn during earlier expeditions.

NASA's Advanced Exploration Systems (AES) Division is pioneering approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond LEO. This work is important to enable exploration missions and ensure that they are safe, affordable, and sustainable. Activities focus on crewed systems for deep space, and robotic precursor missions that gather critical knowledge about potential destinations in advance of crewed missions. Major products include systems development for reliable life support, asteroid capture mechanism risk reduction, deep space habitats, crew mobility systems, advanced space suits, and autonomous space operations. As prototype systems are developed, they are tested using NASA ground-based facilities or flight experiments on the ISS. The AES Division works with the Space Technology Mission Directorate to infuse technologies into exploration missions, and with the Science Mission Directorate on robotic precursor activities. The Space Technology Mission Directorate supports exploration by investing in capabilities needed for deep-space exploration including advanced life support, entry, descent, and landing technologies, advanced space robotic systems, advanced thermal management technologies, advanced batteries and fuel cells, lightweight structures, cryogenic storage and transfer capabilities, and in-situ resource utilization.

Asteroid Redirect Mission: Expanding Our Capabilities for Deep Space Missions

NASA will employ SLS and Orion for an early human exploration mission to perform pioneering human operations further from the Earth than ever before, rendezvousing with and returning samples from an asteroid redirected to at stable orbit around the Moon by the robotic segment of the Asteroid Redirect Mission (ARM). The ARM is composed of three separate elements: the detection and characterization of candidate near-Earth asteroids; the robotic rendezvous, capture, and redirection of a target asteroid to a stable orbit around the Moon; and the crewed mission to explore and sample the captured asteroid using the SLS and the Orion crew capsule. Each mission element is heavily leveraging ongoing activities in NASA's Space Technology, Science, and Human Exploration and Operations Mission Directorates. The mission integrates a variety of technologies and capabilities important to future crewed missions to Mars and other deep space destinations. These include: the acceleration of high-power solar electric propulsion development, which will power the ARM mission and also has future science, commercial, and human exploration mission applications; and rendezvous with and maneuver of a non-cooperative target in deep space, which is enabling for missions to other deep-space destinations. The technologies needed for this mission, for example in power, propulsion, guidance and navigation, life support, and EVA, will be applicable to future human missions to Mars.

The ARM mission is part of the overall plan for human exploration and pioneering. It allows for operations in the proving ground of cis-lunar space, builds off of the skills learned from ISS, prepares the way to support potential lunar activities of our commercial or international partners, and builds the skills and hardware

needed for Mars-class missions. This mission represents a technological challenge—raising the bar for human exploration and discovery, while advancing detection of near-Earth asteroids and bringing us closer to human missions to Mars. NASA has already identified a number of candidate asteroids for this mission; the Agency is also continuing to refine estimated costs, and, at this time, we anticipate that the incremental cost of the mission will be less than half of what the initial Keck Study projected. The ARM would affordably support and leverage multiple efforts across the Agency as it paves the way for journeys to other destinations by helping NASA prove out its new heavy-lift launch vehicle and exploration spacecraft in a near-term mission.

Exploring Mars and Other Deep Space Destinations

NASA has been executing an integrated human and robotic exploration strategy leading to the human exploration of Mars. The capabilities required for a human mission to Mars have been understood for some time. The implementation steps and investments, partner approaches, and technical pathways to Mars are varied. NASA will ramp up its capabilities to reach—and operate at—a series of increasingly demanding targets, while advancing technological capabilities with each step forward. This will include early test and demonstration activities in cis-lunar space as called for in the NASA Authorization Act of 2010. The Agency is tightly coupling the planning of its science and technology portfolios with this strategy where appropriate.

As noted earlier, the Agency will conduct a series of test and demonstration flights, including EFT–1 with Orion flying uncrewed in 2014, EM–1 with Orion and SLS flying uncrewed in FY 2018, and the crewed EM–2 mission with Orion and SLS in FY 2021–22. In this vein, ARM will exercise these and other capabilities now in development. These missions will help develop the foundation for longer journeys to destinations which could include near-Earth Asteroids, the Moon, the moons of Mars, and then Mars itself. NASA's Orion and SLS will enable the Agency to send astronauts beyond LEO for the first time since 1972 and will provide the Nation a capability and architecture designed to also allow flexibility, partnering, and technological on-ramps. This strategy for human space exploration will ensure that the United States fosters a safe, robust, sustainable, and flexible space program by developing a set of core evolving capabilities instead of specialized, destination-specific hardware, to achieve human presence in successively farther destinations across the solar system.

NASA's exploration strategy is consistent with the Global Exploration Roadmap (GER), released in August 2013 by NASA with 11 of our international space agency partners in the International Space Exploration Coordination Group. The GER helps demonstrate how NASA's ARM and milestones leading up to it are important steps toward realizing our goal of future missions to Mars together with our international partners. It also demonstrates that NASA, together with its international partners, shares a common interest in advancing a unified strategy of deep-space exploration, with robotic and human missions to destinations that include near-Earth asteroids, the Moon and Mars. The roadmap begins with the ISS and includes a step-wise expansion of human presence into the solar system, with human missions to the surface of Mars as a driving goal. The roadmap expands on missions to send humans to the lunar vicinity, a proving ground that allows nations to advance exploration capabilities and learn to manage risks while using the presence of the crew to explore asteroids and the Moon. Our support of the GER helps our international partners seek funding support for strong roles in implementing the international strategy.

While there will always be challenges in involving multiple nations with diverse national interests in an interdependent human space effort, pioneering the solar system cannot effectively be undertaken by any one country. The partners' participation in the GER demonstrates their interest in an incremental, international approach to expanding human presence into the solar system. Utilizing the key capabilities of SLS and Orion, this roadmap builds on our collective successes to date, highlights many exploration preparatory activities underway around the world that will drive innovation and new technologies, and encourages collaboration and integration between human and robotic exploration to return great benefit to the global community.

NASA is also discussing with our ISS International Partners exploration uses of and transition beyond the Station. These discussions are being held under the auspices of the Multilateral Coordination Board/Heads of Agencies to fully utilize the research and technology development capabilities of the ISS and to explore partnership opportunities based on the Station partnership.

Conclusion

NASA's exploration strategy will use an approach of pioneering multiple destinations in the solar system. Over time, we will move beyond conducting limited-duration forays to distant destinations and begin to lay the groundwork to establish outposts, build settlements, and utilize *in situ* resources as we expand the reach of humanity. The key to realizing this goal will be to channel all of the factors that have enabled our space achievements to date in a way that will ensure a sustainable foundation on which future generations can continue to build. So we will involve the private sector, taking advantage of entrepreneurial drive and business acumen to find novel solutions to the challenges we face. We will engage international partners, who will bring to the table their own unique scientific and technological expertise—expanding humanity's presence into space is too large a task for any one country to go it alone. Finally, we will strive to achieve the optimal balance of human and robotic exploration, taking advantage of what humans and machines each do best as we search for life in the universe and pursue a variety of objectives and goals. This long-term effort will expand the sphere of human life and activity, and draw upon the pioneering spirit and ingenuity in the face of the seemingly impossible that have helped make the U.S. the exceptional nation that it is.

Mr. Chairman, thank you for the opportunity to appear before you today to provide you with our progress and status over the past year as we look forward to EFT–1 and the award of Commercial Crew Transportation Capability later this year, and the first uncrewed SLS/Orion mission in FY 2018. We have a strong strategy that extends human presence into the solar system—beginning with Mars—in an affordable and sustainable manner. ISS, Commercial cargo and crew, Orion, SLS and the Asteroid Redirect Mission are all first steps in that strategy. I would be happy to respond to any questions you or the other Members of the Subcommittee may have.

Senator NELSON. Senator Rubio is going to submit his opening statement for the record. And, of course, for each of you in your written testimony, it will be inserted as part of the record.

[The prepared statement of Senator Rubio follows:]

PREPARED STATEMENT OF HON. MARCO RUBIO, U.S. SENATOR FROM FLORIDA

Thank you, Mr. Chairman, for having today's hearing on the human exploration of space. It is important that the subcommittee examine NASA's plans for human exploration, including collaboration with international partners and commercial space opportunities. Clearly today's hearing is timely given the impact of national security and current geopolitical issues on our space program.

NASA states that its vision is "to reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind." I certainly agree with this vision. But in order to achieve it, the agency must have a clear mission with a roadmap and timeline outlining how that mission will be accomplished.

But a roadmap and timeline will only take the agency so far. NASA's mission must also be accompanied by a strong commitment to achieving it.

Obviously one of the main factors impacting NASA's mission and its exploration programs is the agency's funding. The current budget environment is forcing NASA to balance priorities, which makes it difficult to achieve large exploration programs while sustaining commitments to other scientific efforts that do not always get NASA in the news.

Given this situation, NASA has to spend wisely. This is why I believe that NASA must identify common sense savings to help prioritize and fund space operations. One area where I believe NASA can reduce costs is by reexamining its many underused and outdated facilities and properties, which cost billions of dollars to keep and maintain.

Infrastructure that is duplicative or no longer needed for NASA's exploration roadmap should be reallocated to commercial users and state and local entities. This would result in savings for NASA, a reduction in the Federal Government's footprint and burden to fund space operations, and an incentive for commercial space activities.

The State of Florida and the Kennedy Space Center (KSC) have already benefitted from reallocated infrastructure. But more needs to be done at KSC and around the country. Every facility must examine ways to reduce costs to ensure the agency can continue reaching new heights and revealing the unknown.

One expenditure that continues to get attention and that is relevant to today's discussion is the $70 million NASA pays Russia to transport one astronaut to the International Space Station. This underscores the fact that the United States, the Nation that has accomplished more in space than any other, currently has no way of transporting its citizens into space. The United States should never have to buy tickets to space.

Now, the purpose of today's hearing is not to prosecute this issue. This committee has had numerous hearings investigating why NASA has to pay Russia for access to space, and how the agency and its commercial partners are working to end this arrangement by achieving commercial crew capabilities.

But that does not mean this committee should not examine who we are paying for access to space, especially when it is a nation and a leader with whom we have strong disagreements. Yesterday I highlighted the fact that Russia uses its energy resources as leverage over its neighbors, and I called for a long-term strategy to break this energy dependence from Russia.

Well it would certainly seem that Russian leverage applies to today's discussion. Not only is it about leverage, but it is also about prestige. Vladimir Putin believes that Russia has lost its influence in the world since the collapse of the Soviet Union, and he views himself as a historic figure that's going to restore Russia to its rightful place, in his mind, as a global power.

One way he sees to do this is to gain influence and leverage over other countries. When it comes to space exploration, the Russians clearly have leverage over the United States. The question is whether Russia is using this leverage to influence the United States and NASA and serve its own space exploration goals.

I hope this hearing and today's witnesses will help shed light on that question and provide the Committee with a better understanding of how the geopolitical situation in Ukraine is impacting America's space program.

Thanks again to Chairman Nelson, and I want to thank the witnesses for testifying before the Committee.

Senator NELSON. Ms. Eisenhower.

STATEMENT OF SUSAN EISENHOWER, CHAIRMAN EMERITUS, THE EISENHOWER INSTITUTE; PRESIDENT, THE EISENHOWER GROUP, INC.

Ms. EISENHOWER. Members of the Subcommittee, thank you for this opportunity to testify before you today. It's an honor to be here.

I hope to address the geopolitical issues surrounding NASA's exploration efforts. It's impossible today to think about space exploration strategy without putting it into the context of today's events in Russia and Ukraine. I support well-targeted sanctions on Russia which will have a direct impact on President Putin's thinking. But for reasons I will outline, I believe that rolling back space cooperation could be counterproductive and damaging to our national security and our long-term space agenda.

International cooperation is vital if missions of increasing complexity are on the international agenda such as Mars. During the Cold War, scientific and technological communities played a vital role in serving as a bridge between the United States and the Soviet Union and then Russia. Especially during times of crisis, many multilateral and even bilateral interactions survived the Soviet invasion of Hungary, Sputnik, the U–2 incident, the Cuban missile crisis, as well as the Soviet invasions of Czechoslovakia and later Afghanistan. But since the Cold War ended, U.S.-Russian cooperation on nuclear security and in space has been at the heart of enhancing the United States' national security.

The restrictive measures on space cooperation announced by NASA last week, however, could well threaten our achievements of the last 20 years. Here are three reasons why we need to lift last

week's ban on all cooperation outside of the operations related to the ISS.

Number one, our national security is greatly enhanced through cooperation. Since 1992, U.S.-Russian cooperation in space has had a positive impact on the transformation of the Russian aerospace industry, which was at the time of the Soviet Union's collapse, a bastion of Soviet hardliners. U.S. interaction with the Russians on the Shuttle *Mir* program and then the International Space Station brought unprecedented transparency and access to sensitive Russian facilities along with a growing adoption in Russia of Western best practices. Since then, the lessons we've learned together have strengthened our overall performance in space beyond just the ISS. And it provided an indispensable window into the workings of the Russian military industrial establishment.

Number two, if the goal of limiting cooperation is designed to send a strong signal to President Putin, we need to be careful. It could well backfire. The Russian scientific community, as opposed to the Soviet aerospace industry, has traditionally been the most progressive of all sectors in that country. But today, both sectors in Russia, both the scientists and the aerospace industry, see themselves as our friends. Rather than sending a strong message to President Putin, suspension of cooperation will strengthen political hardliners who would prefer that Russia "go it alone" or work with countries more sympathetic to their views.

Number three, safety depends on trust. Much has been said about our mutual dependency in space. Safety of human life requires cooperation. At the moment, operations on the space station are proceeding as normal. Trust, however, that invaluable yet fragile commodity, can be easily eroded. NASA's announcement last week that it will suspend "the majority of its ongoing engagements including high-level visits, e-mail exchanges, and video conferencing" could leave many of our friends in Russia high and dry and potentially change the more general atmosphere. Collective attitudes even in the Russian space sector could change, which might negatively impact working relationships on the ISS and potentially even safety.

In conclusion, I would like to reemphasize that we know from history that it is always easier to terminate space cooperation than it is to get it started again. And we will not be able to meet our long-term goals in space without it. We should consider establishing the general principle going forward that space cooperation should be exempt from sanctions. Space has the unique capacity to serve the global community. It can be a force for preventative diplomacy, transparency, and for sustaining and building bonds among those who are willing to put solely national pursuits aside.

The lynchpin of this goal must be engagement. We must be wary of any space policy that provides only short-term symbolic satisfaction just as we should be cautious of those in both countries who might want to exploit this crisis for short-term commercial or political gain. They could ultimately undermine our long-term strategy in space and possibly jeopardize the enormous human and financial investment we have already made.

Thank you very much. I look forward to questions.

[The prepared statement of Ms. Eisenhower follows:]

PREPARED STATEMENT OF SUSAN EISENHOWER, CHAIRMAN EMERITUS, THE EISENHOWER INSTITUTE; PRESIDENT, THE EISENHOWER GROUP, INC.

Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to testify before you today. It is an honor to be here.

I hope today to address the geopolitical issues surrounding NASA's exploration efforts. I served on the NASA Advisory Council for eight years and was also a member of the International Space Station Management and Cost Evaluation Task Force. However, it was not until I wrote *Partners in Space: U.S.-Russian Cooperation after the Cold War* that I fully understood the operational and geostrategic benefits of U.S.-Russian cooperation in space. It is this point that I would like to examine with you today.

