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U.S. HUMAN EXPLORATION GOALS AND COMMERCIAL SPACE COMPETITIVENESS

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE, SCIENCE, AND COMPETITIVENESS

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED FOURTEENTH CONGRESS

FIRST SESSION

FEBRUARY 24, 2015

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED FOURTEENTH CONGRESS

FIRST SESSION

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[1] On March 3, 2015 the Committee finalized Member assignments for its subcommittees. The list below reflects March 3, 2015 assignments. When this hearing was held, on February 24, 2015, formal assignments had not yet been made.

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U.S. HUMAN EXPLORATION GOALS AND COMMERCIAL SPACE COMPETITIVENESS

TUESDAY, FEBRUARY 24, 2015

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

The Subcommittee met, pursuant to notice, at 2:03 p.m. in room SR–253, Russell Senate Office Building, Hon. Ted Cruz, presiding.

Present: Senators Cruz [presiding], Gardner, Blunt, Udall, Markey, Peters, and Nelson.

OPENING STATEMENT OF HON. TED CRUZ, U.S. SENATOR FROM TEXAS

Senator CRUZ. Good afternoon. I would like to thank each of the distinguished witnesses for being here.

Just over a half-century ago, President John F. Kennedy laid down a marker in my hometown of Houston, Texas, and made a commitment that, like the great pioneers that came before us, we too would set sail on a new sea and send man to the Moon. We embarked upon that endeavor as a nation because opening the vistas of space promised high costs and hardship and enormous reward.

Today, we find ourselves at a similar crossroad. The year 2015 is just as critical of a time for our national and commercial space programs as was the case a half-century ago. Future exploration is certain to present hardships, but it also promises high rewards—new resources, frontiers, and economic opportunities.

I am honored to serve as Chairman of this Subcommittee, and, as the Chairman, my first priority for the space component of the Subcommittee will be working to help refocus NASA's energies on its core priorities of exploring space. We need to get back to the hard sciences, to manned space exploration, and to the innovation that has been integral to the mission of NASA.

We need to ensure that the United States remains a leader in space exploration in the 21st century. SLS and Orion will be critical to our medium-and long-term ability to explore space, whether it is the Moon, Mars, or beyond.

At the same time, I remain deeply concerned about our current inability to reach low-Earth orbit. We are right now entirely dependent on the Russian Soyuz system, which is unacceptable from the perspective of space interests and also from the perspective of our national security. Every seat that an American astronaut occupies on the Russian Soyuz costs $70 million.

It is imperative that America has the capability to get to the International Space Station without the assistance of the Russians. America should have the capability to launch a rescue mission to the Space Station should that prove necessary and without being dependent on the Russians. America should have the capacity to launch our critical satellites without needing to acquire Russian RD–180 engines. The Commercial Crew Program is critical to restoring this capability.

I am encouraged by the progress both with regard to commercial cargo and commercial crew, but we need a continued focus on accomplishing the stated objectives with maximum efficiency and expedition. It is terrific to see commercial companies innovating, and, as Chairman of this Subcommittee, I will be an enthusiastic advocate of competition and the enabling of the private sector to compete and to innovate.

In 2013, 81 orbital launches were conducted worldwide, 23 of which were commercial launches. Revenues from the 23 commercial orbital launches were estimated to be more than $1.9 billion. The United States accounted for six of these launches. There is more that can be done to create long-term predictability for the United States commercial space industry so that launch activity will continue to grow.

There is no limit to human imagination or for the desire for exploration. Every one of us, every little boy, every little girl, every man and woman, has looked up at the night sky and wondered what lies out there. That is the mystery, that is the vision behind America's space exploration. America has always led the way in space exploration, and we need to reclaim that leadership.

And, with that, I recognize my friend, the Ranking Member of the full committee, Senator Nelson.

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

Senator NELSON. Thank you, Mr. Chairman.

And, Mr. Chairman, blossoms are breaking out all over Washington because what you just said you and I completely agree on.

As a matter of fact, I offered in the Armed Services Committee the amendment to start—and it passed; it is part of the defense authorization bill—to start the process. As a matter of fact, we authorized $100 million. Senator McCain was a cosponsor of that to develop an alternative to the RD–180.

Indeed, we shouldn't be relying on the Russians to ride. We have in the past, in the two and a half years that we were down after the loss of the Space Shuttle *Columbia* earlier in the last decade. That was our only way to get up to the Space Station. And they were a reliable partner then. But now look at—we can't predict what Vladimir Putin is going to do now.

This was part of the speeches that I was making a decade ago as we were trying to get this thing off the ground.

And I certainly agree with you, and I am just heartened that you came out with such a strong statement on the Commercial Crew, because this is going to be a way that we can get Americans on American rockets quicker back into space since the Space Launch System and its spacecraft, Orion, are going down further in the

decade even though we have already tested Orion on its first test flight.

And so I am just delighted. And, as you know, you and I have talked about this till we are both blue in the face. This subcommittee has always not been bipartisan, it has been nonpartisan. And the subject of the national space program is a nonpartisan issue.

And so I am looking forward to cooperating with you, as we tried last year—it didn't happen—on getting the authorization act. We need to get the authorization act out of here just for the remaining 6 months of this fiscal year, and then let's start looking to the additional fiscal years behind.

And, with that, I will just stop my comments if I may insert my comments that I had prepared in the record for opening comments. And I will just end by saying thank you.

[The prepared statement of Senator Nelson follows:]

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

Good morning and thank you Chairman Cruz. I appreciate you calling this hearing to discuss the importance of U.S. human space exploration and the role of our growing commercial space industry.

In 2010, we passed the bi-partisan NASA Authorization Act. This called on the agency to explore beyond Earth's orbit with the long-term goal of Mars. I'm encouraged to see that NASA has made significant progress toward these goals. NASA is developing a heavy lift rocket, SLS, and the Orion crew capsule, which was successfully launched in December on its first test flight.

NASA has also been working closely with SpaceX and Boeing to begin launching astronauts to the International Space Station beginning in 2017. This partnership is not only good for the commercial space industry but will allow NASA to focus on deep space exploration—specifically, on the path to Mars.

To maintain this progress we need to:

- continue building toward the shared vision Congress outlined in the 2010 authorization;
- provide sustained and predictable funding for the agency over the long term; and
- maintain a balanced portfolio between the complementary science, aeronautics, technology, and exploration missions,
- and continue support for a robust commercial space industry.

These are very exciting times for the future of U.S. human spaceflight and for the entire nation.

This committee has always worked in a non-partisan manner and I look forward to continuing that tradition in this Congress.

Thank you all for being here, and I look forward to your testimony.

Senator CRUZ. Well, thank you, Senator Nelson, for the very kind comments. I hope those are not used against you in your next campaign.

Senator NELSON. I was going to say the same thing to you. Yours is a little more immediate than mine.

Senator CRUZ. And I want to thank each of the three distinguished witnesses that are here. This is a wonderful way to begin the new Congress and the jurisdiction of this subcommittee, by focusing on the overarching goals, that NASA should be focusing on our objectives. And I cannot think of a more distinguished, a more experienced, a more respected panel than the three witnesses who are with us today.

We have first Colonel Walt Cunningham, former NASA Astronaut and Apollo 7 Pilot. We have next Dr. Buzz Aldrin, a former NASA Astronaut and Apollo 11 Pilot. And we have Mr. Michael Massimino, a former NASA Astronaut and Mission Specialist for the Space Shuttle Program.

And I thank each of the three of you for taking time from your busy schedules to join us.

We will begin with Colonel Cunningham's testimony.

STATEMENT OF COLONEL WALT CUNNINGHAM (USMC, RET.), FORMER NASA ASTRONAUT AND APOLLO 7 PILOT

Colonel CUNNINGHAM. Thank you, sir.

I appreciate the opportunity to share my thoughts on where I believe our space program has been slipping and some of the things I believe NASA must do to maintain America's lead in space exploration. While this is my personal opinion, it is shared by many of my contemporaries. Some additional points are in my written testimony that I hope you all will read.

Humans have always been driven to explore the unknown and to open new frontiers. Opening a new frontier demands three things: resources, technology, and, more important, the will to do it. In 1961, America was willing to take the risk of going to the Moon. When President Kennedy made his commitment to land a man on the Moon, not a single American had yet been in orbit.

The success of the Apollo program was due to the collective efforts of 400,000 members of our team—engineers, operators, managers, and contractors. With the whole world watching, we accepted the challenge, took the risk, and changed the way that we all perceived our world.

We accomplished a landing on the Moon in 8 years. Today, 45 years later, the next frontier, Mars, seems decades out of reach, primarily because we do not have a national commitment.

Our Apollo program made America preeminent in space and the world's most technologically advanced nation. It led us to the space shuttle, the greatest flying machine ever built by man; the International Space Station, ISS; and the Hubble Space Telescope. The spin-offs have infiltrated virtually all areas of our industry.

While NASA's portion of the Federal budget peaked at 4 percent in 1965, it has been below 1 percent for the past 40 years. While NASA has accomplished many things and made manned spaceflight much more routine, we have not challenged the next frontier—the manned exploration of Mars. That will only be possible if our government initiates and provides the funding for such a program.

Over the years, NASA has been subjected to more and more political pressure, and the agency has grown increasingly political inside. This has left employees much less willing to express their opinions freely and the agency less attractive to the best and brightest of today's young professionals.

An example: After trying for years, NASA is still unable to reduce the number of space centers that they operate around the country in order to lower their overhead costs. Congress and local politicians have always won out and saved the one in their district.

A commitment to push back the space frontier with a man landing on Mars would drive NASA's budget, while the schedule would be controlled by the rate at which Congress funds it. This could also empower the agency to correct many of the deficiencies that have evolved over time.

A Mars exploration vehicle will have to be assembled in Earth orbit. Moving out of Earth orbit would require heavy-lift rockets, like our Space Launch System and the Orion crew capsule. A reusable launch vehicle similar to our space shuttle may be necessary in order to assemble an interplanetary spacecraft. While these are all costly, they will be essential in order to move humans out of Earth orbit.

Any Mars exploration program will have international partners. In that partnership, NASA should take a strong leadership role, as they did back in the Apollo program, and not just be one more partner in an international effort. Hopefully, it would encompass less politics and be better structured than the ISS partnership.

ISS that we gave birth to in the 1970s is probably the most impressive piece of space hardware ever placed in orbit. While leading the international partnership, we transferred $3 billion to $5 billion to Russia to help resurrect their space industry, increased our cost of the program by $15 billion to $20 billion, and we are now totally dependent on Russia to get American crewmen to and from the ISS.

The success of our space program has always been dependent on private industry, and they delivered. As NASA grew less entrepreneurial, less efficient, and more bureaucratic, they inspired new so-called commercial space companies. While most of these companies have been subsidized by government funding, NASA has less control over their development, operations, and, consequently, their results as they did in the past.

Some people suggest that private space companies should collaborate with NASA for space missions beyond Earth orbit, which means sharing the cost. While commercial companies will always contract with NASA for the hardware and the technology, the government will always be expected to pay the cost of exploration, funded by tax dollars of course.

Space exploration is far too expensive for commercial companies that are driven by profit and return on investment. Space exploration does not satisfy either of these criteria. Government agencies are not profit-driven. Government underwriting permits our agencies to guide, develop, and manage the technology.

Our country's return on investment is the private industry commercialization of the technology that is developed. Since commercial companies move much faster than government agencies, production by private industry will shorten the timeline for a launch to Mars.

In the absence of a Mars exploration program and limited funding, NASA has initiated the Asteroid Redirect Mission, possibly to the Lagrange points. Today, they justify it as a first step in the mission to Mars. Anything it might do that could help a Mars mission could be more officially done with some other projects. While we work on overcoming the problem of radiation exposure and try-

ing to speed up travel, we should return to the Moon to develop a crew facility for semi-permanent living.

Many scientists today are saying, send robots to Mars, because humans are too costly and it is too dangerous. NASA should continue to exploit both manned and unmanned missions, but humans will always be much faster and more efficient because we can think and act in real time.