I would like to make it clear before I begin that it is essential, I think, for the United States and its allies to respond to the ongoing situation in Ukraine with appropriate and well-targeted sanctions on Russia, which will have a *direct* impact on President Putin's thinking. For reasons that I will outline, I do not believe, however, that disengaging in space cooperation is in our national interest.

Near and long-term goals

It has long been NASA's strategy to engage our international partners, who have diverse and valuable scientific and technological expertise. This is vital if missions of increasing complexity are on the international agenda.

This strategy has not only proven to be successful through cooperation on the International Space Station, I believe it will be the only way we can meet our long-term objectives of expanding mankind's presence in space. The issue then is not about long-term strategy, but about appropriate short-term measures—given the current geopolitical environment.

As you well know, strategy has to be informed by a simple calculus. Do the short-term and the long-term goals mesh? Or do short-term actions jeopardize or pose insurmountable road blocks to meeting one's overarching goal?

With those simple questions in mind, I was concerned to read NASA's announcement last week that, in light of the Crimean crisis, NASA will suspend "the majority of its ongoing engagements" with Russia, with the exception of continued U.S.-Russian cooperation on the International Space Station. I believe that sweeping limitations of this kind are a mistake. A brief review of the past is instructive for understanding the vital role the scientific and technical communities have played and can continue to play in serving as a bridge between our two countries, especially during times of crisis.

With the dawn of the nuclear age and later the space age, the administration of President Dwight D. Eisenhower sought to avert the possibility of fostering an atmosphere of "paranoid uncertainty" between the United States and the Soviet Union. In 1953, in his Atoms for Peace speech, the president opened the way for the peaceful uses of the atom. As part of that proposal he initiated, with the scientific community, the Atoms for Peace conferences that brought countries together from across the globe to exchange papers on power generation, nuclear medicine and agriculture. These conferences, initiated first in 1955, survived the Soviet invasion of Hungary, Sputnik, the U–2 incident, the Cuban missile crisis—as well as the Soviet invasion of Czechoslovakia in 1968. As a result of that engagement, the Soviet Union declassified a whole field of nuclear science: fusion.

In 1955, the International Council of Scientific Unions spearheaded an international effort to study the Earth. Scientists from the United States, the Soviet Union, and sixty-four other countries agreed that the International Geophysical Year would be marked in 1957–1958. Among its activities, it called for the Soviet Union and the United States to launch artificial satellites and it created a forum for international dialogue on science and the future of the Antarctic. This cooperation also survived those above mentioned crises. Despite this, the work of IGY continued and was augmented by U.S.-Soviet negotiations that led the way for the Antarctic Treaty, signed by the United States, the Soviet Union and ten other countries in 1959. This assured in perpetuity the demilitarized status of an entire continent, preserving the Antarctic for international scientific research—a benefit for all of mankind. Had this U.S.-Soviet cooperation been suddenly cut off, who knows what the impact would have been on Antarctica, then a contested continent.

Even though the 1950s/60s are considered to be, perhaps, the most perilous times of the Cold War, U.S.-Russian "engagement" was seen as a way to gauge the thinking of our adversaries, to understand how the other side approaches issues, and to build bonds among those who were not their country's chief decision makers. In short: a way to mitigate the potential for "paranoid uncertainty" by achieving some level of transparency. At one point concern was such that there was not enough en-

gagement, prompting the successful effort to sign a bilateral General Exchanges Agreement between the United States and the Soviet Union in 1958. Its role was to foster and, in some cases, mandate science, academic and cultural exchanges. This agreement remained in force until the collapse of the Soviet Union.

Space cooperation was a promising new avenue of engagement with the Apollo-Soyuz dock up in July 1975. But things began to change with the U.S. boycott of the 1980 Olympics and the suspension of other cooperative activities in the aftermath of the Soviet invasion of Afghanistan. Until the Shuttle *Mir* programs (1992) very few people from the space community were schooled in the arts of East-West cooperation. If not for the end of the Cold War, the U.S. and the Soviet/Russian programs might have been doomed to continue operating as rival entities.

With this history in mind, let me explain at least three reasons why U.S.-Russian space cooperation should be continued without restriction.

First, decoupling could endanger safety.

Much has been said about our mutual dependency in space. It is not just our reliance on Russian crew transport that is at issue, Russia also relies on the United States for communications after launch and for ISS operations. The Russians also have scientific instruments integrated into our Martian and Lunar programs.

Even in day-to-day operations, it is logical and important to note that safety of human life requires international cooperation. Last week, NASA Associate Administrator Michael O'Brien wrote a memo to employees explaining the termination of many important relationships:

> "This suspension includes NASA travel to Russia and visits by Russian government representatives to NASA facilities, bilateral meetings, e-mail, and teleconferences or video conferences. At the present time, only operational International Space Station activities have been excepted."

But where does work on the ISS begin and where does it end? Continuous improvement and enhanced work on human safety and hardware investment is often made through tangential contacts and interaction. How easy will it be to draw the line between these baskets of activity if there cannot be visits between our two country's facilities or even e-mail exchanges? This could be of major significance if there is an emergency in space that impacts the community beyond the operational side of the ISS.

Second, if the goal of suspending cooperation is designed to send a strong message to President Putin, we need be careful. It could backfire.

While it is true that NASA and its Russian counterpart, Roscosmos, have maintained a professional, beneficial, and collegial working relationship through the various ups and downs of the broader U.S.-Russia relationship, we are assuming that the ISS program will be unaffected by the current policy. In other words, we are presuming that Russian forbearance in this case is "a given." In recent days, however, there have been cries in the Russian Duma to respond to the cancellation of contacts with the U.S.

Of greatest concern to me, however, is the long-term impact. The Russian scientific community has traditionally been the most progressive of all political sectors in that country. People who are involved in international scientific cooperation are less likely to be nationalists. Rather than sending a strong message to President Putin, suspension of cooperation will strengthen hardliners who would prefer that Russia "go it alone" or work with countries more sympathetic to their views, such as China.

From a U.S. perspective, we cannot afford to lose another generation of people who know how to cooperate with Russia on science and technology, especially with baby boomers retiring.

Finally, those who are aggressively pushing for using space as a way to "punish Russia" should be reminded that contact with countries that have such technical capabilities have, in the past, been a way to enhance transparency.

In my book, *Partners in Space: U.S.-Russian Cooperation after the Cold War* (2004), our research revealed:

> Cooperation has had a dramatically positive impact on the transformation of the Soviet hardliner aerospace industry, bringing unprecedented transparency and a move toward western best practices. Increased transparency has reinforced both expanded commercial cooperation and the political goals of civil space cooperation (*e.g.,* nonproliferation).

Today, "Curiosity," NASA's Mars Science Laboratory, has a Russian instrument on it that uses adapted technology from the heart of the Russian nuclear weapons

program. This is a perfect example of how space cooperation has aided in providing greater transparency on the Russian program.

Partners in Space also found that cooperation with Russia brought significant benefits, not only to our national security, but also to our technical knowledge—as Russians were at that time the leaders in long-duration space flight. Since then the lessons we have learned together have strengthened our overall performance in space and have provided an indispensable window into the workings of the Russian military-industrial establishment.

Conclusion

As we know from history, it is always easier to terminate scientific and technical cooperation than it is to get it started again. Before we codify this potential mistake, we must recall that there are ample historical precedents to support the value of science and technology cooperation, even in times of crisis. Space cooperation should be exempt from sanctions, just as Atoms of Peace and IGY survived the tumultuous ups and downs of the Cold War.

Space cooperation is the ultimate global bridge, and international space has unique capacities to serve the global community. It can be a force for preventive diplomacy, transparency and for sustaining and building bonds among those who are willing to put aside solely national pursuits. Like terrestrial cooperation, exemplified by the International Geophysical Year, space cooperation can serve as a stabilizing factor in space.

The lynchpin of this goal must be engagement. Through consistent interaction, larger goals can also be realized. This can only enhance America's national security. We must be wary of any space policy that provides only short-term symbolic satisfaction, just as we should be cautious of those who might want to exploit this crisis for short-term commercial or political gain. They could, ultimately, undermine our long-term strategy in space and possibly jeopardize the enormous human and financial investment we have already made.

On March 27, 2014, former Senator Sam Nunn and former Secretary George Shultz wrote in a *Washington Post* op-ed, "A key to ending the Cold War was the Reagan administration's rejection of the concept of linkage, which said that bad behavior by Moscow in one sphere had to lead to a freeze of cooperation in all spheres."

I would add that linkages between geopolitical crises and space should be avoided in favor of more direct ways to impose sanctions. Space can serve as at least one example of what it really means for the global community to set goals and see them through for the betterment of mankind.

Senator NELSON. Mr. Gerstenmaier, which policy is NASA operating under? You heard what Mrs. Eisenhower just said about the statements and there were conflicting statements. Which is NASA operating under?

Mr. GERSTENMAIER. NASA, as you've seen in the press exchanges, we've exempted ISS operations from many of the sanctions or any of the issues associated with activities. And then we're reviewing, kind of on a case-by-case basis, the need to go ahead and continue other activities. So there is an activity, a scientific event, this summer in August called COSPAR. That particular item has recently been accepted and that event will occur.

So NASA's methodically going through each one of the events and activities that are scheduled and we're determining which ones are accepted and which ones we need to curtail.

Senator NELSON. What about the acquisition of the engine RD–180?

Mr. GERSTENMAIER. That's really not a NASA issue. That's between United Launch Alliance and their activities.

I'm not aware of any discussion, but that's really not a NASA issue per se.

Senator NELSON. OK. Well we will get into that in the Armed Services Committee.

All right. Dr. Chiao.

STATEMENT OF DR. LEROY CHIAO, FORMER NASA ASTRONAUT; COMMANDER, INTERNATIONAL SPACE STATION EXPEDITION 10; SPECIAL ADVISOR FOR HUMAN SPACEFLIGHT, THE SPACE FOUNDATION; AND CHAIRMAN, NATIONAL SPACE BIOMEDICAL RESEARCH INSTITUTE USER PANEL

Dr. CHIAO. Chairman Nelson, Senator Rubio, thank you both for your service to our Nation and thank you for the opportunity to present my views on the future of U.S. human spaceflight.

U.S. human spaceflight program drives technology development by employing our citizens to advance the state-of-the-art of several fields. Many of these technologies are adapted to purposes which improve the quality of life for people here on the Earth. These are both very good reasons to continue a robust human spaceflight program. But I believe that the biggest return on our investment is prestige and inspiration of the next generation, best put together by the mission statement of the Space Foundation, "To advance space-related endeavors to inspire, enable and propel humanity."

Human spaceflight has become woven into the very fabric of our identity as a nation of explorers, innovators and entrepreneurs. It was exactly the endeavors of Apollo and the programs prior that inspired me and my generation. We must do the same and more for our children and grandchildren and help maintain our position as the world leader.

As you pointed out, I was a member of the 2009 Review of U.S. Human Spaceflight Plans Committee and the current space policy is based on the major elements of one of the options that was put together. However, the main and most important message of the Committee and the report was that, in any case, the program support needed to be robustly supported both politically and financially. Strong bipartisan leadership is needed to sustain the program across administrations otherwise election-cycle changes could cause confusion and waste.

The Committee estimated back then that the 2010 NASA budget would have been needed to increase by $3 billion and the buying power of that sustained in following years, if we were going to have a credible Beyond-Low Earth Orbit exploration program. The implied message was that if we were unable to go ahead and increase the budget by that much, then the proper thing to do would have been to continue to fly space station and robustly support ISS.

Unfortunately, that was not realized and NASA has been directed to attempt to put together a credible Beyond-Low Earth Orbit program within the framework of essentially a flat budget in terms of buying power. The challenge of this cannot be overstated. This is why you've seen a lot of conflicting proposals and different changes over the last several years settling now on the Asteroid Redirect Mission. But the first crewed flight to that asteroid is currently being planned for 2021, which is still some years away. And that assumes that the SLS is developed on-time with no hiccups and no reduction and further reduction in budget.

Thus, the first step, I believe, to go from here to Mars is to ensure that the budget is sufficient to support the program. The realistic sustainable funding level for Beyond-Low Earth Orbit maybe it should be determined a priori and then the program scoped ac-

cordingly. If we cannot adequately support both politically and financially the Beyond-Low Earth program, then we should not attempt it.

The ISS is the current Low Earth Orbit human spaceflight program. It serves not only as a common point for the international partner community but as a critical part of development of the Beyond-Low Earth Orbit program itself. The most challenging aspect about flying Beyond-Low Earth Orbit is not a technical challenge, it's not a matter of computers or navigation or propulsion, but rather how do we keep astronauts healthy that far away from the Earth for that long of a duration of flights. The ISS is critical for the development operational medical countermeasures to ensure that we can keep our astronauts healthy as we contemplate these more demanding flights.

The National Space Biomedical Research Institute, or NSBRI, was formed about 17 years ago by NASA at the recommendation of the National Academies. The NSBRI has built a consortium of the finest Biomedical Research Universities and Institutes across the country. And it's targeting applied research to develop countermeasures to enable these Beyond-Low Earth Orbit flights. This work maps to and adds unique value to NASA's Human Research Program.

The ISS is currently scheduled for decommissioning in 2024, although studies have shown that it can be safely operated though at least 2028 and perhaps beyond. I believe that ISS's life should be extended to as long as practical so that we can go ahead and make sure that we are able to develop these countermeasures.

Similarly, the NSBRI will reach its 20-year life contract in 2017 and I believe it also should be renewed to ensure no loss of continuity in these countermeasure developments.

Commercial flights to Low Earth Orbit is a logical evolution. It was perhaps the most exciting yet the most controversial part of the new space policy but I think the commercial companies have made impressive strides. Already, we have companies delivering cargo commercially to the ISS and we have companies working, with NASA support, on developing the capability to launch astronauts to the International Space Station.

In contrast to what some people think, these commercial efforts are not in competition with the NASA's Beyond-Low Earth program. They're complementary in that these commercial flights support the ISS which supports the Beyond-Low Earth Orbit program. A sustainable Beyond-Low Earth program requires a heavy-lift launcher. So the SLS is something that'll be essential, either the SLS or something like it, for our long-term goals in Beyond-Low Earth Orbit Space.

However, the current budget does not support a reasonable plan, timeline, or complement of missions. As I mentioned before, the first flight with a crew onboard is only planned for 2021. That, again, assumes that everything goes perfectly.

It is important during the buildup of a flight test program, or to have a buildup of a flight test program for a new development, with meaningful and consistent flight rate during the development of something like the Beyond-LEO program. This is so you can develop the ground and flight operations and maintain team pro-

ficiency. If the national budget cannot be increased to support such a plan for SLS/Orion, perhaps we need to start thinking about some other possibilities. If we think of SLS/Orion as Apollo/Saturn flights, maybe we need to take a look at possibly having something analogous to the Gemini program.

The Orion is being currently built and the first flight, as you heard, is scheduled for later this year using an existing launch vehicle and upper stage. A similar configuration possibly could be human-rated and be used in a series of meaningful tests and development missions. Such a buildup flight test program using this configuration could be planned to thoroughly test Orion's systems, develop rendezvous and docking operations, and include first destinations Beyond-Low Earth Orbit. The latter flights will be used to characterize the flight environment beyond Earth's magnetosphere, to develop operations, and to characterize other issues as well; and test biomedical countermeasures.

These flights would pave the way for the more ambitious SLS/Orion missions. SLS will enable robust Beyond-LEO missions which should include the development of a crew-tended base on the Moon. This base would be used as a test bed for hardware and operations to develop for eventual human spaceflights to the surface of Mars.

While it would be technically possible to bypass the Moon on the way to Mars, I believe it would be imprudent and would add risk. The importance of thorough ground and buildup flight test to ensure program success is clear has been demonstrated many times and cannot be overstated.

One of the principal findings of our 2009 committee was that the U.S. can lead a bold, new, international effort in the human exploration of space. Having common, very visible, civil space projects leads to generally better relationships between partner countries and provides the potential for overall cost savings. The ISS is a great example of such a program and future human spaceflight programs should expand on this model.

Currently, for the last 3 years, the only entities able to launch humans into space are Russia and China. Thus, China is an obvious addition to the international human spaceflight partnership, both for the ISS program and beyond.

China has successfully demonstrated rendezvous and docking capabilities, extravehicular activity, and operation of a crew-tended LEO space module. The Chinese have a long-term plan that includes construction of a space station in 2018 with full operational capability by 2022. China is in a unique position to be a unique partner and, to the people who are concerned about security and technology transfer concerns, I would say that we can handle those things the same way we have with the Russians. To my knowledge, there have been no improper transfers in either direction.

America can and should be the clear world leader of international space exploration both in LEO and beyond. What is needed is consistent and sustained strong, political, and financial commitments from the White House and the Congress. NASA requires the resources to create a robust, integrated, international exploration plan that will lead us into the next exciting phase of human spaceflight.

Thank you.
[The prepared statement of Dr. Chiao follows:]

PREPARED STATEMENT OF LEROY CHIAO, PH.D., FORMER NASA ASTRONAUT; COMMANDER, INTERNATIONAL SPACE STATION EXPEDITION 10; SPECIAL ADVISOR FOR HUMAN SPACEFLIGHT, THE SPACE FOUNDATION; CHAIRMAN, NATIONAL SPACE BIOMEDICAL RESEARCH INSTITUTE USER PANEL

Chairman Nelson, Ranking Member Cruz, and Members of the Subcommittee, thank you for your service to our nation, and thank you for the opportunity to present my views on the future of U.S. human spaceflight (HSF).

The U.S. HSF program drives technology development by employing our citizens to advance the state of the art in several fields. Many of these technologies are adapted to purposes, which improve the quality of life for people on the Earth. These are very good reasons for our Nation to maintain a robust HSF program. But I believe the biggest return on our investment is national prestige, and inspiration of the next generation, as called out in the mission statement of the Space Foundation: "To advance space-related endeavors to inspire, enable and propel humanity." HSF has become woven into the very fabric of our identity, as a nation of explorers, innovators and entrepreneurs. It was exactly the endeavors of the Apollo and prior HSF programs that inspired me, and my generation. We must do the same and more for our children and grandchildren, and to help maintain our position as the world leader.

I served as a member of the 2009 Review of U.S. Human Spaceflight Plans Committee. The Committee addressed both Low Earth Orbit (LEO) and Beyond-LEO (B–LEO) exploration, and presented options to the administration. The current space policy is based upon major elements of one of the options presented in the Committee report.

However, the main and most important message of the Committee and report was that in any case, the chosen HSF program must be robustly supported, both politically and financially. Strong, bipartisan leadership is needed to sustain programs across administrations. Otherwise, election-cycle changes cause confusion and waste. If credible B–LEO exploration was to be a part of the HSF program, the Committee estimated that the 2010 NASA budget would have needed to be increased by three billion dollars, and that the buying power of this budget would need to be sustained in follow-on years. The implied message was that if the budget could not be increased to this level, then the United States should continue to operate the Space Shuttle and International Space Station (ISS) and delay significant work towards a B–LEO program.

Unfortunately, this has not been realized, and NASA has been directed to attempt to plan a credible B–LEO program within the framework of what has essentially been a flat budget, in terms of buying power. The challenge of this cannot be overstated. This is why we have seen changing proposals of the first destination and mission over the last several years, settling recently on an asteroid-redirect mission, with the first B–LEO astronaut flight planned for 2021. During that mission, the crew is to fly in formation with the redirected asteroid in Earth-Lunar orbit. But the plans for even these modest goals within the schedule allow for practically no cost overruns. This calls the credibility of the plan into question.

Thus, the first step to plan "from here to Mars" is to ensure that the budget is sufficient to support the program. The realistic, sustainable funding level for B–LEO should be determined, and then the program scoped accordingly. If we cannot adequately support a credible B–LEO program politically and financially, then we should not attempt it.

The ISS defines the current LEO HSF program. It serves not only as a common point for the international partner community, but also is a critical part of the development of the B–LEO HSF program. The most challenging technical aspect of the B–LEO program is biomedical: How to maintain the health of astronauts during long-duration flight, both inside and beyond the Earth's magnetosphere. Research aboard ISS is critical to the development of operational medical countermeasures to ensure astronaut health during these demanding missions. Created and enabled by NASA at the recommendation of the National Academies, the National Space Biomedical Research Institute (NSBRI) has formed a consortium of the finest biomedical research universities and institutes in the United States, and funds targeted, applied research to develop countermeasures to enable B–LEO flights. This work maps to, and adds unique value to NASA's Human Research Program (HRP). NSBRI also led to the creation of the Center for Space Medicine (CSM) at the Baylor College of Medicine. CSM complements government-funded research, both in

space and Earth applications. ISS is currently scheduled for decommissioning in 2024, although studies indicate that it can be safely operated through at least 2028. ISS life should be extended to at least 2028, and beyond if practical, in order to adequately support the development of necessary technologies and countermeasures for the B–LEO HSF program. Similarly, NSBRI will reach its twenty-year contract life in 2017. It should be renewed, to ensure no loss of continuity in countermeasure development.

Commercial flight to LEO is a logical evolution. NASA developed the technologies for flights to and from LEO, and should now focus on B–LEO goals, rather than LEO transportation. The commercial companies currently receiving NASA support have shown impressive progress with multiple cargo deliveries to the ISS, and progress towards crew transportation capabilities to ISS. These efforts should continue to receive full support, so that the U.S. can regain the capability to launch astronauts to ISS in the next few years. This commercial effort does not conflict with NASA's B–LEO exploration program. In fact, it helps to enable B–LEO missions, by supporting important, critical-path research and hardware test bed projects aboard ISS.

A sustainable B–LEO program requires a heavy-lift launcher. The Space Launch System (SLS) is an essential part of the long-term program. However, the current budget does not support a reasonable plan, timeline or complement of missions. The optimistic schedule calls for a flight rate of only 0.75 times per year once operational, possibly in 2021, and only if development proceeds as planned with no schedule slip or decrease in budget. If the budget cannot be increased to accelerate this development and support a higher flight rate, then the U.S. should consider slowing, or delaying SLS development.

It is important to have a build-up flight test plan with a meaningful and consistent flight rate during development of a B–LEO program. This is to develop both ground and flight operations, and to maintain team proficiency. If the national budget cannot be increased to support such a plan and flight rate for SLS/Orion missions in the next few years, alternatives should be considered. If one thinks of SLS/Orion as analogous to Apollo/Saturn flights, an appealing alternative is an analogy to the Gemini program.

The Multi-Purpose Crew Vehicle (MPCV, Orion) is currently being built, with the first flight test (without crew) scheduled for late 2014. The configuration for this first Exploration Flight Test (EFT–1) includes the use of an existing launch vehicle and upper stage. A similar configuration could be human rated, and be used in a series of meaningful test and development missions.

Such a build-up flight test program using this configuration could be planned to thoroughly test Orion systems, develop rendezvous and docking operations, and include first destinations B–LEO. These latter flights would build up flight experience beyond the Earth's magnetosphere to develop operations, to characterize the environment, and to test biomedical countermeasures. These flights would pave the way for the more-ambitious SLS/Orion missions.

SLS will enable robust B–LEO missions, which should include the development of a crew-tended base on the Moon. This base would be used as a test bed for hardware and operations development for eventual HSF flights to the Martian surface. While it would be technically possible to bypass the Moon on the way to Mars, I believe it would be imprudent and add risk. The importance of thorough ground and build-up flight tests to ensure program success is clear, has been demonstrated many times, and cannot be overstated.

One of the principal findings of the 2009 committee was that "The U.S. can lead a bold new international effort in the human exploration of space." Having common, very visible international civil projects generally lead to better relationships between the partner countries, and provides the potential for overall cost savings. The ISS program is an example of such a project, and future HSF programs should expand on this international model.

Currently, and for nearly three years, the only entities able to launch humans into space are Russia and China. Thus, China is an obvious addition to the international HSF partnership, both for the ISS program and beyond. China has successfully demonstrated rendezvous and docking capabilities, extravehicular activity (EVA) and operation of a crew-tended LEO space module. The Chinese have a long-term plan that includes construction of a space station in 2018, with full operational capability by 2022. China is in a position to provide hardware and capability in-kind. Security and technology transfer concerns would be handled exactly as the U.S. does today with Russia. To my knowledge, there have been no improper technology transfers, in either direction.

America can and should be the clear world leader of international space exploration programs, both in LEO and beyond. What is needed is consistent and sus-

tained, strong political and financial commitments from the White House and Congress. NASA requires the resources to create a robust, integrated, international exploration plan that will lead us into the next exciting phase of HSF. It does not have it today.

Senator NELSON. Dr. Chiao, you're not suggesting that the Asteroid Redirect would preclude the lunar mission?

Dr. CHIAO. No, sir. Not at all.

In fact, if there is much to be learned from an Asteroid Redirect Mission and as I—to avoid any confusion—I just want to make clear that my statements about another program or subprogram would be complementary to the SLS and the Orion.

Senator NELSON. And that was the program that you testified where there would be a program on the surface of the Moon.

Dr. CHIAO. Well, the Moon would be part of the SLS/Orion. It would be follow-on to the Asteroid Redirect Mission.

Senator NELSON. Right. Thank you for clarifying that.

Mr. MANBER.

STATEMENT OF JEFFREY MANBER, MANAGING DIRECTOR, NANORACKS, LLC

Mr. MANBER. Thank you, Chairman Nelson, Senator Rubio. Thank you for the opportunity to speak today on behalf of NanoRacks; a private firm which has developed a strong customer base onboard the International Space Station.

Let me start by saying that NanoRacks' business model would be commonplace in any industry other than human spaceflight. We build our own research facilities with our own money. We market these facilities and our services to customers at set prices. We began the company 4 years ago without a NASA contract. Instead, we negotiated access to the real estate onboard the station and access to the NASA launch manifest. Critical has been NASA's willingness to let us attempt a new way of adding services and facilities to the ISS.

I applaud Mr. Gerstenmaier and the Space Station Program Office, led by Mike Suffredini, for allowing a private company to attempt this new role.

At NanoRacks, we are very much aware that we may lose our money. We may fail in the marketplace to continue attracting customers. Our equipment may not always work. But these risks are not borne by the taxpayer; they're borne by our investors. That is how business works in the real world and it's how it should also work in outer space.

How are we doing? NanoRacks has flown 150 payloads to date. We have 100 more in the pipeline and we are averaging just 9 months through the NASA safety process, a tiny fraction of the usual timeline. Today, I can tell you that every single day, NanoRacks is showing that more and more consumers, teachers, researchers, companies around the world, see a value in paying for station utilization and including station in their plans.

For us, for our customers, for the space station, and for the intent of you in Congress, the payoff has been dramatic. We estimate that today there is close to $150 million in private capital from venture capital firms and personal investors now supporting NanoRacks and our customers.

The resulting economic valuation is estimated to be much higher, with significant job creation in California, Florida, Texas, and elsewhere. The global recognition of the power of American-style open markets is perhaps the single most enduring result of the end of the Cold War, whether in former communist nations, now in Low Earth Orbit and yes, I am sure, one day on the Moon and Mars.

Because of the success of companies like NanoRacks contributing to the International Space Station, I believe the viability of market economics in outer space is finally coming of age. NanoRacks' experience is showing there is little difference between a government organization here or abroad and a non-government institution in terms of customers. To us, they are all customers. Our transactions are fundamentally commercial in nature.

Our customer list today includes the German Space Agency DLR, Romanian Space Agency, parts of ESA, and companies and organizations from Israel, Japan, UK, Lithuania, Vietnam and Saudi Arabia. In short, commercial space has become a new form of international cooperation. And I'm really grateful for everyone in the NASA International Office who's allowed NanoRacks to begin to play this commercial role.

NanoRacks has already shown that the divisions and tensions that have sometimes characterized the government versus commercial debate in our industry are becoming, in our view, outdated. For too long, we have considered space exploration as an either/or proposition. Either the program is government-driven, government-operated, and government-funded, or it must be commercial. NanoRacks is showing, on space station, that such distinctions are unreasonable and even unproductive.

The government can, therefore, play many different roles in human exploration. It can be a facilitator, a landlord, and almost always a customer. Depending on where we're going, the private role could be smaller or greater. Whether we're reaching for Mars or returning humans to the Moon, or exploring asteroids, a flexible partnership is where and how we should be heading. Turning to near-term Beyond Earth Orbit exploration, we are committed to using ISS as a launchpad for this new chapter in human spaceflight. We understand NASA's focused on Mars.

At NanoRacks, we too may have Mars in our hearts but we have lunar in our business plans. We can see well, replicating ISS's new commercial environment with a lunar program, off-the-shelf hardware, commercial economic efficiencies, low-cost enough for student participation, market leadership in both technology and market savvy. Sure we can do Mars, but that's going to take a little more doing and understanding in the commercial relationships.

Congress has stayed the course on the International Space Station. Thank you for that. Your reward, our reward, is a stable beachhead in space, both technically and now commercially. I mentioned about our new relationship with NASA. Yes, NASA is our landlord and safety official. But the space agency is, every day, less and less of a competitor, leaving to the private sector those services that we do best.

Thank you.

[The prepared statement of Mr. Manber follows:]

PREPARED STATEMENT OF JEFFREY MANBER, MANAGING DIRECTOR, NANORACKS LLC

Chairman Nelson and Senator Cruz, thank you for the opportunity to speak today. I'm pleased to lead NanoRacks, which is developing a robust customer base for the U.S. National Laboratory onboard the International Space Station. We regard our growing private business on the station as a stepping stone for commercially undertaking projects Beyond Low-Earth Orbit in partnership with NASA and other allied space exploration programs.

Personally, I've spent the last three decades working to bring about a more commercial space marketplace, whether by helping set up the first investment fund on Wall Street for commercial space ventures, working with PanAmSat to break open the Intelsat monopoly on international communications, as well as helping open the door in American-Russian relations on space and later assisting in the marketing of the Russian space station *Mir*. The common thread has been to help realize a human space enterprise that is driven by American-style commercial principles and practices.