There are two things I believe we should focus on also: eliminating permanently any dependence on other countries for launch capability; two, find some way for NASA administrators to become less subject to changes in the administration every 4 years.

The Apollo program took 8 years, it cost $110 billion—that is in today's dollars—and the benefits to our society have been priceless. A manned landing on Mars will probably take twice as long and cost up to three times as much in today's dollars. That is a fraction of what our annual Federal budget deficits have been running, and deficits do not have a return on investment.

The human desire to explore and settle new frontiers will be satisfied, if not by Americans, then by others. Humans somewhere will certainly return to the Moon and go on to Mars. I believe that we have the resources and the technology, but do we have the will to tackle the next frontier, Mars?

Thank you.

[The prepared statement of Colonel Cunningham follows:]

PREPARED STATEMENT OF WALTER CUNNINGHAM, USMC, RET., FORMER NASA ASTRONAUT AND APOLLO 7 PILOT

I appreciate the opportunity to share my opinion on where I believe our space program has been slipping and some of the things I believe NASA must do to maintain America's lead in space exploration. This is my personal opinion but it is shared by many of my contemporaries.

Humans have always been driven to explore the unknown, to discover new worlds, to push our boundaries and then reach out for the next new world. The technological breakthroughs and scientific discoveries from opening new frontiers have benefitted our society for centuries. We have the responsibility and the opportunity to explore the next frontier.

In the 15th and 16th centuries the frontier was in the new world and England, Spain and Portugal were crossing the seas in search of their country's greatness. In 1519, Ferdinand Magellan set sail on one of the most famous voyages of exploration in history—the first voyage around the world. He set out with five ships and 270 sailors. Three years later, only one of the original ships returned with only 18 of the original crewmen still alive.

In the 1960s, we set sail on another ocean; one whose farthest shores we can never reach. This new ocean was more pristine than was the new world before voyages of Columbus and Magellan. As exploration of the new world was inevitable 500 years ago, so too is our exploration of space.

Any project as complex as Apollo requires three things: resources, technology, and—most important—*the will to do it.* In 1961, America was willing to take the risk of going to the Moon. It was human risk, and technical risk, economic risk and political risk. The Apollo Program took initiative and leadership. When President Kennedy made his commitment to land a man on the Moon not a single American had yet been in orbit!

With the Apollo Program, America took the historical role of opening the next frontier. Astronauts were at the tip of the spear and we got the glory but the success of the Apollo program was due to the collective efforts of 400,000 members of the team—engineers, operators, managers and contractors. With the whole world watching, we accepted the challenge, took the risk and changed the way we all perceived our world.

During Apollo, the American space program was unique. Over the past 40 years, NASA has enjoyed many great accomplishments. But as the agency evolved the management culture has changed and it has not always been for the better.

Space is the most hostile environment into which man has ever ventured. NASA should work to prevent mishaps but those efforts should be balanced against the objectives they are trying to accomplish. Spaceflight will always be expensive and manned spaceflight will always involve risk and the chance of failure. Exploration is not about eliminating risk; it's about managing risk!

Motivated by the Cold War and a national commitment, we accomplished a landing on the Moon in eight years. Today, after 50 years of experience and technology development, a manned mission to the next frontier—Mars, seems decades out of reach, primarily because we do not have a national commitment.

Our Apollo Program made America pre-eminent in space and the world's most technologically advanced nation. It led to such things as the Space Shuttle—the greatest flying machine ever built by man, the International Space Station (ISS) and the Hubble space telescope. The technology that made this possible was funded by the American people and it has infiltrated virtually all areas of industry.

NASA's portion of the Federal budget peaked at 4 percent in 1965. For the past 40 years it has remained below one percent and for the last 15 years it has been driving toward 0.4 percent of the Federal budget.

While NASA has accomplished many things and made manned spaceflight much more routine, we have not challenged the next frontier—the Manned exploration of Mars. Manned exploration is the most expensive space venture and, consequently, the most difficult for which to obtain political support. Manned exploration of Mars will only be possible if our government initiates and funds such a program.

While our world has been changing and space technology improving, NASA management has been aging, layers have been added and politics plays an ever growing role. NASA seems less capable and less interested in pushing out the space frontier and focusing more on eliminating risk and looking for absolute assurance that something can be done before committing to do it. This leaves NASA less attractive to the best and brightest of today's young professionals.

Over the years, NASA has grown increasingly political. There was a time when personnel at all levels contributed to success by freely expressing their completely candid opinions on design, testing, operations and management issues. Management today seems less and less likely to speak out because of their concerns about the political repercussions. NASA needs to find a way to return to the environment where people contributed to success by freely expressing what they thought about the issue being addressed.

NASA has also been subjected to politic pressure from outside the agency.

Examples:

> NASA has tried for decades to reduce their overhead by reducing the number of Space Centers they have around the country. Congress and local politicians have always won out and saved the one in their district. NASA is still burdened with the same 10 Space Centers and a half dozen other facilities. This reduces the funds available for science and space applications. When our military faced a similar problem with too many bases spread around the country, it was resolved when Congress passed the Base Realignment and Closure Act of 1990 to screen and close facilities.
>
> NASA should also be focused more on their science obligations and avoid any associated political issues. Goddard Space Center has been involved in global environmental science for many years. For the past 20 years, instead of just sharing the climate science data they collect, they have joined the political argument that humans are the cause of global warming.
>
> At the United Nations Climate Change Conference in Lima, Peru, last December, virtually all of the data available, the presentations and the handouts in the American Pavilion were material furnished by NASA. NASA personnel were making the presentations and the data shown was selected to make the case that humans were the cause of global warming. The American Pavilion was virtually a NASA pavilion. The space agency compromises its scientific credibility by participating in the politics surrounding one of the great scientific hoaxes in history.
>
> To get NASA back to the posture where they excelled, we should commit once more to pushing back the space frontier with a manned landing on Mars. Such a mission will become much more feasible when, and if, we overcome the problem of radiation exposure and/or shorten the time of travel.

Our Mars exploration vehicle will have to be assembled in earth orbit. Moving out of earth orbit will require heavy-lift rockets, like our Space Launch System, and the Orion deep space crew capsule. Assembling an interplanetary spacecraft may re-

quire a reusable launch vehicle similar to the space shuttle. While these are all expensive, they will be essential if we want to move out of earth orbit.

We could also explore the possibility of moving the ISS from 51.6° down to an orbital inclination where it could be/might be useful in constructing an interplanetary spacecraft and/or as a departure point for Mars.

With a national commitment for Mars exploration our space agency's budget and activities would be driven by this strategy. The timing, of course, would be controlled by the rate at which Congress funds the program. If addressed in the way we addressed a manned landing on the Moon, it would enable NASA to deal with many of the internal deficiencies that have developed over time.

Any Mars exploration program will have international partners. If it is our American program, we should take a strong leadership approach in managing that program. With Apollo, the effort was clearly led by NASA. In a Mars program we should obviously lead the way and not just be one more partner in an international effort to go to Mars. Hopefully, it would have less politics and a better structure then the international program we formed around the ISS.

The ISS, that NASA first began to work on in the 1970s, is probably the most impressive piece of space hardware ever placed in orbit. It has had "equal" partners from the beginning, even though more than 70 percent of the cost has been paid by the U.S.

In 1993, after NASA had evaluated and *rejected* what Russia might contribute to our ISS program, President Clinton insisted that Russia be included as a full partner. ISS was a convenient way for America to bail out the nearly bankrupt Russian space program. Our administration claimed that we would lift off two years earlier, it would save us $2B and it would keep Russian scientists from working on nuclear development for other countries.

Reality: After transferring $3–5B to help resurrect the Russian space industry we launched two years late. The cost to us was increased by $15-$20 billion, due primarily to changing the orbital inclination from 28.5° to 51.6° in order to accommodate the Russian launch capability. We are now totally dependent on Russia to get an American to and from the ISS—a program we gave birth to in the 1970s.

In the Apollo Program we were totally dependent on private industry. And they delivered! As NASA has grown less entrepreneurial, less efficient and more bureaucratic over the years, it has inspired new, so-called commercial space companies. While most of these new companies have been subsidized by Government funding NASA has less control over their development, operations and, consequently, the outcome.

Space exploration is far too expensive for private industry without government capital. Commercial companies have a different perspective on space exploration and operations. Commercial companies are driven by profit and return on investment. Pushing back the frontier of space does not satisfy the business case for either of these criteria.

Government space agencies are not profit driven. Our government underwrites the exploration of space and government agencies develop and manage the technology. Our country's return on investment is the technology developed to open that next frontier and the commercialization of that technology in private industry.

Some people suggest that private space companies should collaborate with NASA for human missions beyond low Earth orbit. Collaboration means sharing the cost. Commercial companies will contract with NASA for the hardware and technology but the government will always be expected to pay the cost of exploring the next frontier—funded by tax dollars, of course.

Since commercial companies move much faster than government agencies, production by private industry will shorten the timeline to launch a mission to Mars.

In the absence of a Mars Exploration Program and limited funding, NASA has initiated the Asteroid Redirect Mission (ARM). Today, ARM is characterized as a first step in the mission to Mars. This could be fascinating for some scientists but anything it might do to support a future Mars mission could be more efficiently done with other projects.

The Japanese landed an unmanned satellite on an asteroid and returned with a surface sample 5 years ago. If ARM is funded, it should be an unmanned science mission, NOT a manned mission. Limited manned exploration funds should not be wasted on such missions.

There are manned missions we should be planning in preparation for a manned landing on Mars. While we work on overcoming the problems of radiation exposure and learning how to speed up travel, we should return to the Moon where we can perfect a crew facility for semi-permanent living. It is critical that we learn how to keep crews alive on Mars for months or even years. Crews on the Moon are only four days away from home as opposed to months and even years on a Mars mission.

Many scientists today are saying, "Send robots to Mars because humans are too costly and it's too dangerous."

NASA should continue to mix manned and unmanned missions in order to exploit both. Robots can assess risks to human exploration, determine the presence of environmental, chemical, or biological problems and help to mitigate the risks. Robots are valuable tools in preparing for exploration but they are greatly inferior to humans in terms of speed, grasping what has been observed and judging what to do next. Humans are much, much faster and more efficient because we can think and act in real time.

The Apollo program cost $110 billion in today's dollars and the benefits to our society have been priceless. A manned landing on Mars, after 50 years of technical progress and spaceflight experience and perfecting a crew facility on the Moon, will probably take twice as long and cost 2 to 3 times that amount. That is a fraction of what our annual Federal budget deficit has been running and deficits do not have a return.

A century from now, no one will care how carefully and cautiously we may have survived the 21st century, but they would certainly celebrate our willingness to make a commitment, to accept the risk, to expand our universe and to change the way we perceived our world if we commit to land a man on Mars.

We will not move our society ahead by eliminating risk. Exploration is not about eliminating risk; it's about managing risk!

The human desire to explore and settle new frontiers will be satisfied—if not by Americans, then by others. Humans, somewhere, will certainly go back to the Moon and on to Mars.

I believe we have the resources and the technology for manned exploration of Mars! Do we have the will to tackle the next frontier—Mars?

Senator CRUZ. Thank you, Colonel Cunningham.

Dr. Aldrin?

STATEMENT OF COLONEL BUZZ ALDRIN (USAF, RET.), FORMER NASA ASTRONAUT AND APOLLO 11 PILOT

Colonel ALDRIN. Senator Cruz, Senator Nelson, Senator Markey, Senator Udall, Committee on Space, Science, and Competitiveness, I wish to thank the Committee for the opportunity to speak with you about the future of American human spaceflight enterprise. This is truly an honor, and I applaud you for raising this issue so early in this session.

America must be the world leader in human spaceflight. There is no other policy area which so clearly demonstrates American innovation and enterprise than human spaceflight. American leadership is more than simply getting one step ahead of our global competitors. American leadership is inspiring the world by consistently doing what no other nation is capable of doing. We demonstrated that for a brief time 45 years ago.