NanoRacks has for the past four years worked to realize a truly commercial business onboard the International Space Station, using our own capital and developing our own customer base. Today I'd like to share with you some lessons we've learned about how human spaceflight can be integrated into a commercial environment. In this way, everyone, including NASA, our international space agency partners, private customers and the American taxpayer can all benefit from a new approach to space exploration that harnesses government and commercial resources to achieve our goals in space.

Attempting Traditional Business in Human Spaceflight

Let me start by saying that NanoRacks' business model would be commonplace in any industry other than human spaceflight. We build our own research hardware with our own money. We market these facilities and our services to customers at set prices. To date, we have purchased and modified for use or built microscopes, centrifuges, biopharma hardware and basic research platforms. All normal business. Except our facilities are all located in Low Earth Orbit onboard the space station.

We began the company without a NASA contract (and still don't have a traditional one). Instead, we did negotiate access to real-estate onboard the space station and access to the NASA launch manifest, literally first to the empty nooks and crannies on cargo vehicles headed to ISS. We flew our first equipment with no guarantee that anyone, let alone NASA, would make use of our facilities. And there had never been a proven commercial market for space station facilities, so we couldn't forecast a market based on real world data. Given these realities, we didn't even bother with traditional investors. We say at NanoRacks that our first two investors were MasterCard and Visa.

But we believed passionately that given a permanent presence in Low Earth Orbit, the robust transportation to and from the space station, and NASA's willingness to let us attempt a new way of adding services and facilities to ISS, that we would be successful. Rare, if ever, does a market fail to develop when commercial practices are allowed to thrive.

Placing our own hardware aboard a government facility is a critical part of our success, as it allows us to use commercial practices to design, manufacture and sell the facilities in what is still an immature market. I applaud Mr. Gerstenmaier and professionals in the Space Station Program office, from Mike Suffredini down to the working level, for allowing a private company to attempt this new role. I think their view when we offered to build and market our own equipment with no NASA funding was "let's take a shot and see if these guys can produce."

At NanoRacks, we are very much aware that we may lose our money. We may fail in the marketplace to continue attracting customers. Our equipment may not always work. But these risks are not borne by the taxpayer but by our investors. That is how business works in the real world and should also work in outer space.

A Pioneering and Growing Success

So how are we doing? NanoRacks has flown 150 payloads to date, we have a hundred more in the pipeline, and are averaging just nine months through the NASA safety and payload integration process, a tiny fraction of the usual wait. Our prices are transparent and start low enough to allow parents in school districts to pool their money to fund a genuine space station project, and our facilities robust enough to attract serous academic and industrial researchers. All without NASA funding. When we do receive Federal dollars its because NASA or another agency is buying our services just like any other customer.

And today, I can tell you that every single day NanoRacks is showing that more and more consumers, teachers, researchers, companies and organizations around the world see a value in paying for station utilization.

A final thought on the LEO market today. Just as NanoRacks has customers that are commercial organizations as well as space agencies, it also has space agencies that are competitors. One prime example is the Chinese Space Agency, which is today marketing its space station services to the international community, including my customers. One international client was just about ready to "jump ship" to work with China on a multi-year program. What stopped this client was the U.S. commitment to operate the ISS until at least 2024.

But the Chinese space station program is already today a formidable competitor for NanoRacks, and we are committed to assuring prices low-enough, and services good enough, to thwart their efforts, not because they are Chinese but because that is the nature of commercial competition.

NanoRacks' progress in attracting customers and helping build up the capabilities of space station is being noticed. For example, Aviation Week recently described the growing commercial utilization of the ISS as transforming the station from a marvel of engineering construction into a thriving entrepreneurial marketplace. Music to my ears.

I would not argue that a purely commercial approach should be the only path to ISS utilization. There is always the more traditional, public sector approach, using taxpayer funds, via NASA or CASIS. Typically this involves peer review, with the highest priority given to projects of agreed-on national priority. Our way allows a researcher or entrepreneur who believes in their idea to avoid waiting and try an experiment as quickly as they can develop their hardware.

For us, for our customers, for the space station and for the intent of Congress, the payoff has been dramatic: we estimate that today there is close to $150 million in private capital, from venture capital firms and personal investors, now supporting NanoRacks and our customers. The resulting economic valuation is estimated to be much higher, with significant job creation in California, Florida, Texas and elsewhere. If you add to this the private investment in commercial cargo vehicles from SpaceX and Orbital, and resulting value of their future launch markets, and the economic value of the International Space Station ecosystem already totals several billion dollars.

By creating and realizing commercial value in human spaceflight I believe we are dramatically increasing spaceflight's economic return to our Nation and the world overall. And I am sure that our success in using private capital to leverage government space efforts is transferable not only to other human space stations in Earth orbit but beyond Earth orbit as well.

The global recognition of the power of American-style open markets is perhaps the single most enduring result of the end of the Cold War, whether in former Com-

munist nations, now in Low Earth Orbit and yes, I am sure, one day on the Moon and Mars. Because of the success of companies like NanoRacks working on the International Space Station, I believe the viability of market economics in outer space is finally coming of age.

The Synergy of Commercial and International Cooperation

NanoRacks' experience is showing that there is little difference between a government organization here or abroad and a non-governmental institution. To us they are all customers, and our transactions are fundamentally commercial in nature: a voluntary exchange of reciprocal value. Whether it's a U.S. Government R&D agency like DARPA or a privately funded research foundation or a startup company in Silicon Valley or a school in Colorado, our relationship is based on the commercial contract. Just like in any business on the ground that books a government customer for a plane ticket or purchasing software.

NanoRacks has already shown that the divisions and tensions that have sometimes characterized the government vs commercial debate in our industry are becoming outdated. Working together, we can assure human spaceflight operations are undertaken in a commercially efficient manner and reach out to the widest customer base possible, both domestically and internationally, while accepting that much of the space utilization market still requires some public support, especially the first time we seek to go to Mars, or undertake an asteroid mission or permanently colonize the Moon.

Our low costs, state of the art facilities, and speedy commercial practices are just as appreciated by our international government customers as by our private domestic ones. The internationals appreciate our "business as usual" approach, or as we say: "no flags, just results."

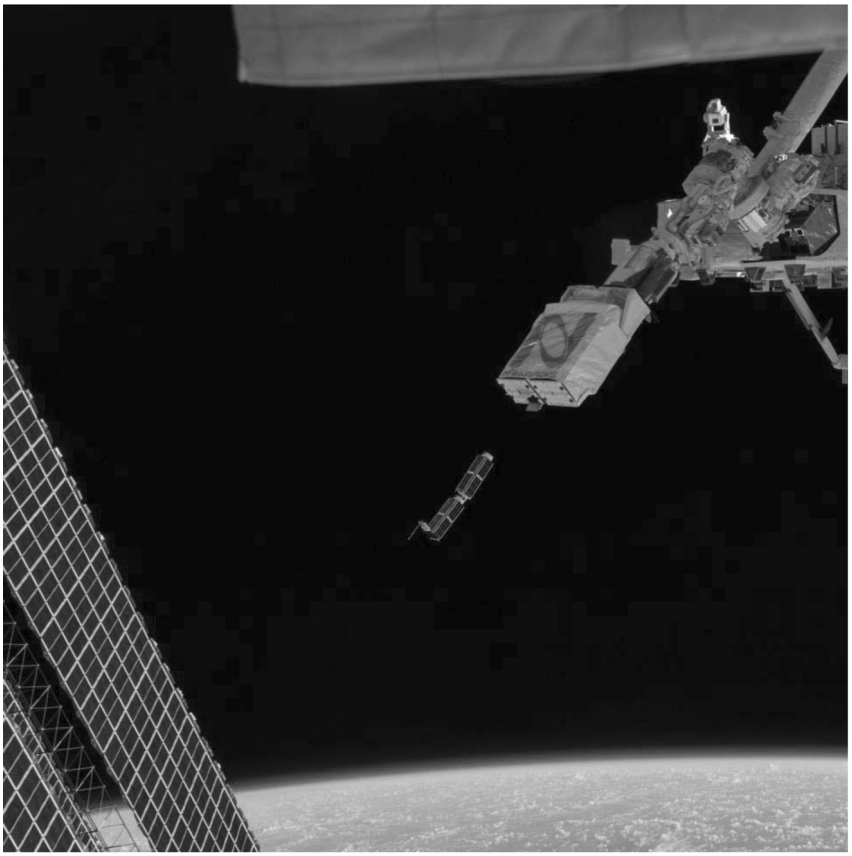
I have no doubt that the next chapter in space exploration must involve a wide range of contributions from international partners, just as any large commercial enterprise already does, from the automobile to telecommunications sectors. On the space station, we have learned without a doubt that other nations have no hesitation to work with a U.S. company like NanoRacks for access to the International Space Station. Our current customer list includes the German Space Agency DLR, the Romanian Space Agency, parts of ESA, and companies and institutions from Israel, Japan, UK, Ireland, Peru, Lithuania, Vietnam and Saudi Arabia. In short, commercial space is another powerful form of international cooperation, and we appreciate NASA's flexibility to allow this new form of space diplomacy to flourish.

Allow me to add another valuable lesson we are learning from ISS operations. And this is the value of the InterGovernmental Agreement (IGA) which is the legal and regulatory framework for managing space station operations among the ISS partners. This document, in my view, provides a solid legal foundation for future international exploration programs. There are certainly improvements to be made as we proceed outward from Earth orbit, but the basic framework and principles of the IGA have withstood many challenges over the past three decades and are extremely sound.

Our commercial utilization of ISS is changing not just the perception of commercial markets in Low-Earth Orbit, but the very behavior of NASA and the other ISS agencies. Skepticism and confrontation towards working side by side with a commercial company's self funded hardware and services has given way to commercial cooperation and shared resources.

To cite just one example, earlier this year we sought permission from NASA to replace the Japanese Space Agency (JAXA) small satellite deployers with our own, which are larger. We didn't ask NASA for funding. We were willing to take the risk that we could find customers if the deployers could hold bigger and more satellites. And we offered slots for NASA use at no cost.

The result? In just seven months we designed the hardware, had it manufactured, passed the NASA and JAXA safety gauntlet, launched it on an Orbital Sciences Cygnus vehicle. With our space agency colleagues we just deployed 33 CubeSats, providing market leadership for three American companies and also introducing two nations, Peru and Lithuania, to the space station. All with no taxpayer funding in that project.



We saw an opportunity for using space station as a small satellite deployer and have invested in the necessary hardware and are finding the customers. Not only is there strong commercial demand for this service but government agencies are now taking advantage of the no-cost slots. That is a win-win for everyone.

A Model for Beyond Earth Exploration

For too long we have considered space exploration as an "either-or" proposition. Either the program is government driven, government operated and government funded, or the program is commercial. NanoRacks has shown on space station that such distinctions are unreasonable and even unproductive. One can well envision a Mars mission which is driven by the space agencies, with basic infrastructure provided by agency funding. The private sector would be invited to risk capital and develop supporting facilities and capabilities which we would then market to space agencies, scientific organizations, and consumers.

The Government can therefore play many different roles in human exploration. It would usually be a facilitator, frequently a landlord, and almost always a customer. Depending on where we are going, the private role could be smaller or greater.

Whether we're reaching for Mars, returning humans to the Moon, exploring Asteroids, or conducting science or business on commercial platforms of the future, a flexible partnership is where and how we should be heading.

Turning to near-term beyond-earth-orbit (BEO) exploration, NanoRacks is committed to using ISS as launch pad for this new chapter in human spaceflight.

We understand NASA is ultimately focused on Mars. At NanoRacks, we too may have Mars in our hearts but our business plan already includes cis-lunar and lunar. We see a commercial market possible with the U.S. Government as customer, modeled on the relationship we have developed aboard space station. Other governments

could also be commercial customers—or if they want to be political partners, that is fine. But commerce must be allowed to flow among the partners.

We can well see replicating ISS' new commercial environment with a lunar program. Off the shelf hardware. Commercial economic efficiencies. Low cost enough for student participation. American leadership in both technology and market savvy.

For me, the key message here is that ISS is not just a science and technology laboratory, but a powerful management and policy testbed for how the government and private sectors can undertake space exploration together.

And the Moon is not the only possible example. NASA could reach an overarching agreement with ESA on a Congressionally funded, administration approved, asteroid rendezvous program, for example, but DLR and other individual national space agencies in Europe might be pleased to go even further, working commercially with a company like NanoRacks for use of privately-funded exploration hardware for research and utilization aboard the visiting spacecraft. At NanoRacks, we would be willing to self-fund a range of research hardware and services in conjunction with such a mission if we were allowed to market commercially to the user community. As on the space station today, everyone gains. Less government funding and more commercial practices that meet customer expectations, whether the customer is a research organization or a space agency.

Conclusion

In conclusion, Congress has stayed the course on the International Space Station. Your reward, our reward, is a stable beachhead in space, both technically and now commercially. The space station is showing us that incorporating commercial utilization into exploration programs will indeed have huge benefits.

And, as on the space station today, U.S. Government strategy should include a way to foster an ecosystem of commercial capabilities that government needs—or very often, the government doesn't know it needs. But given the freedom to operate, commercial will help lower the costs and increase the benefits to government and industry alike of an exploration program.

Finally, I mentioned about our new relationship with NASA. Yes, NASA is our landlord and safety official. But the space agency is every day less and less of a competitor, leaving to the private sector those services we do best.

Taken together, the ISS has emerged as a true laboratory for assuring that our future exploration efforts, like those now on space station, reflect the best values of American leadership and market ingenuity.

Thank you.

BIO OF JEFFREY MANBER, CHIEF EXECUTIVE OFFICER, NANORACKS, LLC

Jeff Manber brings together three decades of experience in realizing a more robust commercial space marketplace.

Currently, as Managing Director of NanoRacks from 2009 onwards, Manber has steered the growth of the first company to own and market its own hardware and services onboard the International Space Station. NanoRacks enjoys a customer pipeline of over 100 payloads from both domestic organizations and foreign governments, has flown over 150 payloads in the last two years and is a recognized leader in commercial space services from sub-orbital to low-earth orbit and beyond.

Previous to NanoRacks, Jeff's accomplishments include:

- adviser to the chairman of PanAmSat, the first privately owned international satellite venture that ended the Intelsat monopoly on international satellite communications and enjoyed a billion dollar IPO;
- co-developer of the first Wall Street fund dedicated solely to commercial space (Shearson Lehman);
- helping create the Office of Space Commerce at U.S. Department of Commerce in the Reagan administration;
- Managing Director of the American office for the Russian space company RKK Energia. Jeff facilitated the current cooperation between the Russian and American space programs. Participant in formation of Energia-Lockheed (ILS), Energia-Boeing (Sea Launch) and other key U.S.-Russian space ventures;
- CEO of MirCorp. While leading MirCorp, Manber signed media and entertainment deals with space tourist Dennis Tito, Survivor television producer Mark Burnett and movie producer James Cameron;

The author of numerous articles and several books, including "Selling Peace," which chronicles Jeff's time working with the Russian space program. Jeff was also

the recipient of the American Astronautical Society's 2011 Lloyd V. Berkner Award and NASA's Exceptional Achievement Medal in 2012.

By Frank Morring, Jr.

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COMMENTARY

Commercial Outpost

Next steps on ISS may include private researchers

The U.S. decision to extend operational funding for the International Space Station (ISS) until 2024 is increasing the odds there will be some significant return on the $100 billion orbiting investment. So is a growing awareness of its unique utility for industrial and academic research, and some long-delayed traction for the commercial-space incubator NASA set up to promote U.S. National Laboratory assets on the station. While it is still too early to know the precise mix of public discovery and private profits that return on investment will represent, there is growing evidence that the engineering marvel of the age will be more than an impressive showpiece like the great pyramids or Taj Mahal.

NASA JOHNSON SPACE CENTER

As big money for public science on the ISS starts to pay off with enticing results, extension of the station's planned lifetime already has encouraged commercial customers at the other end of the cost scale to plan more missions. Jeff Manber, the commercial-space pioneer who founded the NanoRacks venture, says some of his company's repeat customers were beginning to "hesitate" about buying more time on the station until the life-extension decision was announced.

NanoRacks, which has accommodation and generic equipment for experiments on the station and a team of experts who ensure those experiments meet NASA's safety and other technical requirements, is working with the Center for the Advancement of Science In Space (Casis), a Florida-based non-profit that NASA has mandated to promote the station as a commercial research center in orbit.

"We're trying to commercialize the station and inspire the nation by using a minimum of 50 percent of upmass and downmass and astronaut time for the benefit of mankind here on Earth," says Greg Johnson, a former space shuttle pilot who visited the ISS twice and has taken over the Casis helm after a series of false starts slowed its start-up (*AW&ST* June 25, 2012, p. 45). "It's a great value proposition, where NASA is paying for [transport] to and from the [ISS] and we have that astronaut time for free—upmass, downmass for free. We do have to pay for the implementation piece, but we're looking for commercial entities to make a business proposition of the [station]."

Casis has revived the old "space is in it" branding concept for companies that bring products to market that are derived from ISS research. A likely first user is Puma, which has conducted research in orbit that may find its way into golf clubs and other sporting goods. Because of the effects of the station's microgravity environment on microorganisms, pharmaceutical research there has been particularly promising, and Casis has focused early outreach work in Texas, Boston and other biotechnology centers to promote the ISS National Lab capabilities. Now it is moving into Silicon Valley in search of both researchers and venture capital.

Both should be easier to find with the station life extension, said government and private-sector participants in a Space Transportation Association (STA) panel on the ISS status held in Washington March 14. Also boosting the prospects for more commercial work on the station are bandwidth upgrades for data links to station experiments and steps NASA is taking to increase average utilization of the U.S.-controlled station assets to 70% from about 50%.

The latest Orbital Sciences Corp. Cygnus capsule to arrive at the station was unberthed last month using the robotic controls in the station cupola by Koichi Wakata, now the station commander, and NASA's Mike Hopkins, who returned to Earth March 10 (see photo). Developed with $500 million in NASA seed money, both the Cygnus and the SpaceX Dragon can accommodate more cargo than is being carried, Manber says, and the Dragon can bring payloads back to Earth.

In the longer term, it is starting to seem at least possible that someone will adopt the evolving commercial-spacecraft model NASA has promoted to orbit a commercial replacement for the ISS. Orbital Sciences has some concepts in mind for using Cygnus as a free-flyer, and SpaceX has proposed a "DragonLab" version of its capsule, which it is also adapting as a contender in NASA's commercial crew development competition.

But for now the transportation, crew time and other support Congress is funding to spark commercial activities in space is essential, say those who are using it. "That's one of the advantages that we have" Johnson argues. "I know SpaceX, with the DragonLab concept—that's a real challenge for them because they don't have that help from the government."

Ultimately, it may also be possible for industrial or academic researchers to spend time on the ISS without being selected as NASA astronauts, perhaps on the model of the industrial and military payload specialists who flew on the space shuttle, according to Sam Scimemi, the ISS director at NASA headquarters. "One model may be to have private astronauts doing private research," he says.

Senator NELSON. Mr. Manber, you remember, it was not too long ago, that the space station was supposed to cease to exist in 2015.

Mr. MANBER. Yes, indeed.

Senator NELSON. And that was extended to 2020. Now, fortunately, the President's budget has recommended that it be extended to 2024. From this Senator's standpoint, that's the least we could do. It seems to me, it ought to go to the end of the decade. A $100 billion investment, with all the things that you have just testified, clearly is worth continuing.

Mr. Gerstenmaier, sequester is part of the budget for the next 8 years unless we can change it. And there are some of us in bipartisan discussions right now that are trying to change that. But limited funding is a reality over the course of the next several years. So would you make the case for the record of why the Asteroid Redirect Mission is doable, number one? Number two, does not preclude a lunar mission. And number three, develops the technologies and procedures that ultimately get us to the goal of Mars in the decade of the 2030s?

Senator Rubio, my question was for Mr. Gerstenmaier to make the case: with limited funding, which is a reality over the course of the next several years, for Mr. Gerstenmaier—who is the best of the best at NASA—to make the case of why the Asteroid Redirect Mission, number one, develops the procedures and the technologies ultimately going out to the goal in the 2030s of Mars. And, number two, does not preclude a lunar mission as many people have spoken, it's like it's either/or. And doing that within the context of limited budgets.

Go ahead, Mr. Gerstenmaier.

Mr. GERSTENMAIER. Again, if I try to go back to a little of what's in my testimony, the way I would describe it is, if we look at any other real activity, it's going to require a significant amount of new investment on NASA's part. So if we try to go to an asteroid in some distant location away from the Moon, we need to build some kind of habitation module to augment Orion; we need to do significant medical research to keep our crews healthy during that period of timeframe; we have to do significant life support development. So that's a lot of new development to go do an activity there.

It has been talked about, you know, Mars fly by missions. The same kind of thing. If you look at the amount of investment that needs to occur to make that a reasonable mission to keep the risk down to appropriate levels, a tremendous amount of investment.

So the Asteroid Redirect Mission, it moves essentially a piece of the solar system to a location around the Moon, which we can get to with Orion and SLS the way they're being designed today. So the first test flight of Orion, EM2, scheduled in Fiscal Year 2021 to 22, that mission with crew can go to the Moon and that vicinity with really no changes. The Asteroid Redirect Mission doesn't require any changes to the Orion capsule. Basically, we can do the spacewalk from the Orion capsule the way it's designed. So there's no unique hardware needed in that aspect.

It also puts us in the vicinity of the Moon, which we think is a great proving ground to go understand how to operate in space. You know, we'll now be 5 days away from an immediate return back to the Earth. On station, we can get back in a couple hours.

But in the Moon environment, we're going to be roughly 5 days away. We'll use lunar gravity assist, which will be an important technique to learn how to operate for missions to Mars and other locations.

Also, being in the vicinity of the Moon and lunar orbit, it enables, if our partners want to do something on the surface of the Moon or commercial activities want to do things on the Moon, we can assist them in those activities with Orion. So it effectively uses exactly what's there for SLS and Orion.

It also took advantage of what the Science Mission Directorate was already doing. They already had an asteroid observation campaign. So we did not have to build a unique asteroid observation campaign. We leveraged off of what they were doing already.

The Space Technology Mission Directorate, it was building a solar electric bus to be demonstrated to look at electric propulsion which will be needed for Mars-class missions. We'll leverage off of their work that they are doing and it uses SLS and Orion.

So it essentially uses all the pieces we had put together and allows us to make signification and real progress toward gaining the capabilities to go to Mars and it also enables the Moon. So when you put all of those together for the modest investment, I think it makes sense moving forward.

And last, the bus that we used to actually go capture this asteroid and redirect it around the Moon, that same electric bus would be used for cargo missions to Mars. So that is extensible going forward.

So when I look at the options in front of us, I look at the budget environment that you've described; the uncertainty. This is the way we can make significant progress moving forward that keeps us focused toward Mars but doesn't preclude the Moon but yet it keeps us moving in a positive direction and helps us work with our international partners and stay a leader in space.

Senator NELSON. Just to close this out and it is affordable within that time-frame over the course of the next five to 10 years of which, if we went directly on a mission to go back to the Moon's surface, you're talking about a lot more money. Is that correct?

Mr. GERSTENMAIER. Yes. The difference would be to go back to the surface of the Moon with a human-class mission. We would have to build a human lander to go to the Moon. We don't see that as necessary for Mars.

You know, to enter into the Martian atmosphere with its atmosphere is much more difficult. To do entry, decent, and landing into Mars requires new technology development. We think that's where our focus ought to be for the next big lander. We ought to be looking at how we land a crew-size capability on Mars and not go back and replicate to some extent what we've already done on the Moon for Moon landing.

But now, if a commercial company would like to do that or an international partner would like to do that, we will be capable with Orion to be in cis-lunar space and we can assist them with those activities.

So we don't preclude that activity but, in this limited environment, we want to invest in the technologies that have not been

done and the things that will help us and keep us a leader and keep us moving forward toward ultimately Mars-class missions.

Senator NELSON. But you said, "But we don't preclude that activity."

So if the geopolitics suddenly changed, that it was important to the United States to get back to the surface of the Moon before, say, the Chinese would with humans, if that were the case, we'd already have a lot of the technologies developed and we'd be sitting out there close to the Moon already. Is that correct?

Mr. GERSTENMAIER. Yes. That's correct.

And I would say that, if you look today, countries talk about building an Orion-class capsule that could go to the vicinity of the Moon. There's no country doing that today other than us. And this vehicle, you can go down to Florida and you can see today it's getting ready for the test flight this fall, that is the basic capsule shape that is mostly the avionics it will fly, it's mostly the software that's there. So we are again, being a leader and we are building a capsule that allows us to take humans Beyond-Low Earth Orbit to the vicinity of the Moon.

The SLS is also another rocket that other countries talk about. They've conceptualized that. They're not putting hardware together. You can go to New Orleans and you can actually see barrel sections of the oxygen and hydrogen tanks, actually manufactured as test articles. You can see this large welding equipment; the largest in the world. It will use state-of-the-art reaction friction stir weld to assemble tanks. We're moving forward. We're at the Marshal Space Flight Center today doing acoustic tests of scale model rockets firing solid rocket motors next to the model to go look at launch activities down in Florida. We're modifying Pad 39B to accommodate the new launcher capability.

So this country again is leading and we are making real investments and real hardware that you can go out, see, visit, touch, and they all fit in this ability to get humans Beyond-Low Earth Orbit, which other countries talk about but we are still the leader in doing that and our activities will enable and we'll be able to cooperate with them and their activities as they move forward.

And the global exploration roadmap shows their desires, what they would like to go do. It also shows where we fit and then this allows each country to kind of decide for themselves what their role is in in human spaceflight and how they want to fit and build hardware. But we are the leader with the SLS and Orion that we're building today.

Senator NELSON. As I turn to Senator Rubio, would you describe one of the activities of a rover on the surface that could be controlled from Orion with Orion being in cislunar space?

Mr. GERSTENMAIER. We see the ability of getting into the vicinity around the Moon, either a Lagrangian point, which is a gravity location around the Moon, or in a distant retrograde orbit. We can use crew members in Orion to actually command a robotic space craft or robotic rover on the surface of the Moon and do activities.

There's a lot of interest on the far side of the Moon. There's some discussion that's occurred about putting a radio telescope on the far side of the Moon where it's shielded from the radio interference from the Earth. You could actually deploy that antenna on the far

side of the Moon from an orbiting space craft from Orion orbiting the Moon and actually do those kinds of operations on the surface of the Moon.

And we did a demonstration of that from space station. We actually used space station to drive a rover in California that deployed essentially a plastic antenna on a simulated lunar field in California to go actually see if we could go do that. So, when we get to this vicinity of the Moon, we can do robotic activities on the surface of the Moon from Orion as a temporary space craft in a roughly five to six day orbit around the Moon.

Senator NELSON. Thank you very much.

Senator Rubio.

STATEMENT OF HON. MARCO RUBIO,
U.S. SENATOR FROM FLORIDA

Senator RUBIO. Thank you. Thank you, Chairman, for holding this hearing and all of you for being here.

Let me just start by segueing from that last question that was asked. To be clear, as we talk about this long-term goal of landing on Mars in 2030, I think what you're describing is that all the things that we are doing now in the interim all build upon each other. In essence we're creating capability along the way. These are not separate programs though they have separate aims and segues. The general path, as it is with all space exploration, is that previous missions create technological platforms upon which we can build in the future. That they're all moving, ultimately, in the same direction. So we're not really duplicating efforts here, we're kind of constructing one on top of the other. Is that an accurate assessment?

Mr. GERSTENMAIER. I think that's accurate. And I think the other thing we need to take advantage of with this group here is that there's also significant advantage we can get from international partners in this activity and also from the commercial sector. So we need to change our thinking a little bit where it used to be an only government program and look at creative ways we can use the commercial sector and use the international community to augment what we're doing.

Senator RUBIO. Well, that's what I wanted to segue to. Before—and I've already cleared this with the Chairman. I want to submit a statement for the record by Mr. Dean Cheng, who's a Senior Research Fellow at the Heritage Foundation. He is an expert in our relations with China regarding space matters. He's unable to participate in today's hearing but he has submitted his testimony and he brings forward some interesting perspectives on the issues we'll discuss today.

[The prepared statement of Mr. Cheng follows:]

PREPARED STATEMENT OF DEAN CHENG, SENIOR RESEARCH FELLOW, THE HERITAGE FOUNDATION

PROSPECTS FOR U.S.-CHINA SPACE COOPERATION

My name is Dean Cheng. I am the Senior Research Fellow for Chinese political and security affairs at The Heritage Foundation. The views I express in this testimony are my own, and should not be construed as representing any official position of The Heritage Foundation.

My comments today pertain to prospects for cooperation with the People's Republic of China (PRC) in outer space. While the United States should not avoid cooperation with any country out of fear, at the same time, it is vital that cooperation occur with full understanding and awareness of whom we are cooperating with, and that such cooperation serve American interests.

In the case of the PRC, the combination of an opaque Chinese space management structure, a heavy military role in what has been observed, and an asymmetric set of capabilities and interests raise fundamental questions about the potential benefits from cooperation between the two countries in this vital arena.

To this end, it is essential to recognize a few key characteristics of China's space program.

First, that China possesses a significant space capability in its own right, and therefore is not necessarily in need of cooperation with the United States. Too often, there is an assumption that the PRC is still in the early stages of space development, and that we are doing them a favor by cooperating with them.

Second, that the Chinese space program is closely tied to the Chinese People's Liberation Army (PLA), their military. Therefore, any cooperation with the PRC in terms of space must mean interacting, at some level, with the PLA.

Third, that the Chinese space program has enjoyed high-level political support, is a source of national pride, and is therefore not likely to be easily swayed or influenced by the United States, or any other foreign actor.

These three issues, in combination, suggest that any effort at cooperation between the United States and the PRC will confront serious obstacles, and entail significant risks.

A Brief Overview of China's Space Program

The PRC is a major space power, by which we mean that the PRC has the range of space-related capabilities to be able to access and exploit space for its own purposes, at times and places of its own choosing. Indeed, the PRC has a range of space capabilities that arguably equal or exceed those of Europe, and places it ahead of every other Asian country.

China possesses three space launch facilities (Jiuquan, Taiyuan, and Xichang), and is building a fourth on Hainan Island, in the southernmost province of China. From their current launch facilities, they can place satellites into low, middle, and geosynchronous orbit, relying entirely on the Chinese-manufactured Long March family of launch vehicles. It is expected that China will be launching the new Long March 5 heavy lift vehicle from the new Hainan facility.