If we wish to retain American leadership in space, I believe that early in the next administration the nation must commit to developing a permanent presence on Mars. Another Apollo-like mission to put flags and footprints on Mars does not ensure sustained leadership, and lunar settlements will only require a small step for the other nations to catch up.

I have a multi-decadal plan with compelling vision that will establish world leadership for the remaining of the century and initial landings on Mars by 2038. It is an integrated plan that knits together return to the Moon on a commercial and international basis, leveraging asteroid rendezvous, and settling Mars on a carefully developed risk-mitigation architecture.

It includes the use of a robotic cycler between Mars and Earth that will revolutionize the economics and safety aspects of human

missions to Mars. Much analysis has been done on this concept in partnership with the commercial sector, the international community, and especially the academic community. All this can be done without being a major budget-buster for NASA.

The architectures I have developed are driven by several technical principles, which I believe are essential to achieving this goal. These principles are part of what I call my "Unified Space Vision."

One, current programs for commercializing crew and cargo transportation to the International Station could expand to provide transport of crews with lifeboat rotations to two redundant stations on either side of the Moon.

The U.S. will lead other crews from these stations for distant controls of the assembly and checkout of habitational structures and their life-support systems. Also, intricate rovers will provide ice to rocket fuel resources and other resources.

We also have a reliable, developed and test most of the systems needed for Mars. We should participate in lunar development but avoid getting our human spaceflight budget captured by lunar gravity's expensive consumption of funds. Let's establish a lunar infrastructure which barters visits to the surface on international landers.

Number three, reduce the cost of sustaining a presence on Mars by deploying outbound cycling spaceships that orbit between Earth and Mars without requiring a great deal of propulsion. Each successive mission would only have to send astronauts, landers, and the minor provisions. The ending provisions are reusable on the cycler—radiation protection. The vast majority of the mass would remain in the orbit between Earth and Mars.

Number four, focus on people to Mars to stay. Bringing everyone home after a relatively brief stay is a cost-driver. I envision many of the people who go to Mars to remain and establish a permanent settlement. We have developed an inbound cycler as a means of bringing people back for certain contingencies. But the cost of effectively sending the entire launch system to return everyone home on every mission can make the entire venture prohibitively expensive.

I provided most of the detail in my written statement and will have a much more complete version of this plan once the study of my cycler concept is conducted by an Aldrin-Purdue study that will be finished near the end of April.

In closing, I encourage you to think about the ability of free markets in space to reduce the cost and power of American ingenuity to solve the most difficult technical challenges. In my opinion, there is no more convincing way to demonstrate American leadership for the remainder of this century than to commit to a permanent presence on Mars.

I thank you for your time and look forward to the Committee's leadership.

[The prepared statement of Colonel Aldrin follows:]

PREPARED STATEMENT OF COLONEL BUZZ ALDRIN (USAF, RET.), FORMER NASA ASTRONAUT AND APOLLO 11 PILOT

Senator Cruz, Members of the Senate Subcommittee on Space, Science, and Competitiveness, I want to thank the Committee for the opportunity to speak with you

about the future of the American human spaceflight enterprise. This is truly an honor, and I applaud you for raising this issue so early in this session.

Some of you may wonder why an 85 year old former Astronaut is here, testifying in Washington DC, rather than playing golf in Florida. Well, in the first place, while I do live in Florida, I am a truly horrible golfer. I am a much better orbital dynamicist. But more importantly, I love my country and I believe the future of the American space program is one of the most important issues we face as a nation. We are at an important inflection point in our Nation's space program. Over the next few years we must choose whether we are to go forward as a nation and lead the extension of global civilization to a permanent presence beyond Low Earth Orbit, or to allow American leadership in space to erode over the next decades.

America must be the world leader in human spaceflight. There is no other policy area which so clearly demonstrates American values of innovation and enterprise than human spaceflight. I have dedicated the last 50 years of my life to this proposition and I do not intend to stop any time soon. I think there is broad agreement in the space community and the panelists you are hearing from today on this point.

There is decidedly less agreement on how we should do this. We do not have long to decide, and this Subcommittee will play a critical role in setting the agenda for this decision. I hope that my testimony today can contribute to this process. I think it will come as no surprise to Members of the Subcommittee and my fellow panelists that I have my own opinions.

Allow me to begin with a question: What do we mean when we talk about American leadership? American leadership is more than simply getting one step ahead of our global competitors. American leadership is inspiring the world by consistently doing what no other nation is capable of doing. We demonstrated that for a brief time 45 years ago. I do not believe we have done it since.

I believe it begins with a bi-partisan Congressional and Administration commitment to sustained leadership. If we wish to retain American leadership in space, I believe that early in the next administration, the Nation must commit to developing a permanent presence on Mars. Another Apollo-like mission to put flags and footprints on Mars does not ensure sustained leadership, and restarting a failed constellation program will only require one small step for China to catch up.

I have spent much of the time since I landed on the Moon thinking and writing about the future of the space program. But we cannot get there with conventional thinking. The architectures I have developed are driven by several technical principles which I believe are essential to achieving this goal. These principles are part of what I call my Unified Space Vision.

(1) Development of the commercial space transportation sector to provide crew and cargo transportation systems. Current programs for commercializing crew and cargo transportation to the International Space Station could lead to augmenting and expanding that commercial capability to transport mixed crews with lifeboat rotations to control stations in the vicinity of the Moon.

(2) The U.S. should lead commercial and support international development of the Moon with extensive telerobotic complex engineering assembly of habitation structures and scientific and commercial rovers in order to provide necessary fuel resources and develop reliable systems for Mars. We should participate in lunar development but avoid getting our human spaceflight budget captured by lunar gravities expensive consumption of funds to create, support, and sustain human landings. Let's establish a lunar infrastructure which can be commercially self-sustaining, relying on bartered visits to the surface on international landers. This makes far more economic sense for scientific and commercial activities.

(3) Reduce the cost of sustaining a presence on Mars by deploying cycling spacecraft which perpetually orbits between Earth and Mars only requiring a small trim propulsion. The primary cost of getting to Mars is the fuel required to send a complex base of habitable structures to Mars. Each successive mission would redundantly send astronaut pioneers in Mars landers of increasing capacity. The majority of the mass including radio mitigation would remain in orbit between Earth and Mars.

(4) Focus on sending people to Mars to stay. The huge cost driver for Mars missions is the cost of bringing everyone back home after a relatively brief stay. I envision a program of settlement that schedules most of the crews who go to Mars will remain and establish a permanent settlement there. Naturally, we have to develop the Inbound Cycler as a means to bring people home who need to return for whatever reason. But the cost of effectively sending an entire launch system to return everyone home on every mission can make the whole venture prohibitively expensive.

These are the basic principles. Let me turn briefly to just a few notes from my Unified Space Vision on just how we would execute this program and establish a permanent presence on Mars before 2040.

- We can begin as soon as 2018 with the launch of an inflatable 1st generation exploration module (XM) to a low earth orbit station with Orion or Dragon. Then hopefully one of these spacecraft to be launched with another inflatable XM will be transported to the near libration point, L-1 of the Moon in July 2019 for the Apollo 11 50th Anniversary! The purpose of these flights is to test exploration modules and to provide locations from which to remotely construct international lunar bases. These lunar activities will provide the necessary experience to later remotely construct (from Earth and then from Phobos) a base on Mars. They also provide the basis for extended international and commercial lunar operations, including *in situ* resource utilization, as well as a capability for future human missions to asteroids. I believe that the development of commercially provided resources from space will be critical to enabling human missions to Mars.
- As we begin to develop our capabilities on the Moon, sometime between 2020 and 2030, I envision a one year Orion mission with an inflatable to an in-orbit asteroid that arrives a few days before a complex sampling robotic spacecraft arrives from a slow, fuel saving solar electric propulsion transit of 1.5 years. This would give 60 days for a crew including scientists, asteroid mining and the robotic experts. This mission would also enable us to further test human spaceflight systems in deep space.
- In 2031 an Orion with a rigid 2nd generation exploration module will join the inflatable at LEO, L-1, and L-2, and will then land on the Moon as a lunar habitat.
- Once the lunar bases have been established, beginning in 2028 (before first humans are sent to Mars) and through 2034—nine unoccupied 3rd generation exploration modules, will be launched to Mars and two XM habitats sent to Phobos.
- In 2031 an Orion with a rigid XM will be launched on an "Inspiration Venus" one year flyby of Venus mission with a crew of two women. On return to Earth we will perform two aerocapture maneuvers before reentry.
- One of defining highlights of the mission architecture is the use of "cycler" spacecraft that would travel between Earth and Mars perpetually every synodic period. (A synodic period is the time that the orbits of the Earth and Mars bring the planets closest together--about every twenty six months.) My architectures features two cyclers. The larger capacity outbound cycler (heading from Earth to Mars) and the smaller inbound cycler (traveling back from Mars to Earth) alternately encounters Earth roughly every four and a half years.
- The first outbound cycler will be intercepted by three smaller landers with one crew member each. One unmanned lander lands on Mars to demonstrate and checkout Mars landing procedures, and two landers land on Phobos with three crew members. The Phobos crew will remotely connect up to nine surface modules telerobotically, using techniques developed at the Earth-Moon libration facilities. These XM habitats are low thrust transported and landed five years before the 1st outbound cycler reaches Mars. Then the XMs are transported by rovers slowly from dispersed landing locations by long delayed control from Earth to within a few feet of each other at the desired base location.
- When the first outbound cycler crew of three is cleared to land, the crew transfers from Phobos to the Mars surface. If the crew is not cleared to land, then they could return to Earth with an inflatable module and a Mars lander and storable propulsion system, all stationed on Phobos or by intercepting the first inbound cycler for its return to Earth.
- The second outbound cycler transit to Mars carries three landers with a total of nine crew members. One lander with three crew members replaces the original three crew members on Phobos. The remaining two landers land on Mars with a total of 6 crew members establishing the first permanent settlement on Mars.
- The Inbound Cycler when not used for crew return can be intercepted to return high value cargo. The lander capacity could be increased to six. Also a second outbound cycler can be introduced to make transits every synodic period instead of every other.
- Every four and a half years the population of Mars will continue to grow as recurring outbound cyclers bring additional crews of up to 9 new inhabitants. The

list of potential tasks the surface inhabitants of 18 might accomplish is far too long to enumerate in my remaining time, but I would just note that Steven Squires, the Principle Investigator of the Mars Pathfinder mission once said that a single crew could accomplish in one week what took two rovers five years to do.

Over the coming months you will listen to a great deal of how hard and expensive it is to go to Mars just once, let alone stay there. But, in closing I encourage you to think about the ability of free markets in space to reduce the cost and power of American ingenuity to solve the most difficult technical challenges. In my opinion there is no more convincing way to demonstrate American leadership for the remainder of this century than to use 20 July 2019 to commit to and execute a permanent presence on Mars.

I thank you for your time and look forward to this committee's leadership.

Senator CRUZ. Thank you very much, Dr. Aldrin.

Dr. Massimino?

STATEMENT OF MICHAEL J. MASSIMINO, PH.D., PROFESSOR, DEPARTMENT OF MECHANICAL ENGINEERING, COLUMBIA UNIVERSITY, AND FORMER NASA ASTRONAUT

Mr. MASSIMINO. Chairman Cruz, Ranking Members Nelson and Udall, and members of the Subcommittee, thank you very much for having me here today. I have gotten to do some cool stuff in my life, and this is right up there. I really am honored to be here. Thank you.

I want to describe to you a few things I learned as an astronaut, some benefits that our space program has provided not only for our country but I think for the whole world. And there are three of them I want to point out from my personal experience. And then I want to tell you a story from one of my spaceflights I think kind of wraps it up. So that is what I am going to try to do.

The first benefit I want to tell you about is how the human exploration program can benefit science and life on Earth. And there are lots of examples we can use, but the one I am most familiar with is the one I got to participate in firsthand, and that is the Hubble Space Telescope servicing program.

Both of my shuttle flights were to the Hubble Space Telescope. And Hubble has given us some great discoveries, so far one Nobel Prize. And I say "so far" because I think there are a lot more coming. The 25th anniversary of the telescope in orbit is coming this spring. And it has given us a window into the universe out there. It has found black holes, dark matter, dark energy, inspired many people to continue studying the universe, and it has shown us the beauty and the wonder of what is out there.