Satellites. China fields a significant array of satellites.

- It has a *communications satellite array* that includes both domestically produced and foreign satellites, including at least two military communications satellite constellations: the Shentong and Fenghuo systems.
- It is only the third country to field a *satellite navigation and positioning system,* the Beidou/Compass system. The Beidou system was first orbited in 2000, with several satellites in geostationary orbit. This was an active system which required the user to transmit a signal to help determine the user's location. This active signal also provided a communications channel, which could handle messages of up to 140 characters. The Compass portion (sometimes referred to as Beidou-2) is comprised of 35 mid-earth orbit satellites. The Compass portion is currently being deployed and is in regional service.
- It has a *weather satellite constellation* that includes both sun-synchronous and geosynchronous meteorological satellites (the Fengyun series). There has been discussion in the United States of relying on China for weather satellite data, due to repeated delays in replacing American meteorological satellites. The Chinese 2007 ASAT test involved a defunct FY–1C weather satellite in Low Earth Orbit.
- It fields a number of *earth observation and reconnaissance satellites.* The Ziyuan series was the first Chinese observation satellite to be able to beam their data to Earth. It is the product of a joint development effort between the PRC and Brazil (in the form of the China-Brazil Earth Resources Satellite, or CBERS).
- China has also fielded a large *array of small satellites,* including the "Practice," "Experiment," "Gaofen," and "Innovation" series. These have carried a variety of payloads, including synthetic aperture radars (SAR), electro-optical imaging equipment, and monitoring equipment believed to support military intelligence requirements. A Chinese small satellite, believed to be from the "Experiment" series, was recently launched with a robotic arm. Previously in 2010, two "Practice" satellites deliberately "bumped" each other in orbit.

Manned Space Program. China has an active manned mission program that involves the Shenzhou manned spacecraft, which has now had ten successful flights (five manned, five unmanned), and the Tiangong space lab. With the completion of the 2013 Shenzhou-X mission, China has also successfully demonstrated docking capabilities between the Shenzhou and Tiangong spacecraft, as well as relatively extended duration missions. (Shenzhou-X lasted 15 days.)

To support the manned program, China established its first overseas bases with mission support facilities in Swakopmund, Namibia, and Kiribati in the South Pacific. Chinese documents have indicated that a space station, perhaps in the 60–80 ton range (smaller than the U.S. Skylab) is expected to be deployed by 2020.

Lunar Exploration Program. The Chinese lunar exploration program has launched two lunar orbiters (Chang'e-1 and -2), as well as a lunar rover (the Jade Rabbit on Chang'e-3) since 2007. The lunar rover has exhibited erratic performance, but is still considered fairly successful. The final part of the Chang'e program is expected to be a lunar sample retrieval mission in the 2017–2018 time frame.

At this point in time, there is no official indication of plans for a manned mission to the moon. In the 2011 Chinese white paper on space, it was indicated that initial studies were now underway to explore the requirements for such a mission.

Supporting these various space efforts is a major space industrial complex mainly comprising two state-owned enterprises (SOEs): the China Aerospace Science and Technology Corporation (CASC) and the China Aerospace Science and Industry Corporation (CASIC). Each of these SOEs is believed to employ over 100,000 people and is dedicated to producing aerospace and missile-related systems. Thus, unlike their American counterparts (*e.g.,* Boeing and Lockheed-Martin), these companies do not manufacture aircraft or helicopters. On the other hand, not only do they produce rockets and satellites, but also ground test equipment and specialized vehicles associated with space launch, etc. In this regard, they somewhat resemble large, vertically integrated corporations.

The two SOEs are also responsible for manufacturing missiles for China's Second Artillery, the equivalent of the Soviet Union's Strategic Rocket Forces, as well as tactical missile systems for the PLA as a whole. Thus, subordinate research academies within the CASC manufacture not only the Long March space launch vehicle, but also the DF–21 medium-range ballistic missile (MRBM), which comes in an anti-carrier variant (the DF–21D) and serves as the launch vehicle for the Chinese anti-satellite system (the SC–19).[1]

The PLA and China's Space Program

The close links between the Chinese military and space are not restricted to the Chinese military and space industrial complexes. The PLA has consistently played a key role in the Chinese space effort, and China's space program is closely identified with the military. Indeed, the Chinese space program dates its creation to October 8, 1956, with the establishment of the Fifth Academy of the Ministry of Defense by Dr. Qian Xuesen.

Since then, the Chinese military has played an essential role in the management of various Chinese space programs. This is reflected today in the continuing role of the General Armaments Department (GAD) in Chinese space affairs. The GAD is one of the four General Departments of the PLA (along with the General Staff Department, General Political Department, and General Armaments Department) that form the core of the Central Military Commission (CMC). It is the CMC that actually manages the military. The Ministry of Defense, by contrast, has little authority, compared with the two uniformed vice chairmen of the CMC.

All of China's space launch facilities, mission control facilities, and tracking, telemetry, and control (TT&C) facilities, including its fleet of space tracking ships, are all subsumed within the GAD. Indeed, the facilities are typically referred to by their base number in Chinese literature: Taiyuan Satellite Launch Center is Base 25, while the Xichang Satellite Launch Center is Base 27. Not surprisingly, the various facilities and ships are all staffed by units of the GAD. The personnel are trained at the Academy of Command Equipment and Technology, which is a subsidiary organization of the GAD.[2]

In addition, China's manned space program is managed through the GAD. The website of the China Manned Space Engineering Office (CMSEO) lists the chief commander of the program as Zhang Youxia. General Zhang Youxia was appointed

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[1] Sean O'Connor, "PLA Ballistic Missiles," Air Power Australia, APA–TR–2010–0802, April 2012, *http://www.ausairpower.net/APA–PLA-Ballistic-Missiles.html#mozTocId274945* (accessed April 7, 2014).

[2] "2007 Researcher Application Form," Academy of Equipment Command and Technology, China, *http://yz.chsi.com.cn/adv/zbxuyjs.htm* (accessed April 7, 2014).

director of the GAD in October 2012.[3] Another deputy chief commander (apparently the senior deputy) of the program is Major General Niu Hongguang, one of the deputy directors of the PLA General Armaments Department. Other deputy chief commanders are drawn from the military and space industrial complex, reflecting the integrated nature of this key industrial sector.

Indeed, it is useful to recall that the U.S. prohibitions currently limiting the ability of the PRC to launch any satellites containing American parts, under the International Trafficking in Arms Regulations (ITAR), were put in place due to the transfer of aerospace-related information to Chinese companies in the 1990s. As the Cox Commission report noted, information that was given to China regarding items such as the fairing on the Long March-2E space launch vehicle led to improvements for Chinese ballistic missile programs. In particular, it led to changes in both rocket design and Chinese operations that improved the reliability of all Chinese rocket launches.[4]

Meanwhile, China's satellite programs are often linked to military, as well as civilian, users. Like the United States, for example, China's satellite navigation system (Beidou) is linked to the military—specifically, the General Staff Department Satellite Navigation Station.[5] There is even a website celebrating this organization's achievements.[6] Military officers from key GSD departments apparently were part of the design effort for the Chinese weather satellite system. Military participation in space efforts is hardly unique to the PRC, but should serve as a reminder that any interaction with the Chinese space program will almost certainly mean a PLA role and presence.

More to the point, there is no obvious civilian counterpart to the PLA in terms of China's space efforts. The most regularly mentioned equivalent to NASA is the Chinese National Space Administration (CNSA). But the head of CNSA is typically described in Chinese writings and press coverage first as a vice minister of the Ministry of Industry and Information Technology (MIIT), then as a deputy director of the State Administration of Science, Technology, and Industry for National Defense (SASTIND), before being mentioned as the head of the CNSA. This suggests that the position of the CNSA is a third-tier bureaucracy, standing below the key superministry for advanced technologies, and the managing authority for China's military industries (SASTIND).

By contrast, the PLA is a key part of the Chinese power structure. One of the key positions for the top Chinese leader (Xi Jinping, Hu Jintao, Jiang Zemin) is the chairmanship of the Central Military Commission. That role, along with being General Secretary of the Chinese Communist Party (CCP), is what vests Xi, Hu, and Jiang with their power—head of the Party and head of the military. In short, bureaucratically the CNSA is dwarfed by the Chinese military (which may explain the CNSA's absence from the top echelon of Chinese manned space management).

The Importance of Space to the Chinese Leadership

As early as 1958, months after Sputnik was placed into orbit, Chinese leaders saw the development of space capabilities as reflecting on China's place in the international order. In May 1958, Chairman Mao Zedong advocated the creation of a Chinese space program, declaring at the Second Plenum of the Eighth Party Congress, "We should also manufacture satellites."[7] This high-level support has varied at times, but space has generally been seen as contributing to "comprehensive national power" by facilitating national economic development, strengthening military modernization, and supporting the legitimacy of the CCP. It is therefore not surprising that senior Chinese leaders have made sure that they are present for key events such as the inauguration of satellite communications in the 1970s, or the launch of China's first manned spacecraft, the Shenzhou-V.

For China, its space program is emblematic of its steady advancement since 1949, especially since most of it has been accomplished through its own efforts. When the Sino-Soviet split occurred in 1960, Chinese access to foreign technology was abrupt-

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[3] "Management," China Manned Space Engineering, *http://en.cmse.gov.cn/list.php?catid=40* (accessed April 7, 2014).

[4] Select Committee on U.S. National Security and Military/Commercial Concerns with the People's Republic of China, *The Cox Report* (Washington, D.C.: Regnery Publishing, 1999), pp. 220 and 221–222.

[5] "A Record of the General Staff Department Satellite Navigation Station's Commitment to the Beidou Navigation System," Xinhua, November 9, 2013, *http://www.gov.cn/jrzg/2013–11/09/content__2524730.htm* (accessed April 7, 2014).

[6] "The Stars in the Sky Join Beidou," *http://military.people.com.cn/GB/8221/71065/370766/* (accessed April 7, 2014).

[7] Deng Liqun, ed., *China Today: Defense Science and Technology,* Vol. I (Beijing: National Defence Industry Press, 1993), p. 356.

ly ended. As a result, China had to rely on its own efforts, in what became known as the "two bomb, one satellite" program. This effort saw the Chinese focus their national energies to develop an atomic bomb, a hydrogen bomb, and a satellite. This reflected the long-standing dual-use nature of China's space efforts—if China was to have a full-fledged nuclear deterrent, it would have to develop a delivery system, which in turn could also serve as a space launch vehicle.

"Two bombs, one satellite" went beyond a programmatic objective, however. The term also referred to the idea of homegrown development of advanced capabilities. Because of the Sino–Soviet split, as well as the ongoing Cold War with the United States and broader isolationist policies pursued by Beijing, Chinese development of these capabilities would have to wholly rely on their own resources. The phrase "two bombs, one satellite," therefore, came to also be associated with the idea of indigenous development and self-reliance. These characteristics remain hallmarks of today's Chinese space program. For the same reason, Chinese "firsts" (*e.g.,* the first satellite and first manned mission) tend to be of longer duration and incorporate more extensive tasks than other nations' firsts.

Moreover, in keeping with the Chinese memory of the "Century of Humiliation," Beijing will want any cooperative venture to be, at a minimum, on a co-equal basis. For the PRC to be treated as anything other than a full member in any program or effort would smack of the "unequal treaties" that marked China's interactions with the rest of the world between 1839 and 1949. For the same reason, China has generally been reluctant to join any organization or regime in which it was not party to negotiating. For the CCP, whose political legitimacy rests, in part, on the idea that it has restored Chinese pride and greatness, this is likely to be a significant part of any calculation.

At the same time, space is now a sector that enjoys significant political support within the Chinese political system. Based on their writings, the PLA is clearly intent upon developing the ability to establish "space dominance," in order to fight and win "local wars under informationized conditions."[8] The two SOEs are seen as key parts of the larger military-industrial complex, providing the opportunities to expose a large workforce to such areas as systems engineering and systems integration. It is no accident that China's commercial airliner development effort tapped the top leadership of China's aerospace corporations for managerial and design talent.[9] From a bureaucratic perspective, this is a powerful lobby, intent on preserving its interests.

China's space efforts should therefore be seen as political, as much as military or economic, statements, directed at both domestic and foreign audiences. Insofar as the PRC has scored major achievements in space, these reflect positively on both China's growing power and respect (internationally) and the CCP's legitimacy (internally). Efforts at inducing Chinese cooperation in space, then, are likely to be viewed in terms of whether they promote one or both objectives. As China has progressed to the point of being the world's second-largest economy (in gross domestic product terms), it becomes less clear as to why China would necessarily want to cooperate with other countries on anything other than its own terms.

Prospects for Cooperation

Within this context, then, the prospects for meaningful cooperation with the PRC in the area of space would seem to be extremely limited. China's past experience of major high-technology cooperative ventures (Sino-Soviet cooperation in the 1950s, U.S.-China cooperation in the 1980s until Tiananmen, and Sino-European space cooperation on the Galileo satellite program) is an unhappy one, at best. The failure of the joint Russian-Chinese Phobos-Grunt mission is likely seen in Beijing as further evidence that a "go-it-alone" approach is preferable.

Nor is it clear that, bureaucratically, there is significant interest from key players such as the PLA or the military industrial complex in expanding cooperation.[10] Moreover, as long as China's economy continues to expand, and the top political leadership values space efforts, there is little prospect of a reduction in space ex-

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[8] For a more extensive discussion of this topic, please see Dean Cheng, "China's Military Role in Space," *Strategic Studies Quarterly* (Spring 2012), *http://www.au.af.mil/au/ssq/2012/spring/cheng.pdf* (accessed April 7, 2014).

[9] Mark Stokes, "China's Commercial Aviation Sector Looks to the Future," Futuregram 09–002, Project 2049, *http://project2049.net/documents/chinas_commercial_aviation_sector_looks_to_the_future.pdf* (accessed April 7, 2014).

[10] It is worth noting here that the Chinese Ministry of Foreign Affairs is not a part of the CCP Politburo, a key power center in China. Thus, the voice of the Ministry of Foreign Affairs is muted, at best, in any internal debate on policy.

penditures—making international cooperation far less urgent for the PRC than most other space-faring states.

If there is likely to be limited enthusiasm for cooperation in Chinese circles, there should also be skepticism in American ones. China's space program is arguably one of the most opaque in the world. Even such basic data as China's annual space expenditures is lacking—with little prospect of Beijing being forthcoming. As important, China's decision-making processes are little understood, especially in the context of space. Seven years after the Chinese anti-satellite (ASAT) test, exactly which organizations were party to that decision, and why it was undertaken, remains unclear. Consequently, any effort at cooperation would raise questions about the identity of the partners and ultimate beneficiaries—with a real likelihood that the PLA would be one of them.

It is possible that the Chinese could be induced to be more transparent when it comes to space, although the unwillingness of Beijing to engage in substantive discussions on space during the last several Strategic and Economic Dialogues (S&ED) would cast doubt on this. But this would argue for a "go-slow" approach, at best. There is room for greater interaction, especially in the sharing of already collected data, such as geodesy information. As both sides set their sights on the moon, exchanges of data about lunar conditions and the lunar surface and composition all might help create a pattern of interaction that might lower some of the barriers to information exchange. Even there, however, concerns on both sides about information security and electronic espionage, etc., is likely to raise serious doubts about how freely one should incorporate data provided by the other side.

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Senator RUBIO. Let me begin with Mr. Chiao.

You mentioned at the close of your statement about cooperation with China. Let me step back for a second and make this statement. We Americans have always viewed the space program, certainly over the last 30 years, as the sort of cooperative effort that certainly helps our country but benefits all mankind. We have viewed it as a peaceful endeavor, as one that can unite people. And we've seen the fruits of it.

But I think we have to be cautious that not every other nation has the same view. And I think China, in particular, potentially poses a pretty interesting dilemma for us. Certainly, their space program has military components but our space program is largely driven by civilians and has civilian methodology and civilian purposes behind it. Everything in China, but certainly the space program, is deeply linked with the PLA and we've seen evidence of that.

I would like to further expand on your statement. I don't necessarily disagree. I think in an ideal world we'd want cooperation with China because I think three major powers: Russia, China, the United States, and others working in conjunction if in fact we all have the same goals could certainly get some of these things accomplished quicker than any nation on its own.

But I also think we have to be careful and realistic that we not somehow ascribe our motivations and our way of thinking to that of another nation that perhaps has different aims and goals for their space program. And one of the things highlighted in Mr.

Cheng's written testimony is warnings about that. About the threat of potentially seeing China use sensitive information to improve its ballistic missile capability and so forth but also its desire to quite frankly achieve what they have termed in their own documents and what they've called "publicly spaced dominance" which is not our view. The U.S. may not necessarily want to be the most predominant space power in the world but we don't view it as a dominance thing, we view it as something that great nations do great things.

So here's my question. In your experience, and certainly because you've mentioned it in your statement, do you see any potential pitfalls in terms of the Chinese attitude toward the space program that, in essence, places them in an incompatible position to our own view to what space would be about?

Dr. CHIAO. Well, as you mentioned, and it's certainly true that the Chinese space program is part of the PLA. Now operationally-wise and that's kind of the way I think, you know, I understand the distinction but functionally it shouldn't make that big of a difference because we're going to be working on civil space together. And they have a clearly delineated civil space part of their organization. So I don't see any roadblocks if you were or stumbling blocks.

And as far as sensitive information is concerned, we have the safeguards that we can put in place to make sure that there are no technology transfers. And, you know, frankly from a, you know, guidance system, ballistic missile, those aren't things that we work on at NASA. We don't develop the guidance systems. We certainly don't transfer it to our partners, information like that. So it can be controlled and, as far as I know, it has been very successfully controlled with our relationship with the Russians.

Senator RUBIO. And again, the ideal scenario is that we will be able to work with them cooperatively. I'm just always concerned that somehow we ascribe to other countries the same motivations as we have for the space program and sometimes that those things don't add up. And I just want to make sure we're cautious about it.

But I think we all share your goal that it's achievable which I pivot now to Ms. Eisenhower. Your testimony was about Russia. And I think you've raised some interesting points in your testimony about things like, for example, Russian scientists associated with the space program are among the most progressive elements in their society. We've enjoyed a depoliticized relationship with them. There are safety concerns about cutting off interaction with them. And then, there is also the geopolitical realities of what's in the headlines today.

Maybe you can expand a little more about how we balance those two things. Because, on the one hand, there are geopolitical realities. I think when Americans see what's happening in Ukraine, we're uncomfortable about the fact that we're paying the Russians, what is it, $70 million to go to the International Space Station. Does that sound right?

Ms. EISENHOWER. $70 million, sorry?

Senator RUBIO. To get a seat on those flights to the Russians. And we depend on them now, for being able to launch our astro-

nauts into space. So you can understand the political implications of that domestically. And on the other hand, you've raised some interesting points—that we don't want to cut off the scientific community in Russia that quite frankly has been either apolitical or in many instances progressive in their thought process in terms of our ongoing relationship. And it seems to be a relationship that has some significant degree of cooperation. It has been able to overcome whatever is happening politically elsewhere in the world.

So perhaps you can describe that a little bit better for us, in terms of what that actually looks like and maybe a roadmap moving forward. How do we navigate this, for a lack of better term, minefield that we find ourselves in?

Ms. EISENHOWER. Thank you very much, Senator Rubio. And it's an honor to be able to be here and to share my thoughts on this.

I think this requires, this particular situation, requires a really very nuanced strategy, which of course is extremely difficult in today's world where everything is given a bumper sticker.

But, nevertheless, I think a nuanced approach is important for the simple reason that we want to make sure that we express our displeasure with Russian behavior and we do so in a way that's going to count with the regime and not punish our friends. Everybody here would back me up by saying that the Russian space program is much more important, or space in general, is much more important in Russia than it is in this country. If this were a Duma committee you would have a full room. And so, yes, it has a very big symbolic impact but we have made extraordinary strides in the last 20 years in bringing what was a very, very hardline aerospace community into a fully cooperative relationship as we've seen over the last years.

If I were in charge, I would be organizing sanctions to hit exactly at the heart of the regime itself: the people that interact most directly with Vladimir Putin and others. If the scientific community had that kind of influence with Vladimir Putin, they would not have lost their recent political struggle over the future of the Russian Academy of Sciences. So I do think that that is the political reality on the ground.

And then, the other point I would make is that none of this interaction—maybe this'll actually have some reference to Dr. Chiao's comments too, about China. I think we engaged the Russian Federation after the collapse of the Soviet Union, not to do them a favor, but to do us a favor. We gained unprecedented access to some of their most sensitive facilities. And I think, if you look at the China situation, we could well gain every bit as much as they might in terms of understanding how our two societies view this area; this important area. And also, to give us that kind of access in China. Bill Gerstenmaier played a leadership role in negotiating the agreements with the Russians at that time.

By the way, I have supplied a copy of *Partners in Space* for both of your committees. But, in any case, I think this is really about enhancing our national security and we want to make sure that we don't jeopardize our national security and lose access to those important communities while we're legitimately trying to express our displeasure to the Russian government.

Senator RUBIO. And for my last question, I'm going to go back to you, Mr. Gerstenmaier. Because I think in your written testimony—but this is open to any of you that want to answer this because I think this is a more, big picture, broader question. In your statement you talked about, "To channel all of the factors that have enabled our space achievements to date in a way that will ensure a sustainable foundation under which future generations can continue to build."

I think the key part for me of that statement is "future generations," and the notion that we, the scientists, and engineers, many of the people who will work on a 2030 mission, for example, to Mars are probably in college right now or thinking about what they're going to major in in college. And maybe I'm wrong, but my sense is that on a broader public level, we have lost some of the public awareness and/or enthusiasm of what the space program means for the country and I would like some ideas from you, I guess—from all of you, is on how we can reinvigorate that.

I think if you go back to 1960 when President Kennedy made that promise that we would land a man on the Moon and return him safely to Earth by the end of the decade. That invigorated the American scientific community to pursue with a singularity of mind that in addition to getting a man on the Moon and back safely—also, by the way, held all sorts of commercial and technological advances that were made that benefited our economy and society as a whole.

How can we reinvigorate a new generation of people to pursue or go into these fields that are so critical? And, more importantly, this comes at a time when we have so many young people looking for what fields they can go into that will provide stable middle and higher income jobs that have opportunities in the twenty-first century.

So my question is, from a public relations standpoint, what can we do more of to excite people about what space can mean for the future and get more people interested in the fields that are the backbone of any successful endeavor?

Mr. GERSTENMAIER. That's a really difficult question. You know, my experience has been, when I expose folks to what we're doing, and by folks I think of high school kids and maybe even grade school kids, they really get excited about what we're doing. And sometimes, when I'm kind of down in the mouth and I'm worried about sequester and budgets and I look at all the wonderful things we could do if we just had more budget, I forget what we're really doing with what budget we have. And when I go expose some of the younger students and some of the other folks to what we're doing, that excitement comes back and then I get reenergized again and then I'm ready to go back.

So one thing is I think we need to talk to them unashamedly about what we're doing and capture some of the excitement. If you think about what we're doing with the Asteroid Redirect Mission, we're going to grab a piece of the solar system. We're going to deflect it around the Earth to deflect it around the Moon and insert it into a distant retrograde orbit around the Moon where our crews can go visit with the Orion capsule.

You know, that seems kind of boring to some folks when I say all that, but if you talk to some kids that are still excited and they think about what we're really doing. That has a really big deal. I mean, to think we are moving a piece of the solar system for our use that will allow us to learn skills and techniques that we need to push human presence into the solar system, that's a pretty awe-inspiring statement.

But I think we get so jaded because we talk about, well, why don't we go to the Moon or let's go to Mars or let's do some other activity. We have kind of, you know, buyer's neglect, right? It's when you order your food in the cafeteria and you look over and you see what somebody else ordered and immediately what's in front of you isn't appetizing enough. You wish you would have ordered what that person next to you did. I think we have to ignore that a little bit and look at what we've got in front of us with what this country can do and not be ashamed about what we're doing moving forward.

Senator RUBIO. And by the way, I agree. I don't have a public polling on this, but I would venture to guess that an extraordinary majority of Americans are unaware of the existence of that program. Certainly, a majority of our young students and even in college are. And I think we can rally people around a goal like that. But I think it's incumbent upon us in public office who hold these positions and have these forums to make people aware of what we are actually working on; what's there and what's tangible.

I think people would be very excited about thinking that they can be a part of an effort like that or the subsequent efforts that will lead off from that. But, I just think a lot of people don't even know we're doing that.

Dr. CHIAO. Yes.

If I could just add a few comments. I think the key to stoking public interest is flying more and flying sooner. And that's why, in part of my remarks, I talked about the need for possibly a new subprogram of earlier flights that'll get us Beyond-Low Earth Orbit more quickly.

Now, as I mentioned also, for a sustainable program we do need a heavy-lift like SLS and Orion. And as Mr. Gerstenmaier has said in his remarks, I think it's absolutely possible that we can do these kinds of missions in partnership with commercial and with international and just do it maybe without a lot of big increases in the NASA budget.

So I'm hopeful that somewhere in the near to mid-term we could be flying more often and doing missions that will develop the capabilities to go back to the Moon one day and then on to Mars. And this could be done in partnership context that might be very creative and synergistic, and I think that's the way we get the public interested in space flight.

Senator NELSON. That is correct. Once you start putting Americans on American rockets, the interest in this country is going to accelerate. How many people have come up to me and said, "Did you see the movie 'Gravity'?"

They were really gripped by it. Well, they'll be gripped when you see an American climbing in and strapping into an American rocket. And that's the good news. The bad news is that it's going to be

2017, in a commercial rocket getting to the space station (unless you believe some of the commercial companies that it can be 2016) and then Orion, it's not going to be until 2021. But these things are complicated. And so, that excitement will return, but we've got to keep pressing on.

We have a vote that is called right now. I'm going to recess and quickly run over and vote and come right back. It's not a series of votes. It should be just one vote. And then we'll continue with the questions.

Thank you so much.

The Committee will stand in recess.

[Recess.]

Senator NELSON. The Committee will resume.

I want to ask a quick question to a couple of you about the Commercial Crew Program.

Mr. Gerstenmaier, would additional funding allow us to speed up the start of domestic flights to the ISS?

Mr. GERSTENMAIER. Again, I think probably the most critical thing, right now, is to get the funding that we've requested in the President's budget in 2015. We have a pretty solid plan. Our goal is to select a commercial provider in the August–September timeframe of this year. But to make that happen and to be there by the end of 2017, as we've talked about, I really think we absolutely need the funding level that the President has requested. 2015 is probably one of the more critical years in terms of where we are in development and activities. This is really the paramount year of when we need funding for Commercial Crew.

So any support we can get to the President's budget for that activity is absolutely what we need.

Senator NELSON. So the answer to that question is yes, because the President had requested about $850 million for Commercial Crew and over the years, it had gone from $300 million to $500 million to develop Commercial Crew, start the competition, et cetera. Then, to about $700 million and now, for Fiscal Year 2015, which starts October the first, to about $850 million. I agree with you. And so, the answer is yes.

All right. Dr. Chiao, how does commercial access to Low Earth Orbit support further exploration?

Dr. CHIAO. Well, thank you for the question, Senator.

Commercial Crew will ensure access for Americans to the International Space Station. And, as you know, the ISS is designed to be operated internationally. That is we need the crews on the ground and in the station working together in conjunction in order to effectively operate the space station.

The space station is critical for developing the medical, biomedical countermeasures that we need to develop and test before we can send crews Beyond-Low Earth Orbit for any significant period of time. The station also, of course, serves as a test bed for technology, although, new things that we're going to be developing and proving out before we can start sending crewed missions farther from the Earth for longer durations. And so, in that way Commercial Crew very directly supports the station which directly supports the Beyond-Low Earth Orbit program.

Senator NELSON. Ms. Eisenhower, what lessons might we take away from the lapse of, what you mentioned in your testimony, of the need for engagement even during diplomatic uncertainty? The space cooperation agreement between the U.S. and the then-Soviet Union lapsed in the years following the Soviet invasion of Afghanistan. So, given from that lapse, what was the key to managing the relationship through the many crises of the Cold War?

Ms. EISENHOWER. Yes. Well, that lapse between Apollo-Soyuz and 1992, when the Shuttle *Mir* program began, I think the biggest impact is that a generation of people were lost who actually knew how to engage in this kind of cooperation. Even though Apollo-Soyuz was not a huge program, there just wasn't the interactive culture that we see today. And one reason I'm concerned about space being involved in some of the measures we may take in response to the current crisis, is that it would be very sad to see anyone disengaged in this process because long-term space cooperation is going to require the Russians, long-term. So I think that gap does have workforce implications.

As I said in my testimony too, the Eisenhower Administration, which was the administration in power during the dawn of the space age, was also at a crucial stage at the early part of the dawn of the nuclear age. The administration's greatest concern was the development of what might be called "paranoid uncertainty." And so, these kinds of programs, that would be the Atoms for Peace conferences and later work around the International Geophysical Year, as being stabilizing. Precisely because of those crises.

It's remarkable that, after Sputnik actually, the United States and the Soviet Union engaged in private negotiations over the future of Antarctica. And it was as a result of the International Geophysical Year and the fact that that cooperation had not suspended that we managed to demilitarize an entire world continent, which is the Antarctic, which is, today a real test bed and laboratory for the scientific community.

So I think I know that, as NASA understandably goes through reviewing all of its programs, that it should not underestimate the importance of these conferences because the conferences, in fact, at least in the past, played a very significant role.

Thank you, Senator.

Senator NELSON. Would you think that that kind of collaboration that you're talking about, would that ultimately apply to our relationship with other up-and-coming space-faring nations, such as China and India?

Ms. EISENHOWER. Well, I must say that since cooperation with Russia since 1992 has been so successful, I really do think that it makes a lot of sense to be able to look at engaging other countries more deeply. As I said earlier, we didn't do it for them, we did it for us.

We not only had an opportunity to create more transparency, but actually, in the book *Partners in Space,* which I've left a copy for you, we learned a lot from the Russians too. They had some very, very elegant ways of handling complex situations on a very tight budget; which actually could be quite a useful discipline these days. I'm sure the Chinese have very interesting and creative ways of looking at solving exactly the same kind of problems in space.