But none of this would have been possible without human exploration, without the shuttle program, spacewalking astronauts, our ground control team, to be able to react to problems and get the job done so that we can provide that great instrument to the astronomers and scientists on the ground.

So, the human exploration program and how it can affect science and benefits on Earth.

The second thing I want to point out is international cooperation. When I was a new astronaut in 1996, we were starting to work with our international partners to build the Space Station. None of the elements had launched yet. And sitting there listening to the briefings as a new person not knowing really what was going on

at the time, I wondered, how are we going to make this work? How are we going to work with all these countries of Europe, with Japan, with Canada, and with the Russians? The U.S. was clearly about to be a leader, but how were we going to work with everybody? Different cultures, different languages, different ways of doing things, different systems of measurement. How are we going to make this all work?

And what I discovered was, when we all had a common goal, it didn't matter what country you were from. We wanted to build a space station, we wanted to produce this laboratory. And with that common goal, we were able to achieve a great thing, which is the International Space Station, which is orbiting above us right now.

So international cooperation is a second benefit that I discovered of the space program.

And the third is inspiration for young people. OK, I am sitting next to two of my boyhood heroes. I watched this man walk on the Moon when I was 6 years old, and it changed my life. And it inspired me to become an astronaut. And not too many younger than me can remember that, but the ones who are at least my age and older that I trained with will point to that episode, what Walt and Buzz did as astronauts, that inspired us as young people.

And as an astronaut, I often wondered, what are we doing now that is going to get this next generation of American kids interested in studying math and science and going to space? And it never was really clear to me until lately.

This past year, I have been teaching up at Columbia. I left NASA; I am a Professor at Columbia. And there are some smart kids up there, all right? And what I found was they are just as excited as me and my colleagues were years ago about the space program.

And it is not just NASA inspiring them, though I have had lots of students who have gone to work for NASA, different NASA centers, for NASA contractors. But these kids want to change the world, and they want to be entrepreneurial. They see the space program as a way that they can be entrepreneurial. They see these really smart, successful entrepreneurs putting their efforts into trying to help the economy through space, and they see these people as role models that they want to follow.

So it is almost, I think, better than when I was a kid, in some ways, because it is not just NASA doing big projects; it is also this entrepreneurial spirit, where they think they can provide economic benefits for the world, as well.

The story I want to tell you: On my second spaceflight—or my first spaceflight, my second spacewalk, I had a chance to look around during the spacewalk. And at Hubble we are about 100 miles higher than where the Station was—nowhere near as far as Buzz was away from the planet. But I was able to see the curvature of the Earth, and you can see it in its entirety. It takes up your whole field of view, but it is really beautiful.

And my first spacewalk, I kind of stuck to my job. On my second spacewalk, I wanted to see what it was like. And there are really no words to describe to you how beautiful our planet is from up there. So I will just tell you what was going through my mind.

And the first thought was, if you were in heaven, this is what you would see. If you could be up there in heaven, you could look down on our planet and you would see how beautiful it is.

And I was thinking about it, and it wasn't enough, and I thought, no, no, there is more than that, it is more beautiful than that; this is what heaven must look like. And, at that moment, I felt like I was looking into paradise. That is how beautiful our planet is. It is fragile, it is a paradise, and we need to take care of it.

Thank you.

[The prepared statement of Mr. Massimino follows:]

PREPARED STATEMENT OF MICHAEL J. MASSIMINO, PH.D., PROFESSOR, DEPARTMENT OF MECHANICAL ENGINEERING, COLUMBIA UNIVERSITY, AND FORMER NASA ASTRONAUT

Mr. Chairman and members of the Subcommittee, thank you for this opportunity to appear before you to discuss the accomplishments of America's space program during my missions and my perspective on our Nation's current goals and priorities for the future of human spaceflight and space exploration. Being asked to testify for this committee is an honor, and I am privileged to share my experiences and opinions here with you today.

I became an astronaut in 1996 and have been fortunate to fly on two space shuttle missions: STS–109 in March of 2002 and STS–125 in May of 2009. Both of my flights were Hubble Space Telescope servicing missions. The Hubble servicing missions are vital examples of how human spaceflight can contribute to ground-breaking research being done by scientists on Earth. Based upon my experience, I believe NASA's joint focus on innovation in scientific research and its commitment to human spaceflight continues to be a worthwhile goal for our space agency. More than that, it is an noble endeavor for us as a nation and as custodians of this incredible planet we call home.

NASA has made great headlines in recent years, most notably by landing a rover on Mars, but amazing as that achievement is, putting human beings in orbit remains the single most important element of successful space exploration. My first mission set a team record of spacewalking time on a single space shuttle mission. My second mission broke that record. During each spacewalk, having an astronaut on the scene was what saved the day. For example, on one of my spacewalks I was required to improvise a solution no robot or rover could have possibly done: manually pulling off a handle that was held fast onto the telescope with a stripped fastener. This was the only way to complete the repair of the Space Telescope Imaging Spectrograph, a scientific instrument that can, among other capabilities, analyze the atmospheres of planets in other solar systems in order to establish the possibility of finding other places in the universe capable of sustaining life.

The efforts of the human spaceflight program during my missions, in partnership with NASA's on-going ground control operations and scientific research programs, have allowed the Hubble Space Telescope Program to increase our understanding of the universe. Our servicing missions have enabled scientists from around the world to make major discoveries, including dark matter, dark energy, black holes, and the existence of planets in other solar systems. In addition to these great scientific advances, through Hubble's iconic images we have also brought the incredible beauty of the universe to the citizens of the world.

NASA has also in recent years accomplished much in terms of building and expanding international partnerships, an endeavor that I believe should continue with our Nation's leadership. While an astronaut from 1996 to 2014, I had the opportunity to contribute to the planning, building, and establishment of scientific operations of the International Space Station (ISS). Among the many achievements of the ISS is bringing different countries together toward a common goal. Through the ISS and its work, the United States, Russia, member countries of the European Space Agency, Canada, and Japan work together as partners on international space projects and research. We live in this world together, and working in unison to study it can only help us all. The friendships, alliances, and accomplishments of the ISS have shown that, given common scientific and exploration goals, countries can accomplish great things together.

As a Professor at Columbia University and the Senior Advisor for Space Programs at the Intrepid Sea, Air, and Space Museum in New York City, I have seen first

hand how the space program can inspire students to pursue degrees and work in STEM fields. I have seen how space travel inspires them to dream of accomplishing great things in life. Just as I was inspired as a small boy by my astronaut heroes in the Apollo program, today's students are inspired by NASA's accomplishments. They are excited about the opportunities that NASA and commercial space companies have waiting for them when they complete their education. I have not found any other engineering or science endeavor that can inspire students to study in the STEM fields the way that our Nation's space program can.

When I speak to my students about their interest in space-related STEM careers, there is a major opportunity open to them now that was not readily available when I was a college student over 30 years ago. The commercial space opportunities created by partnerships with NASA are very appealing to young people. There is still great interest in working for NASA and its contractors, but many students see themselves as future space entrepreneurs. Thanks to developments from NASA, many highly successful entrepreneurs see space as the next frontier for economic success in the private sector. I think we will continue to see major success stories in commercial space enterprise, and they will play a major role in inspiring young people to pursue STEM careers while also providing economic benefits for our country.

Lastly, I would like to share a story about my experiences in space and how it affected my perspective on the precious life we have here on planet Earth. During a short break in my tasks during my second spacewalk on STS–109, I had the opportunity to take in the beauty of our Earth from 350 miles up in orbit. From that height you can see the curvature of the planet, this bright ball of blue set against an endless infinity of black. The first thought that went through my mind was, "This is the view from heaven. This is what our planet must look like from heaven." But then a second thought immediately replaced that one. I said to myself, "No, it's even more beautiful than that. This is what heaven must look like. Maybe this is heaven." I felt as if I were looking into paradise. That is how beautiful our Earth looks like from space. It is a fragile oasis. It keeps us alive, safe from the chaos and dangers of space, just above our atmosphere. It is our home, and we need to take care of it.

Thank you again for inviting me to testify here today. I have had some great experiences in my life, and being able to provide input to your subcommittee is a great honor for me and an opportunity I very much appreciate.

Senator CRUZ. Well, thank you very much. And thank you for that powerful and evocative imagery, as well.

I appreciate each of you being here. I appreciate your expert judgment.

I think all of us here agreed that America should lead the world in space exploration. We have done so for decades. But I would like to start by just asking the panel, how good a job are we doing today leading the world in space exploration, and how could we do better?

Colonel ALDRIN. We are not really leading the world.

Senator CRUZ. If you would hit your microphone, please.

Colonel ALDRIN. We have a facility up in space, and we have invested a lot in it. We have gone to it—put it together, gone to it for quite a while.

And then we changed our spacecraft to move to another program. And that program didn't come together because of problems with the booster not being powerful enough, so we had to go to another booster to take a spacecraft from a company that hadn't built a spacecraft before. So it was gaining weight and wasn't able to put itself and the lander into lunar orbit, so we had to make the lander even bigger.

And that same rocket for Ares I was being used on Ares V. So it just appeared as though we weren't able to get the crew up there with the existing rocket, so we continued to develop the Orion and sort of shelved the heavy-lift vehicle. And without the Orion going

somewhere, there is no point in continuing the lander. So the program really fell apart.

[Phone ringing.]

Colonel ALDRIN. Excuse me.

Senator CRUZ. Just tell us if that is a call from the Space Station.

[Laughter.]

Mr. MASSIMINO. Make sure it is not collect.

Senator CRUZ. You know, Colonel Cunningham, you talked about what you perceived to be excessive politicization at NASA and the challenges that presents.

I was curious if you could elaborate on that. And what steps could be taken to help NASA focus on what should be its core mission?

Colonel CUNNINGHAM. I mentioned a little bit of the politics from outside of NASA that increasingly over the years has grown increasingly on NASA. And it has had a lot to do with controlling what projects they went into and what they did not. But it also, in my opinion from the outside looking at it, it has infected the agency itself. People inside of NASA are just not as willing to speak their mind on things to get them done.

And some of these programs, money has been spent on them and money has been canceled. And we tried a single stage to orbit one time, I think a billion dollars on that. So what has happened is NASA has changed; in my opinion, they have become a much more risk-averse agency over the years.

For example, we all realize that, until we launch the Webb Telescope, the Hubble Space Telescope is the greatest telescope we have ever had. Well, we are going to have the use of the Hubble Space Telescope for at least another 5 years, it looks like, but that wouldn't have happened had we not had the last servicing mission that went up there to service it.

And that mission originally was going to go up a couple of years earlier and was canceled by the then-administrator at the time because he said it was too risky and they canceled it, because they had lost some people on *Columbia.* So it is a mental kind of thing.

Back on Apollo, we lost crew on Apollo 1. We had people that we are just fortunate they are still alive from Apollo 13. But you have to have the will to keep going.

Fortunately, we had another administrator that came on after that one, and that administrator took a look at it. It was worth the risk, and they went back and had the last servicing mission, and we had the greatest telescope in history.

So I don't know how to do this, because our society seems to be moving more risk-averse. But we need to have an agency that understands, you have to pay your money, take your chances, and get out there and push the frontier.

Senator CRUZ. When it comes to priorities in NASA, there are a host of exploration priorities that have been discussed, whether it is asteroid retrieval, whether it is going to the Moon, whether it is going to Mars, whether it is going beyond.

I would welcome the views of the witnesses on this panel as to what the top priorities of NASA should be. Which of those projects yield the greatest benefits? What order should they be staged in?

And to what extent should the focus be on manned exploration versus robotic exploration?

Colonel CUNNINGHAM. Well, I can't tell you what degree, and I am not an expert and totally up on internal affairs at NASA anymore at all. But as I watch it, I find that what NASA has been trying to do for, oh, over the last couple of decades, they recognize that the public at large is looking for a demand for going to the next frontier, which happens to be—it is Mars now.

And so they have also attempted, then, to rationalize whatever they were working on as a step along that program. Some of the things that they have proposed certainly will have scientific value to scientists. Will they help us on that program? I doubt it.

And there are other ways of doing it. For example, you don't hear NASA really talking about returning to the Moon now. I used to be one of those that was not wild about stopping at the Moon in order to get back to Mars. But I began to realize that we have to have a facility that is going to keep people alive on Mars, and it is going to be a whole lot cheaper and easier to develop on the Moon than the other way.

So I just think we need to get back on a program that is going to have the Moon as an intermediate step and only as it fits in to go to the next frontier, Mars.

Mr. MASSIMINO. You know, it is interesting, because Buzz was talking about going to Mars, and Walt, Moon and Mars. And I left the astronaut office this past July, and we used to talk about this for years. You know, where are we going next? You know, we are going to go beyond Earth orbit; where are we going to go?

And you can make an argument, I think, for almost any one of them. But I think the thing that it has in common is we need to go somewhere. And I do think that NASA does have a plan to take us away from low Earth orbit. We are working with the companies that have been selected to provide—we have already got the cargo going to the Station, and now we are going to have our astronauts flying to the Station with the commercial crew. That is the plan. I think that seems like it is taking the right steps and going in the right direction. But the ability to leave the planet, to leave our orbit, is common to all of those things.

So I have been thinking about this. What would we pick as the destination? Which one do we pick? Because there are so many arguments, right? Yes, you are going to get different opinions from—you know, people changed their mind in the same day when we talked about it, right? "Oh, that is a good point."

Maybe we don't exactly know exactly where we should go. But we know we want to go somewhere if we can get the lift capability, the Orion capsule ready to go. We had the test back in December, which was successful. They have a plan for another one in a couple years. It has picked up a lot of momentum. A lot of my friends—I was working on it when I was in the office. A lot of my friends are still working on little displays. People are spending money; they are building hardware to go.

Whether that destination is to the asteroid, whether that destination is to the Moon or Mars, I think we are probably going to get clearer on that as we get a little bit further. Maybe we can go all the way to Mars. Maybe the propulsion research and technology

we develop can get us there quicker; maybe not. Maybe we can go to the Moon; maybe not. Maybe we can go to the asteroid if that is the closest case, the one that is least cost that is going to keep us in the budget, maybe that is the right answer.

But I think they are taking the right steps to get away from low Earth orbit. You can make an argument for each one of these. Maybe the idea is that we plan on leaving, take those steps now, and it might be clear to us where that destination is going to be a few years from now.

Colonel ALDRIN. Let me see if I can integrate these things together.

In the 1960s and 1970s, we learned how to go and land on the Moon and stay and do some things there. To do that again 50 years later just does not seem to be something that would be attractive to the people involved or the people who are supporting this.

We did not build permanent there. Other countries will build landers. While they are doing that, we can build the permanent structures. But those permanent structures will be the same ones in the same base design that we will do at the Moon.

In order to build those on the Moon, we need a fairly redundant facility on the near side and on the far side to robotically build those. We can design them with our concepts of a base, and we know that Europe has a company that built pressure vessels for the Space Station, and they can get additional resources from South Korea and India. So they can build the modules that will go to the Moon based on our design.

They need to be standard. And we have uneven terrain and a gravity field. So you pick one off of a lander and put it where you want it. Now, another lander is over here; you pick this one up and bring it over. They won't line up. You have to level them. You have a difference in elevation; you have to account for that.

This is too much for the students at Purdue. It will be done, but I am going to another resource to help the students at Purdue in their study to do that.

But the habitats that will be based on what we want at Mars will then be exercised at the Moon. Before we do that, we will use the Big Island of Hawaii to make sure that the things all come together.

We need an inflatable right away at Earth orbit L1 and L2. We will develop a rigid, and we will put it at those two places. Those rigids are what we construct things on, and they are the ones that will be similar to what we are going to build and send to Mars with a buildup so that at the time our cycling system deposits the first people on Mars, that buildup will be complete. So we have something that is integrated.

Now, what can we do with that inflatable and Orion? Well, we could send it to an asteroid. And we could send a robot, year-and-a-half mission. And a crew gets there in 4 months, 2 days before. But it has 60 days at that asteroid with a scientist who knows about asteroids, a robotics scientist. That is a crew and a robot at the same asteroid in place.

Now, that is with the inflatable. When we get to the rigid, we can send Orion with the rigid on a round fly by of Venus. We can do that in a year. It takes a whole lot longer to do it at Mars. When

we come back, we can exercise aerocapture maneuvers that need to be done at Mars.

So we will be doing these things, and we will be landing. Different people will be building and landing, and we will be getting these habitats, the different habitats, nine. We will take three of them, and we condition it, for it is the cycler. And we get it in its cycle, and then we use three landers for triple redundancy. Because all a lander has to do is to get on the cycler. Cycler supplies it with everything it needs. It gets off and lands, and the facilities are there for them to take care of.

And each pass that that outbound, we reuse the same facility so we don't have to build them again. And we can have an inbound cycler that can bring people back in emergencies.

It is a plan that is build and integrated, evolving as we go along.

Senator CRUZ. Thank you very much, gentlemen.

Senator Nelson?

Senator NELSON. Mr. Chairman, I want to defer to Senator Udall.

And I would just say, with our goal of going to Mars, going to an asteroid, going back to the Moon, if we are going to the Moon, then show me the money. That is the question as we are going forward on the budgets that we are projecting. And I will get into that a little later when I get to my questions.

STATEMENT OF HON. TOM UDALL,
U.S. SENATOR FROM NEW MEXICO

Senator UDALL. Thank you, Chairman Cruz, for calling this important hearing.

And, Ranking Senator Bill Nelson, thank you for your courtesies in allowing me to go forward first in questioning on this side.

And thank you to the witnesses. You have given some very impressive testimony. Thank you for your service today.

Scientific research and improving technology transfer and commercialization is smart investment. There is just no doubt about it. And it is vital to our Nation's future and for national defense and for our economy.

In my home state of New Mexico, we know this firsthand. NASA workers in New Mexico support crucial missions, including communication with the International Space Station. Astronomers at our research telescopes are making new discoveries about black holes and planets outside our solar system. One of those astronomy operations is called the Very Large Array, which is in New Mexico and does a lot of that work. Researchers at our national labs and universities are working hard to keep America safe and to create jobs through innovative technologies like advanced photonics.

So I look forward to working with Chairman Cruz and the Ranking Senator Nelson on legislation before this committee, including America COMPETES Act, the Commercial Space Launch Act, and NASA's reauthorization.

And I also want to thank Senator Nelson as our previous Chairman. Under his leadership, the Senate passed the bipartisan NASA Authorization Act of 2010. Very few Senators have been astronauts like Senator Nelson. He may be the most passionate advocate for

space exploration who has ever served in the Congress, and I am honored to serve with him on this committee.

Now, Dr. Massimino—and I would put the rest of my opening statement in the record.

[The prepared statement of Senator Udall follows:]

PREPARED STATEMENT OF HON. TOM UDALL, U.S. SENATOR FROM NEW MEXICO

Thank you Chairman Cruz—for calling this hearing today.

Scientific research—and improving technology transfer and commercialization—is a smart investment. It's vital to our Nation's future—for our national defense and our economy.

In my home state of New Mexico, we know this firsthand.

NASA workers in New Mexico support crucial missions—including communication with the International Space Station.

Astronomers at our research telescopes are making new discoveries—about black holes and planets outside our solar system.

Researchers at our national labs and universities are working hard—to keep America safe—and to create jobs through innovative technologies like advanced photonics.

So I look forward to working with Chairman Cruz on legislation before this committee—including the America COMPETES Act . . . the Commercial Space Launch Act . . . and NASA's reauthorization.

I also want to thank Senator Nelson—our ranking member and previous chairman. Under his leadership, the Senate passed the bipartisan NASA Authorization Act of 2010.

Very few Senators have been astronauts like Senator Nelson. He may be the most passionate advocate for space exploration who has ever served in Congress. I'm honored to serve with him on this committee.

From our earliest history, humans have gazed up at the sky in wonder. Yet once we traveled to space, we looked back at planet Earth with the same wonder.

A NASA astronaut captured this for all of us—in a classic photograph of our blue planet Earth. The image became known as "The Blue Marble." It is the most widely distributed photo ever. It gives us all a sense of how unique and fragile our planet is.

That is an important perspective to keep in mind—as this committee considers how Congress can support both space exploration and NASA missions—and help us better understand our own planet.

In New Mexico, we are putting the finishing touches on Spaceport America. Commercial space capabilities are growing. Suborbital spaceflight will be a reality for more people than ever before.

This is the latest chapter—of New Mexico's history of space exploration—which goes back to Robert Goddard's early rocket experiments.

So these are exciting times—and challenging times. Space flight still involves significant risk. We were sadly reminded of this by the fatal crash of a test flight a few months ago. But commercial companies are persevering. And still aiming for the stars.

In recent years, NASA has worked to transition from the space shuttle program—to a new future for human space exploration.

In 2010, this committee set NASA on its current course. We passed legislation to support:

- an exploration program focused on reaching Mars;
- robust use of the International Space Station;
- development of a commercial space industry in Low Earth Orbit;
- balanced science programs; and
- continued commitment to aeronautics research.

NASA's leadership is essential. In addition, the commercial space industry has an important role to play—in our Nation's broader space exploration objective—beyond expanding access to sub orbital space and trips to and from the International Space Station.

International cooperation is also key—as we work toward a strong and sustainable human space exploration program.

So this is an important discussion. I'm very pleased that we have three distinguished American astronauts on our first panel. Thank you for your service—and welcome. I look forward to your testimony. Thank you.

Senator UDALL. But Congress passed the last NASA authorization act in 2010, as I just mentioned. This law continues to guide NASA as a multi-mission agency, and to quote that multi-mission from the statute, quote, "balanced and robust set of core commissions in science, aeronautics, and human spaceflight and exploration."

Could you share your thoughts on the advantages of keeping NASA as a multi-mission agency, which encompasses not just human spaceflight but also initiatives such as space-based observations of the Earth?

Mr. MASSIMINO. You know, in my time as an astronaut, there were a lot of things going on in our country. You know, we had military situations, we had economic effects. A lot of things happened. And I kind of got the sense that, as a government agency, if we had resources, that could help. Whatever that meant, to whatever our country needed, that it was important for us to try to contribute what we could.

So you make the example of—you mentioned Earth observations, for example. Well, on the International Space Station, it was a great engineering project, international. It is amazing that this thing is up there, this great laboratory, and we can do a lot of basic research up there. But in addition to that, we are able to have this perch above our planet where we can take amazing photos.

In fact, my students in my class, our project for the semester is an astronaut assistant to help them take these photos. And the reason is, it is not just fun photos. They can show us natural disasters that occur. You can get a lot of information from them. Changes in the planet, whether it be irrigation problems or volcanoes erupting or whatever it might be, there is a lot of science data that can come and help our country, help our planet, by the astronauts taking photos from the International Space Station.

That might be somewhat of a simple example, but I don't necessarily think it is. We are using our resources to help other agencies and improve life and increase our understanding.

So I think if there is a way that NASA can contribute to that—and I am not a NASA guy anymore, but I always felt when I was as an astronaut, if there was anything that I could do to contribute that would help our country or help the world, that we owed it to do that. It may not be our primary focus, but guess what? We maybe can make a contribution in those areas, as well.

Senator UDALL. Just a quick question, because I only have a few seconds left. But it seems to me there is a great potential to develop the STEM fields, in terms——

Mr. MASSIMINO. Absolutely.

Senator UDALL.—of what we are talking about here.

Mr. MASSIMINO. Yes.

Senator UDALL. Could you just talk a little bit about that, in terms of——

Mr. MASSIMINO. Oh, yes, absolutely.

I think what I have found—again, a lot of this comes from my more recent experience as a university professor—that the kids

need something to be excited about. Studying math and science—I am not as smart as Buzz was at MIT. Buzz was a really smart guy. I struggled up there. It was tough, OK? And I needed inspiration to hang in there and get through.