And that's why I alluded to the fact that we in fact have a much more robust effort in space today because we did share ideas about how to solve some of these common problems. What came together, actually, at the end was something that was really not like the way it was for anybody before, because we put different scientific and technological perspectives together to create something very robust and strong.

Senator NELSON. I must admit that I am shaped in part by my past experiences, for example, in the 1980s. Out of an administration policy in the 80s, they started allowing American satellites to be launched on Chinese Long March rockets. And basically, there was supposed to be a firewall there so that they couldn't get our technology and, of course, they got it.

It's many years later and we're confronted with a different situation but I personally think that the United States was taken advantage of by the Chinese, because of some well-meaning folks in the administration at the time. They were so well-meaning, in my judgment, they were naive. But it is what it is. And here we are in the year 2014. What do you think, Dr. Chiao, about the international collaboration? And do you think we can best engage now with these up-and-coming space-faring nations?

Dr. CHIAO. Well, Senator, I have to admit, in the early 90s, you know, I grew up during the Cold War. And so, during the early 90s I was one of the skeptics of working with the Russians and I was wondering why we were doing this. But after I went over there and started working with these folks and started seeing the advantages and the big picture of international relations and bettering things not only between, you know, cooperating in space but just between our two countries, I became a big believer in international collaboration.

And so, I think there will always be risks. I mean, first of all, you know, it's clear to everyone, I think, that the Russians are trying to spy on us, you know, the Chinese are trying to spy on us. We're spying on everyone. Everyone is spying on everyone else. So there are going to be attempts to get technology from all sides. And I think the safeguards that we have in place, that we put in place with the Russians, as I mentioned earlier, I'm not aware of a single instance where there has been an inappropriate transfer of technology.

Now, to your point about the Chinese missile technology being benefited from some American advice, unfortunately, that was due to naïveté at the time I think. It was not anything directly to do with launching satellites on their vehicles except that in the post-accident investigation some American experts naively gave them some advice which probably helped improve their rockets. That's something we've learned from I think. And as I mentioned, the safeguards that can be part of the safeguards that I think will make the benefits of cooperating more outweigh the risks of possibly losing some technology.

As Ms. Eisenhower mentioned, you know, we can gain great insights into the Chinese program. I've been over and seen their technology. I've seen their rocket factories and their space center, their control center, and it's impressive. They're doing some really

impressive things. And I think we would gain a lot of insight into what they're doing in this relationship if it were to happen.

Senator NELSON. Ms. Eisenhower, do you have an additional comment on how did the United States still manage to benefit from the Russian technologies even though we beat them to the Moon? As a matter of fact, they had a big rocket and it blew up on the pad. And it was their Moon rocket.

Ms. EISENHOWER. Are you talking about the period after——

Senator NELSON. Back then.

Ms. EISENHOWER.—started cooperation? Yes.

Senator NELSON. Right.

Ms. EISENHOWER. Well——

Senator NELSON. With the Soviet Union.

Ms. EISENHOWER.—first of all, some of this is outlined in my book. But I think we learned, for instance, a number of things that the Russians, for instance—and actually probably Bill ought to be answering this question in large measure. But we learned a lot about how a completely different group of people would launch rockets. They were organizing their rocket launches—having their rockets horizontally maintained and then hoisting them up and launching them. I think we learned a lot about redundancy. Help me here, Bill. It's been a long time since I wrote that book, but we used numerical redundancy. They used functional redundancy. Would you like to maybe—could I cede my——

Senator NELSON. Absolutely.

Mr. GERSTENMAIER. I'd just say, again, we've learned an awful lot and both Jeff and Leroy can also add their own experience.

When you solve the same physical problems and you see another country, another group of engineers, solve that same physical problem, and because you've been isolated, you see their solution to that problem in a very different light. And that gives you tremendous exposure. And that's one of the true advantages of cooperation.

Space station is amazing. If you look at the heat shield, the debris shields on the outside of a space station, there's a Russian design for—and we're all protecting ourselves from micrometeorites; small penetrations of the pressure shell.

You can see how the Russians solved the problem; you can see how the Italians solved the problem; you can see how the Europeans solved the problem; how the Japanese solved the problems; and how the U.S. solves the problems. And every one of them does exactly the same job but they do it in a very different manner, fundamentally. So you gain a tremendous experience and a new way of thinking that really helps you become innovative and creative as you try to build your next program.

Dr. CHIAO. Yes. I would totally agree with all of those comments. You know, during my experience with the Russians, as I mentioned earlier, my going in position was why are we doing this, our stuff is so much better. What do we have to learn from them? But the fact is, as Mr. Gerstenmaier just said, the fact is that when you see perspectives, you know, different cultures, different entities, solve the same technical problems from a different approach, it really broadens your own perspective. And personally, having done spacewalk using both American spacesuits and Russian spacesuits,

I really came to admire certain elements of their design, the approach and it's really been eye-opening. And that's just one example.

Senator NELSON. So did Sandra Bullock in "Gravity."

[Laughter.]

Senator NELSON. Another example, I think, is the Russian engine, RD–180. It creates temperatures and pressures because of some alloys that they are very, very good at. That it's an extraordinary engine. And we have the license to it, but we don't know all the techniques of how they blend all those metals to be able to have that kind of thrust in an engine.

Mr. Manber, tell me about—why do you, or do you think that we are nearing a point where commercial exploration could become viable?

Mr. MANBER. I know we are, because I have a lot of customers.

[Laughter.]

Senator NELSON. And why is that, that we're nearing that point?

Mr. MANBER. Well, apologies, Mr. Senator.

I think the primary reason is the stability we enjoy and policy in Low Earth Orbit. We have actually reached a moment in the midst of all the politics we have in Washington where this Congress has given us, in the space community, at least the 10-year horizon. And that is extraordinary.

And we were about to lose a significant foreign customer, in fact, to the Chinese. And the reason was, they were looking at a long-term project onboard space station and we were planning to bring down the station in 2020 and the Chinese are out there commercially marketing this space station now. And when the announcement was made that we're extending it to at least 2024, they came back.

And so, I think the answer to the question, and I think it's a lesson for us as we look at Beyond-Low Earth Orbit, is we have a stable policy now. We have robust transportation to and from the station. We have bipartisan agreement that the station should be continued. We have NASA not competing with the private sector. And we have a very good regulatory framework; the IGA, the Intergovernmental Agreement which lays out the rules of the road. In that environment, I'm willing, my investors are willing, to make investments, and customers are willing to make plans.

So the answer to the question is we have a stable policy and existing hardware in space.

Senator NELSON. And do you have any suggestions what NASA could learn from the commercial partners?

Mr. MANBER. Oh, do I.

[Laughter.]

Mr. MANBER. Yes.

What government does best, as Mr. Gerstenmaier has said in these hearings so many times—what government does best, what NASA does best, is plan and develop. The government does not do operations that well in any industry. They don't run our airlines, they don't, you know, they don't operate our car industry. You don't rent a car from a government agency.

And so, I think what NASA can learn from the experience we are having together on the space station, is to relax a little bit. If they

can provide, with congressional funding, the infrastructure, let the commercial sector in on it.

We have a small satellite program now on space station. We just deployed 33 small satellites on the station with no additional taxpayer funding. We took the risk, we invested the money, we built the hardware, we got it through the NASA safety process and the Japanese Space Agency safety process, and it's all working fine. And I think what we're learning is: NASA should not be trying to do the bells and whistles. Provide the opportunity, provide the infrastructure if that's, you know, the basic facilities, and then let the commercial sector invest its own funds. We still don't have a NASA contract, unfortunately.

But no, we still don't have a NASA contract. And we're very happy with that because they don't design our hardware and we take the risk. And so, I think the lesson for both sides to learn is let the commercial sector do what we do best in any market including space.

Senator NELSON. What can the commercial efforts do to generate more excitement among young people until we can actually get American bodies in American rockets flying back?

Mr. MANBER. When we started NanoRacks, we did not start to do education. I'm not a teacher. I didn't think of education. Today, we have an unbelievable program at NanoRacks where, through our educational partners, we've flown over 45 or 50 school districts in America. We're flying Florida high schools, universities—there's a program in California at Valley Christian which is now 14 Christian high schools.

It's even gone international. We fly Israeli high schools. All with no NASA funding. It's not a NASA program. NASA is the landlord. NASA is the safety. NASA and the taxpayers have given us this opportunity. And I will say that, you know, NanoRacks is a small company. We're not in "Space News" and the industry publications that often. But we're in the, you know, "Albany This" and all these small-town newspapers where we're giving these kids the opportunities. We have parents doing bake sales to fly on the space station. And we have some students, now, that have gone from high school to Stanford and other national universities.

And both at the high school level and in university, they're doing projects on space station through us. And so, I guess the answer to your question is we move so quickly, we're able to do these student projects in one school-year. And it takes NASA, unfortunately, far longer to get through the process and the payload integration for whatever reason.

And so, I think the answer is just with us willing to invest our own hardware, education, partner with educational schools, we're partnering with CASIS now, the nongovernmental organization, to do even more schools. And I think at times people get bothered when you put the word "commercial" and "education" in the same sentence.

But I think what we're seeing is we move so quickly, we invest our facilities, the teachers say that kids never forget that opportunity. So the more that we—we're not an educational company—the more folks who come to us to do it, the more schools, high

schools, homeschooling (we're even reaching out to now), the better it is. And I think there's a lot of excitement under the surface.

What Senator Rubio was talking about, I think, under the surface there's a lot of excitement on station. We shouldn't forget about space station.

Senator NELSON. You dealt in commercialization with the Russian station, *Mir.* Is that correct?

Mr. MANBER. Yes, it is. I admit it.

Senator NELSON. From that experience and your ISS experience, what would you anticipate would be your challenges on a Chinese station?

Mr. MANBER. You mean, commercially or——

Senator NELSON. Commercially.

Mr. MANBER. Well, the Chinese are now competing against us now, and I'm trying to match, already, what I know what their prices to be.

First, what I've learned from the experience with *Mir* is you can market a space station. That was where we learned you can.

And second, you can work with a government's agency even if, and in this case it was Russian, a different government. I think what we'll learn is that, from all indications we're seeing at NanoRacks, is that the Chinese will pursue a commercial pathway. They're offering, already, opportunities with other sovereign nations in exchange for minerals or exchange for other opportunities.

And so, I think what I'm taking away from the experience on *Mir* and ISS is that the Chinese will be a formidable commercial competitor. I want to win in the marketplace not because they're Chinese but because they're a competitor to us. We can work with them but I think the lesson we have got to be clear on in this country is that space stations are commercial platforms. They have political purposes as well. They're important. They're going to be more important. And we need one.

And I did fight in the 1990s to ensure that the *Mir* did not come down. And I lost that battle. But now, I'm fighting to make sure the ISS doesn't come down. And for many of the same reasons. It's extraordinarily critical that we keep the ISS going as long as it's technically feasible because it has political implications and it has commercial implications, as well, for us.

Senator NELSON. We're going to try to do that in a NASA authorization bill if we can ever get over the problems of sequester.

Mr. MANBER. Yes. I appreciate that.

Senator NELSON. Any final comments from anybody on the panel?

Thank you. It's been most illuminating. Thank you for your expertise and your testimony. And thank you for your devotion to our space program.

The meeting is adjourned.

[Whereupon, at 11:51 a.m., the hearing was adjourned.]

A P P E N D I X

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO WILLIAM H. GERSTENMAIER

Question 1. Due to budgetary constraints, NASA has previously had to withdraw from international collaborations, with notable examples including the ExoMars mission and, recently, the proposed suspension of the SOFIA airborne telescope. What steps can the government take to better protect its relationships with international partners during long-term mission planning?

Answer. NASA has a long history of very successful cooperation with nations around the world, and part of that history has from time to time included actions taken by NASA and some by our international partners to re-phase, redesign, or even terminate planned cooperative activities. Even the most robust space partnerships, such as those among the International Space Station partners, have weathered such developments. Our partners are very aware that in all instances our cooperation is based on the availability of appropriated funds, just as we are aware that their participation has similar funding constraints.

Currently, NASA has over 600 active agreements with over 120 countries and anticipates that international cooperation will remain a cornerstone of all of its future activities. As international collaboration in space exploration continues to increase (as resources remain constrained world-wide), maintaining an open, frank dialogue with partners and potential partners will be a key component of sound international partnership practice.

Question 2. Based on your substantial experience with and knowledge of international space exploration efforts, how might NASA's international partners collaborate with the United States on the asteroid redirect mission?

Answer. NASA has identified a number of areas where international collaboration on the asteroid redirect mission could provide mutual benefit. Examples could include:

- Data sharing and lessons learned analysis involving other asteroid/small body missions;
- Asteroid identification and characterization, both near term as NASA works to down-select candidate asteroid targets, and longer term to support preparation for the selected asteroid;
- Asteroid capture system contributions including both deployable structures and autonomous robotic manipulators;
- Rendezvous sensor contributions that could be used for a wide range of mission applications including automated rendezvous and docking and asteroid characterization and proximity operations; and
- Secondary payload contributions to either the Asteroid Retrieval Vehicle or the SLS that could advance either science or future exploration capabilities.

Question 2a. How might that collaboration benefit both partner space programs and our own?

Answer. There is global consensus of the value of human and robotic exploration—with Mars as the ultimate destination—as reflected in the Global Exploration Roadmap released by the space agencies in the International Space Exploration Coordination Group (ISECG) in August 2013. The ISECG member agencies further recognize that collaborative efforts toward this goal are necessary to maximize success in this multi-decadal endeavor while also strategically managing investments across national economies. Coupled with the need for space agencies to demonstrate near term, specific and collaborative steps toward that long-term goal, NASA feels that significant mutual benefit can be realized in each of the areas outlined above.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO
DR. LEROY CHIAO

Question 1. Based on your substantial experience with and knowledge of international space exploration efforts, how might NASA's international partners collaborate with the United States on the asteroid redirect mission?

Answer. International partners will collaborate with NASA on all Beyond-Low-Earth-Orbit (B–LEO) exploration missions, as an extension to the current collaboration on the International Space Station (ISS). Their astronauts will have future opportunities to fly on these missions. They will also contribute to hardware for the exploration programs. As an example, the European Space Agency (ESA) is currently developing the Service Module (SM) for the Orion spacecraft, which will enable it to maneuver in LEO. In addition, there will be opportunities to collaborate on an Earth Departure Stage and other hardware in support of the redirect mission.

Question 2. How might that collaboration benefit both partner space programs and our own?

Answer. International collaboration benefits all partners in many ways. First, it allows partners to have a stake in, and develop different components of the exploration program. This serves as technology drivers in their own countries, while providing employment in the aerospace and other high-technology sectors. Second, similar capabilities provide redundancies that have proven to be critical in the past. For example, the U.S. Space Shuttle supported the Russian MIR space station during the late 1990s. Similarly, the Russia Soyuz supported the ISS after the Space Shuttle Columbia accident. Third, working together on a very visible civil space program helps to improve overall relations between the partners, as they are all focused on a common goal. Furthermore, the partners are highly motivated to be successful, for the overall benefit of all partners. The ISS is a shining example of this.

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