And I think that a lot of students today need that, as well. It is not easy studying this stuff. And if you have a goal at the end, that, hey, if I can finish this up, maybe I can make a contribution to whatever technology they are interested in, that is the kind of motivation they need.

I have not found any field—I would throw the challenge out there, if you find anything else that could inspire kids, young people, to study those fields other than the space program. I haven't found it. It encompasses so many different areas. It excites them. It is something they think is really cool. It is the future. It is making a contribution back to the planet. They just love it.

And now, when you add this opportunity to be entrepreneurs, I think we are really on to something. So I can't think of anything that would excite them more.

And I see this in New York City, which, you know, doesn't have its own NASA center up there and there is not so much of a presence as we have in other parts of the country. There still is great interest up there.

Senator UDALL. Thank you very much. And I have seen that with astronauts that travel to New Mexico, the excitement——

Mr. MASSIMINO. There you go.

Senator UDALL.—that is there with the young people, in terms of all of the STEM fields.

So, sorry to excuse myself. Secretary Kerry is in Foreign Relations. I hope to get back and ask some additional questions. But thank you both, Senator Nelson and Senator Cruz.

Senator CRUZ. Thank you very much.

Senator Gardner?

STATEMENT OF HON. CORY GARDNER, U.S. SENATOR FROM COLORADO

Senator GARDNER. Thank you, Mr. Chairman. And thank you for holding this hearing today. And I will be following my colleague from New Mexico on the way up to the Foreign Relations Committee after the question and dialogue we have here.

You know, I don't think there is anything, as you just said, Mr. Massimino, that captures the human imagination like exploration. And 28 years ago, I think it was, probably around 1983, I wrote a letter—I would have been 9 years old—I wrote a letter to NASA. Here is the copy of the letter. I took a picture of it because it is not on e-mail; it is a hard-copy, typed-out letter.

And this is the response back from NASA. This is the first paragraph that they wrote back to me in my letter to them: "Thank you for your recent letter and your interest in wanting to become an astronaut. We are especially happy to have the young people of the world show an interest in our space program. We have received hundreds of letters similar to yours."

Now, I doubt if they are receiving letters today; they are receiving e-mails today. And I doubt if they are only receiving 100; they are probably receiving thousands. But this letter talks about the

need to go into mathematics, the need to go into engineering or medicine. It talks about the importance of our space program.

They also sent a little photograph of the crew. I think it was the—this is Sally Ride. It was STS–7, I believe, the first woman in space from the United States on the space shuttle program and, obviously, first woman in space from the United States.

But that was 28 years ago—actually, more than that now, but it was 2011, 28 years since I wrote this letter to NASA, 2011, 1983, and I stood with my colleagues in the House of Representatives as we watched the closing of the chapter of the Space Shuttle Program.

So I was 9 years old, writing a letter about how I wanted to become an astronaut. Obviously, I failed miserably at it. But 28 years later, standing in the cloakroom of the U.S. House of Representatives with my colleagues from around the country, watching this program come to an end, the program that had made me so interested in wanting to achieve more.

I mean, Horace Greeley said, "Go west, young man." And we followed that phrase in American history, and we explored, and we fought, and we pioneered, and that is who we are.

And so I am so concerned about the testimony today, the comments that you made, that we aren't capturing that imagination like we once were, that we are not driving new innovation. We are driving new innovations like we were, but how do we really instill that notion of exploration and really make it a reality?

And it goes to the heart, I think, of what you have talked about today in the Orion program, and I want to kind of get to that.

We did the test launch, we did the test launch of the Orion, December 5, 2014. We did it atop a ULA Delta IV heavy rocket. We tested this. And now it doesn't look like we are planning to carry astronauts until 2021.

Can this country afford to wait until 2021? Can we wait that long? What can we do to push this up? How do we, again, capture that imagination that drives so many of us to imagine, to aspire to space?

So I guess I would start, what is it that we need to do to really drive this mission, this idea, this value of space? It is not just reports and paperwork; it is something that we have to do ourselves.

Colonel CUNNINGHAM. I think it would help to refocus NASA back on what they did that did provide that inspiration.

Just to give you another thought, I was listening here about the STEM education. I am a strong believer in that. That is what my education was. It is what probably everybody here's education was at this table. We work with the Astronaut Scholarship Foundation, and we give—now we are up to 30 or 32 awards every year for this kind of education.

But if we look at the organization NASA, NASA is also giving out many scholarships now. Now, NASA is a space agency. I think that if they are going to be giving scholarships, if the funds could maybe be diverted to someplace where they focus on that.

NASA needs to be spending their time and their focus on those things that inspire people to do these. Exploration is what I happen to believe is the long-term look at it. But they need to be spending

their money on those things that inspire others to make their scholarships and derive from other places.

I work with scholarships all the time. I believe in them. But I think that the agency, it is just one more thing that they probably have, let's just guess, maybe a couple of dozen people that are working just focusing on that, as opposed to doing what they did before and letting the inspiration drive those things.

It is just another alternative I am raising about it.

Senator GARDNER. Dr. Aldrin? Please.

Colonel ALDRIN. I would like to tell a little story about the months before I left NASA in 1970.

I was asked to go down to another center, where the next program to follow Apollo was being looked at. And there were hundreds of aerospace engineers. And let me describe what the next system was. And this was 1970; we may have flown Apollo 12 and maybe 13. It was two-stage, fully reusable, an orbiter with wings and wheels and a booster with wings and wheels. And it carried the crew; it didn't carry cargo. You want cargo? Use a reusable booster, and you put the cargo on top of that.

So I went down there to look at the assembly of people. They had seven teams, a contractor for a booster and the orbiter—seven of those. And some of them doubled up, of course, here and there. And they built models. So my job was to look at the upper stage, the orbiter—okay?—and to see what the people could see during launch, orbit, and come down and land.

And I happened to glance down, and I saw windows in the booster. OK? I can explain that now, for high-speed taxi, et cetera. But I asked the guy, what are these windows here? Oh, when we go up as a booster on a normal mission, we have a cockpit with two people and a booster. And I said, you what?

We have seven teams, and before they started their study, we asked them to do a real short study, manned versus unmanned booster. Now, if you are one of these seven teams and you know what the client wants, and if you give him what he wants, you are going to make more money, obviously all those reports said, yes, you are right, we are going to put a cockpit of two in the booster. Totally unnecessary.

By the time that started getting implemented, Bob Gilruth said to another person, I wonder if we should have put a cockpit in the booster. OK? It was canceled. We had to rush in to the shuttle.

We would love to have a program like that now, but it was because jealousies of individual centers and wanting to do things and the companies wanting to take a bid that would get them more money and maybe bring it back to where their states were doing things. That was inexcusable to me.

And there are other examples like that. We have three different spacecraft to come back, commercial spacecraft, and one advanced one that has been looked at by the Russians, looked at by the Air Force, and wind tunnel tests, and it brings things back. What do we do? Finance the two capsules with not really new technology, and we don't finance the one that can land on a runway.

I think we are making not so good choices many times.

Senator GARDNER. Thank you, Mr. Chairman.

Senator CRUZ. Thank you very much.

Senator Nelson?

Senator NELSON. First of all, I want to welcome our guests, dear personal friends, and thank you for what you have done for this country, each of you in your own contribution, as we have built this amazing thing that we are discussing today, our American space program.

The goal is to go to Mars. The goal is to get NASA beyond low Earth orbit. And the question is, over the course of these years, as we target the decade of the 2030s, with the budget that we are going to have, how do we do it? How do we develop the technologies, the techniques, the systems, the life-support systems, the propulsion systems that will get us to a foreign body such as Mars with a crew and return them safely?

So we may want to go back to the Moon as we develop this, but, as I said earlier, show me the money.

Dr. Massimino, I want to ask you to comment on the plans to capture an asteroid, bring it back into a stable lunar orbit, and send a crew up there to land on it, that as part of the steps as we prepare all of those things I just mentioned, eventually to go to Mars in the decade of the 2030s.

Mr. MASSIMINO. Thank you, sir.

I think we need to remember one thing overall, that going to space is hard. And I think we need to remember that there has only been one country that has put people out of Earth orbit, and that is us. And we did it a long time ago, when we sent Buzz and his colleagues up there. But still the United States of America is the only country that has been able to figure that out. It is not so easy going to space. It is even harder to go beyond low Earth orbit to places like the Moon or Mars.

And if we decide we are going to take an incremental approach, which would be the asteroid mission, I think there is definitely a lot that can be learned there. We can test this big rocket that can take us places beyond low Earth orbit. We can test the spacecraft that would do it.

We can test life support. Space is a very hazardous place. There is a lot of radiation, and it gets worse as you get further away from the planet. The radiation dose we took on Hubble was higher than what the men and women get on Space Station, because we were 100 miles higher. Going to the Moon is even worse. Going beyond that is even worse. We need to understand how we can protect our people from that, right? And we are taking those steps with the research that we do on the Space Station.

How are we going to keep them healthy? All the changes that happen to the body. How are we going to keep people healthy enough to be able to withstand the journey to Mars, be able to land a spacecraft, and be able to work and then come home.

This is tough stuff. We may or may not be able to do that all in one big swing. It may be too much to do it in one swing. But I think we need to start taking those first steps.

The first step is get the big launch vehicle going, like we have with a successful test flight and the other ones that are planned. They are far in the future, but these are tough things to do. And I don't know if more budget would make it quicker. I don't know. Maybe it would, maybe it wouldn't. Maybe it would give you a bet-

ter chance of getting there, but I don't know if it necessarily makes you more efficient. But these are hard things to do.

But if the asteroid mission is the right thing to do, I think there is certainly a lot we can learn from it. I think we can work out the spacecraft, keeping the people healthy, understanding how to work that launch system. And it is also—it is a destination. You are not going to land and have to blast off again from it, like you would on the Moon or Mars, but it is a place you can go to, and we certainly can learn a lot from it.

Is it necessary? I don't know. It might be, because we might need that incremental step before we can take the big leap. But I think right now the important thing is to try to be consistent with it. And to pull the rug out from where we are, I think there might be a penalty there, as well.

There were a couple programs—in my career as an astronaut, we worked on different spacecraft. I had dinner with two of my friends last night who are now former astronauts that are here in Washington. We talked about all the stuff that was canceled while we were astronauts, all the stuff we trained on while we were astronauts. And to make a big, huge direction change sometimes isn't always the best thing.

Senator NELSON. Well, you were there in the astronaut office when the Constellation program was canceled. It was way behind, and it was over, way over budget. So that is what you are talking about——

Mr. MASSIMINO. Actually——

Senator NELSON.—what you sacrifice if you make a major change in the human spaceflight program.

Mr. MASSIMINO. Yes. And that was a big one, but there are other ones too, like our cockpit avionics upgrade on the space shuttle. They started doing the wiring on that in one of the space shuttles. We had spent a lot of time designing that upgrade, for example, and then that got cut. And the story we had was that it was going to cost almost as much to pull it out as it was to finish the job.

There were other options for spacecraft, rescue spacecraft, from the Space Station that we were developing. They did tests out in the desert, dropped them out of airplanes, landing tests. A lot of cockpit design work was done. Again, these projects were cut.

So I think there is a penalty to pulling everything back. And, you know, whether, again, if we go with the asteroid or we go to the Moon or Mars, I think it is important to keep the momentum going of getting the spaceship ready, getting the rocket ready, keeping your options open until you are really sure which one you want to go to. Because you might find that you might not pick the right one right off the bat.

Maybe we can go to Mars in one swoop, but maybe we can't. And the asteroid mission is a great way to test our systems out and get the knowledge. Because we want to be successful when we go to Mars. That is a huge leap. That is a really long journey. And that is not even—compared to the Moon, it is a long way. This man went a long distance from our planet. That is a heck of a lot further.

We want to make sure we get it right when we do that. And if that asteroid mission or something we do with the Moon is going to help us get there, that is great.

Colonel CUNNINGHAM. Can I add a thought to the question that had to do with budget? It is always going to be expensive for what they are talking about trying to do.

I mentioned that for 40 years the NASA budget has been less than 1 percent of the Federal budget. For the last 15 years, it has been driving down to 0.4 percent of the Federal budget. Unless the country, which really is Congress here, decides to put more money in it, this is just talk that we are going through here. The budget has got to go up for NASA.

And that is another reason why I feel very strongly that NASA has to be operating more efficiently and not doing some of the things which would be marginal as opposed to it. You have to focus it on what has to be done.

NASA's budget is way too low to do the things that we talked about doing here this afternoon.

Colonel ALDRIN. Absolutely.

And I would like to point out that I have this study being done at Purdue, due the end of April. I have assembled 25 other academic institutions that deal with exploration. Academic institutions are supposed to be unbiased. They are supposed to teach the general background. So if we can come up with a number of questions—some of them are yes/no/maybe. Some of them are "tell me shortly."

How do we get the public behind what it is we are trying to do? Well, they are going to know what I am trying to do, briefly, because I am going to show them and I am going to give them my assumptions that I have had to make.

What is the strategy to get the public behind us? And what kind of strategy do we need to fund something in 2040? Do we step-increase to make up for things, and then do we have a ramp-up, not just cost of living but a ramp-up? Because expenditures are going to be greater. They did during the Apollo program.

Now, another question: Do we have a relationship with China? It is very significant if we are going to deal with leadership. I don't want to get into a lot of that, but I think if we don't, if we really do, or in between, we shouldn't do things differently at the Moon. We still should build things there so we can build somewhere else. But we don't have to land there. China needs the things we can build. We have to exert leadership by working with them in low Earth orbit.

Next July is the 40th anniversary of Apollo-Soyuz. 1975 was pretty contentious, in the cold war, much worse than our relations with China today. Why did we refuse them to come to our space station? It doesn't make any sense to me. We should be doing that sort of thing together, building on, sharing what it is we are doing. They have a lot of things to do with the Moon. We can help them in their permanence, because it helps us with our permanence at Mars.

Now, if I ask them about asteroid—you can fly it the way it is, you can cancel it, or you can do something smart in between. Now, if you understand what that smart is in between by sending a robot

there to an asteroid, then send a crew to it, and on board the crew you have an asteroid scientist, a robotic, and they can stay there 60 days, the combined mission is better than a robot or better than a crew mission.

Don't these people talk to themselves in Washington? Why do I have to come up and say, if you combine the mission, it is a whole lot better?

And you can do it where an asteroid is, like the National Research Council said we should do. But maybe that is not essential. I happen to think it is, where you can fly Orion with a long-duration support system. That is what we are going to do when we go to L1 or L2. We are going to take an Orion up there, and there is going to be a system that lets us stay for much longer. We are going to be rotating commercial crews up and down, not just to the Space Station, but commercials are going to go to the vicinity of the Moon.

We are going to do these things, and we are going to build. But we don't have to put all the money in building those habitats, because the foreigners are going to want them, and we are going to want them there, and we are going to want them at Mars. The foreigners have to land. OK? We are going to develop a very sophisticated landing system, and we are going to be landing so many people at Mars that we can take them along on the first landing. OK? Take us along as visitors on your landings.

Let's not go broke by doing things back at the Moon, but let's astutely learn to do things there that do make sense.

And I think if you ask industry or if you ask government, you are going to get a biased answer. But if you ask academia—I am looking forward to this poll on significant questions coming back from 25 different academic institutions.

Senator CRUZ. Well, thank you very much.

And I want to ask one additional question, which is: Each of the three of you are learned scientists and national heroes. And if I have understood your testimony here today correctly, each of you has discussed as a major objective, a grand goal for NASA, going to Mars.

I would ask each of you to take a moment to address the American people and, in your judgment, explain the benefits to America and to the world of going to Mars and what will be required to accomplish that objective.

Colonel CUNNINGHAM. Well, I would start by saying the technology that is required to get us to Mars, such things as radiation or finding new velocities and the like to do that, that will create the kind of spin-off—we have benefited for 40 years from solving the problems that we had to go to the Moon. Some of those were started before, but some of it was totally unexpected. You didn't know what was going to come up, but you solved the problem, and now it is almost like a cancer in all areas of our industry, and we are benefiting from it.

The most important thing that has to be done is they have to be willing to pay the money. I am not optimistic about us being able to put the kind of funds out there that out to, because we are busy spending money in the government for all kinds of things for which

there is no return and for all kinds of things which do not really inspire people. So I just happen to believe it is a good use of money.

Colonel ALDRIN. Rarely does a time come along in the advancement of humankind on this planet Earth that we gain the potential of really demonstrating to ourselves and to the rest of the people the fullest of the challenges.

We can put together what is necessary to send people to Mars in an efficient way. And we can do it by stepping up, by using some things at the Moon, but not getting bogged down with a lot of investments that are involved in landing humans, building the rockets to land them, and then storing them. We don't need to do that anymore. We can observe how other people store people there, take care of them, but where we want to do that is at Mars. And we need to invest in the things to get to Mars.

If we invest in an ascent stage to go along with the people that are going there, it is going to cost more money. Going there with the ascent stage interferes with just the lander. By building that ascent stage and the return capability, it is taking longer to do that in time.

The cost per person on the surface of Mars is less if they stay there. If we start bringing people back—okay, the biggest thing to me is all of this thing comes along on Earth, with humanity being able to advance, to do all the wondrous things. And it is going to cost billions and billions of dollars. And we are going to select some human beings to do that, and we are going to train them, and we are going to send them there.

Now, I have gone and come back from a place. Let me ask you, what do you think you are going to do with those people that go there and bring them back to continue to pay off the investment of their being the first, the pioneers, the building up of a growing settlement? They can do far more by keeping Mars occupied, helping the new people that come in. You bring them back and they can visit different places, but if you broadcast from Mars, you can reach everybody in the world, because they are going to be listening in, and you can give them the stories of what you have been doing right there while you are there.

There is no doubt in my mind that the value that we have invested in people from whatever the country is and we have put them there on Mars, that is where they need to stay. And they need to know and understand that this is their opportunity to serve humanity.

Mr. MASSIMINO. Thank you, sir.

So, benefits for our American people, what we could get out of this, what can we imagine we would get if we were to do this grand exploration.

I think eventually we are going to have to get off of this planet or learn how to do it for our own survival. Learning what else is out there is great, would help our understanding of where we are in the universe, but also just to have another place where we could live as another place where we could survive would be a good thing for us to have. And so Mars might be that place. So if we decide to go there, it is giving us another option.

And if we would decide to go and do this, can you imagine what would be needed, what would be developed in order to get us there?

If you look back to what we did when we developed the Apollo program and also the shuttle program, all the new technology and the spin-offs, and the benefits that came not just for the space program but in other industries were tremendous. Now we are going to make a giant leap; we are going to go all the way to Mars. Can you imagine what would come out of that?

I think it is also probably going to have some type of international flavor to it—maybe, maybe not. I think the United States would be the leaders of that, I would hope, but I think that we would also maybe be doing it with some of our friends. So I think it would be a great thing for our international cooperation with other countries around the world, providing that benefit for us.

And then I get back to the inspiration. And the inspiration is not just because it is a nice thing to do for kids. It is because that is where our future is. We are going to depend on these people to take care of our planet and build our economy and keep our country strong for many, many years.

They may not all go and become astronauts. Hopefully more people will have that option and keep them interested in the space program, but they may not all go on to do that or even work for NASA or be involved in it. But I do think that exploration, particularly something like you are describing, going to Mars, would inspire them to stay in school and get their education, and maybe they will find something along the way that they like even better than space. Maybe it will be better for us for certain students to go into medicine or study what they can study in the classroom other than going to space. But I certainly think it is going to keep their interest, and I think that is kind of an intangible benefit that we would get from it, as well.

But I really see it as an investment in our future, to inspire young kids, and also, I think, to help our country, our economy for many years to come. I think it would be a glorious thing to do.

Senator CRUZ. Thank you very much.

Senator Nelson, do you have any additional questions?

Well, then I want to thank each of the three of you for coming and joining us. This has been a very productive panel.

And we will conclude this panel and immediately move on to the second panel that will start momentarily.

Colonel ALDRIN. Thank you, Senator.

Senator CRUZ. Thank you very much.

[Recess.]

Senator CRUZ. OK. The hearing will come to order.

Now I want to move on to the second panel, and we are fortunate to have three very experienced witnesses: Mr. John Elbon, Vice President and General Manager of Boeing Space Exploration; Dr. Scott Pace, Director of the Space Policy Institute, the Elliott School of International Affairs at George Washington University; and Mr. Eric Stallmer, President of the Commercial Spaceflight Federation.

And we will start with Mr. Elbon.

STATEMENT OF JOHN ELBON, VICE PRESIDENT AND GENERAL MANAGER, BOEING SPACE EXPLORATION

Mr. ELBON. Thank you.

Chairman Cruz, Ranking Member Nelson—always good to see you, sir—members of the Committee, thank you for this opportunity to provide Boeing's perspective on U.S. human space exploration goals and commercial space competitiveness.

I want to applaud you both for your opening comments. That spirit of cooperation is heartwarming and absolutely essential to our path forward. Thank you very much for that.

America's economic growth and competitiveness depend on our capacity to innovate, to reach beyond today's possibilities, stretch farther and faster than our competitors around the world. Our future depends on developing the next-generation technologies, but more important are the next-generation minds.

Just as seafaring ships explored and returned to home shores, bringing unforeseen discoveries, so too will space-faring nations reap the benefits of our investment in exploration. Robots are great at helping us scratch the surface, but humans are ultimately needed to truly explore.

The success that U.S. space missions have achieved and the recognition that these innovations have gained have made the United States the most attractive global partner for other nations seeking to advance their own space aspirations. This plays a significant role in the United States' soft diplomacy efforts to increase U.S. influence in global affairs and in strengthening our alliances.

The International Space Station has been orbiting Earth for more than 16 years. Astronauts have been continuously living aboard the ISS for 14 years, and we have been learning valuable lessons about living and working in space in preparation for sending humans beyond low-Earth orbit.

The ISS is a model for space cooperation, currently counting 15 nations among the international partnership. Because of the ISS, space is an area where international cooperation remains constant and serves as a bridge for other diplomatic discussions.

As a leader and major supporter of the ISS, the United States is in a position to supply a vision for space global exploration. With the ISS, we have demonstrated an ability to build long-term, crewed space habitats effectively. The ISS crews are testing technologies required for deep space and working to understand the effect of extended space travel on the human body.

What we have found from the development and operation of ISS is that large space programs do best when three conditions are met: first, industry involvement with wide-ranging expertise; second, long-term, stable government investment; and, third, international cooperation.

With NASA's Space Launch System capability, we can apply the lessons learned in building and operating the ISS to new endeavors in deep space. We must rally a shared commitment to NASA's vision for the ISS, commercial crew, and super-heavy-lift Space Launch System rocket, or we risk losing an important investment in the irreplaceable brain trust of decades.

NASA has the foundation for sending humans farther into the solar system than ever before, through the NASA Authorization Act of 2012, which this very committee passed. We must continue down that path in support of the building blocks that are so important to future success.

First, we have invested years of brain power and billions of dollars in the International Space Station as a testbed for preparing for the next leap.

Second, we have a commercial space program that ensures U.S.-launched crew and cargo transport to ISS. The Boeing CST–100 spacecraft combines proven design in spaceflight technology with modern innovation for a reliable and sustainable crew and cargo transportation system. Use of commercial transportation to sustain ISS lowers costs and leaves room in NASA's budget to develop the capabilities for exploration beyond low-Earth orbit, SLS and Orion.

And, third, SLS provides unprecedented payload capability that can enable human and science deep space missions not previously achievable. And last December's flawless launch of the Orion crew capsule returned a great deal of data, which is a huge step toward Mars.

Finally, the world's space agencies agree that Mars is our ultimate destination. NASA has the programs in place to move down the path toward Mars, starting with the International Space Station as a testbed, commercial crew transportation systems to transport crew and cargo to the ISS, and Orion and the SLS for super-heavy-lift and crew transportation beyond low-Earth orbit.

Thank you again for the opportunity to testify here today, and I look forward to answering your questions.

[The prepared statement of Mr. Elbon follows:]

PREPARED STATEMENT OF JOHN ELBON, VICE PRESIDENT AND GENERAL MANAGER, BOEING SPACE EXPLORATION

Chairman Cruz, Ranking Member Udall, and members of the Committee, thank you for this opportunity to provide Boeing's perspective on U.S. Human Space Exploration Goals and Commercial Space Competitiveness. I am John Elbon, Vice President and General Manager, Boeing Space Exploration

Mr. Chairman, America's economic growth and competitiveness depend on our capacity to innovate, to reach beyond today's possibilities and stretch farther, faster than our competitors around the world. Our future depends on developing the next generation technologies—but more important are the next generation minds. We need to inspire scientists, engineers, researchers and technologists everywhere by offering the opportunity to be part of something that transcends known boundaries. America needs to reinvigorate that Apollo era passion that changed the world, launching new industries and opening new doors into the universe. From everyday conveniences like scratch-resistant lenses to world-changing satellite-enabled communications, our lives are better today because of cutting edge NASA research innovations—borne of our drive to explore. Just as seafaring ships explored and returned to home shores, bringing unforeseen discoveries—so, too, will "spacefaring" nations reap the benefits of our investment in exploration. Robots are great at helping us scratch the surface of new knowledge. Humans ultimately are needed to truly explore—and to pioneer.

NASA research has certainly met the goal of advancing science and technology innovation. This research has energized a strong U.S. economy, providing growth, security and resiliency. The success that U.S. space missions have achieved, and the recognition that these innovations have gained, have made the United States the most attractive global partner for other nations seeking to advance their own space aspirations. This plays a significant role in the United States' soft diplomacy efforts to increase U.S. influence in global affairs and in strengthening our alliances.

The international community has aligned with Mars as the ultimate destination, and NASA has in place the programs needed to lead us toward that goal. It starts with the International Space Station as a national laboratory and testbed for future exploration. For affordable crew and cargo resupply to the ISS, NASA has contracted with commercial partners, freeing up funds for NASA to focus on the difficult task of deep space exploration with Orion and Space Launch System as the initial capabilities for deep human space exploration capabilities.

NASA's extraordinary teams have been breaking new ground for decades, returning with innovations that range from medical advances to commercial wonders, using the International Space Station as a unique on-orbit laboratory. The International Space Station has been orbiting Earth for more than 16 years. Astronauts have been continuously living aboard the ISS for 14 years. During an average 6-month period on the station, as many as 200 investigations operate, with between 70 and 100 of them being new studies.

I'd like to spend a minute or two highlighting some of the real science we are seeing from the International Space Station.

Duchenne (du-shens) Muscular Dystrophy: Duchenne Muscular Dystrophy is a recessive form of muscular dystrophy that affects over 1 in 3,000 boys (over 50,000 young males in the U.S. today). Average life expectancy is 25 years.

Research has been conducted on the ISS to identify a treatment or cure for Duchennes Muscular Dystrophy that could lead to identification of a cure due to the unique capabilities of the ISS. The ISS enabled researchers to crystallize an improved complex structure and an associated water molecule not previously known.

Bone loss: The FDA approved AMGEN's drug Denosumab in 2010—used for treatment of postmenopausal osteoporosis and subsequently for treatment of bone metastases. Both were developed in partnership with the ISS sciences team.

New Treatment through Ultrasound: ISS astronauts were trained to use portable ultrasound to diagnose issues like broken bones and collapsed lungs that might happen on orbit where medical facilities are limited. This same method is now being used to train third-world doctors and care providers to treat patients where modern technology is not available. This training has translated to treatment of more than 40-thousand patients in underserved countries, like Brazil, due to diagnosis through portable ultrasound.

Closed-Loop Water Recycling on ISS: A closed-loop water recycling system is used on the International Space Station. Not only does this include drinking water, but it includes recycling sweat, urine and even exhaled water molecules.

Similar to how we reuse our waste water on board the ISS, schools in third world countries are utilizing this technology where fresh water is scarce. A school in Morocco's capitol became the first public facility in May of 2014 to use this type of recycling system that reuses urine and waste water.

The system relies on a set of organic and ceramic membranes with holes just one ten-thousandth of a millimeter in diameter, which is 700 times thinner than a strand of human hair. These tiny pores can filter out unwanted compounds in water, including nitrate—a problematic pollutant that comes from agriculture fertilizers.

Targeted method of chemotherapy drug delivery; clinical breast cancer trials now in development: This treatment has the potential to change the landscape for how we address cancer—a devastating illness that has touched many of our lives.

Patients who suffer through invasive cancer treatment can endure ravaging side effects, including nausea, immune suppression, hair loss and even organ failure, in hopes of eradicating cancerous tissues in the body. If treatments target a patient's cancerous tissues, it could provide clinicians with an alternative to lessen the delivery of toxic levels of chemotherapy or radiation.

Aboard the ISS, a particular series of research investigations is making further advancements in cancer therapy. A process investigated aboard the space station known as microencapsulation is able to more effectively produce tiny, liquid-filled, *biodegradable* micro-balloons containing specific combinations of concentrated anti-tumor drugs. Using specialized needles, doctors can deliver these micro-balloons, or microcapsules, to specific treatment sites within a cancer patient. This kind of targeted therapy may soon revolutionize *cancer treatment delivery.*

Imagine the quality of life from such therapies for patients. Remarkably, research that began in space may soon result in such options here on Earth.

The ISS is also a model for international space cooperation, currently counting 15 nations among the international team. The ISS and shared launch systems helped the United States bridge the diplomatic divide with Russia after the fall of the Soviet government and continues to facilitate the development of an integrated, global definition of science and technology policy.

Because of the ISS, space is an area where international cooperation remains constant and serves as a bridge for other diplomatic discussions. As the leader and major supporter of the ISS program positions, the United States is in position to supply a vision for global space exploration.

With the ISS, we have also demonstrated the ability to build and sustain long term crewed habitats effectively in space. The crews aboard ISS are testing technologies today that are required for deep space exploration, providing better information about the effects of extended space travel on the human body. In fact, next month astronaut Scott Kelly and cosmonaut Mikhail Kornienko will fly to the ISS and spend one year on-orbit as part of a study that will help us to understand the effects of long-duration, off-planet exposure to our astronauts in preparation for even longer spaceflights to Mars.

NASA has further enabled this path forward by turning over to private industry the routine business of crew and cargo transport for the ISS while NASA concentrates on the development of deep space systems. Two contracts were awarded last September to U.S. companies to provide crewed transportation to and from the ISS starting in 2017. In addition, commercial companies submitted proposals in December of last year for the follow-on commercial cargo contract, which will be awarded this summer.

Boeing is proud once again to partner with NASA to provide crewed services to the ISS. With a heritage dating back from Mercury, Gemini, and Apollo to our more recent history on the Space Shuttle, we have a commercial space program in work that promises to not only secure affordable crew and cargo transport to ISS, but to build an even more robust—unparalleled—aerospace capability for America. The Boeing CST 100 spacecraft combines proven design and spaceflight technology with modern innovation for a reliable and sustainable crew and cargo transportation system.

By leveraging these commercial contracts to support the ISS, NASA is focusing investment in the Orion and Space Launch System, which are critical elements in the future exploration architecture. The December flight test of the Orion crew capsule was flawless, and returned a great deal of data—a huge first step toward Mars. The next test flight for Orion will be on top of the Space Launch System (SLS) for Exploration Mission 1. The SLS provides unprecedented payload capability that can enable human and science deep space missions not previously achievable. We are building the hardware, testing the hardware and production tooling, and installing ground operations for a rocket that will deliver nine times the thrust of the largest private rocket. It is designed to transport the mass and volume necessary to affordably build such an outpost, while safely launching crew deeper into space.

A whole new generation of engineers are building. . .side by side with experienced space veterans . . . this next generation rocket.

But you can't build the world's biggest, fastest, most capable rocket with only existing technology. We're also applying innovative approaches to the business, the technology, and the people.

- We are relying on the very best of Boeing and NASA engineers to execute parallel rocket configuration/design with design and installation of the manufacturing facilities. We tapped into the vast resources across the Boeing enterprise to create the most experienced design team.
- By partnering in new ways between engineering and manufacturing we reduced the manufacturing facility footprint and workforce required in assembly & operations. We are using fewer, larger tools to build the rocket by making them multi-use. That cuts down on facility footprint, tooling cost, and workforce required for production. But that also means efficient low rate production (which aligns with NASA funding).
- Using an affordability-driven engineering approach, engineers started with existing hardware and capability to leverage as much as possible current taxpayer investment in space programs. They then innovated to incorporate that hardware to the greatest degree possible, consistently making engineering trades to optimize capability while managing cost and schedule commitments.

This rocket opens doors we've never seriously considered in the past. For the first time in 40 years, the Orion and Space Launch System (SLS) projects will allow astronauts to leave low Earth orbit and completely escape Earth's gravitational field—ultimately opening the door to landing humans on Mars.

Last year, a congressionally mandated report from the National Research Council recommended that the United States pursue a disciplined "pathway" approach that encompassed executing a specific sequence of intermediate accomplishments and destinations leading to the "horizon goal" of putting humans on Mars. The success

of this approach requires a steadfast commitment, international collaboration and a consistent budget that aligns with our Nation's human exploration goals.

We cannot abdicate our place in human spaceflight to other countries that ARE willing to step up, to set aside differences, and align around a path forward. All the right building blocks are in place, right now, for success. NASA's industry team is leveraging decades of knowledge, hardware, and infrastructure so we can save money and begin with a proven, reliable baseline. NASA is laying the foundation for taking the next important step—human exploration beyond the Moon and to Mars. It is that vision that awakens the explorer in all of us.

Chairman Cruz, Ranking Member Udall, and members of the Committee, thank you again for the opportunity to testify here today and I look forward to answering your questions.

Senator CRUZ. Thank you, Mr. Elbon.

Dr. Pace?

STATEMENT OF DR. SCOTT PACE, DIRECTOR, SPACE POLICY INSTITUTE, ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS, GEORGE WASHINGTON UNIVERSITY

Dr. PACE. Thank you, sir.

Thank you, Chairman Cruz, Ranking Member Nelson, members of this Committee. It is an honor to follow the previous panel, and thank you for this opportunity to discuss the important topic of the future of human spaceflight.

While space touches every aspect of modern life, I would like to focus on human space exploration, as that topic is the one whose future is most in doubt today.

This is unfortunate, as human space activities are among the most interdisciplinary of enterprises, requiring skills from every field of technical endeavor. Their successful accomplishment requires a degree of system engineering skill found only in the most complex and demanding programs. The ability and willingness of a nation to lead such endeavors conveys much about the nature and intentions of that society.

It is my argument that international space cooperation, space commerce, and international space security discussions could be used to reinforce each other in ways that would advance U.S. interests and the sustainability and security of all space activities. At present, however, these activities are largely conducted on their individual merits and are not part of an integrated national strategy.

International space cooperation is not an end in itself but a means of advancing national interests. Those interests can be for security, commerce, science, international influence, or any combination thereof. A human space exploration effort driven by geopolitical interests and objectives would provide and does provide the historic model and rationale, I believe, for the United States.

The next steps beyond low Earth orbit will require international partners for practical and political reasons. Therefore, it makes sense to ask what our partners would like to do and what they are capable of doing in the future. The answer is: the Moon, with Mars and other destinations in the distance. A U.S. commitment now to lead a multinational program to explore the Moon would be a symbolic and practical first step as well as a means of creating a broad international framework for space cooperation.

At the same time, the geopolitical benefits of improving relations with growing space powers through greater U.S. engagement could

support more ambition space exploration efforts than science alone might justify.

On the commercial side, providing cargo delivery, for example, to the lunar surface would be an attractive post-ISS market for U.S. industry. The volume and duration of that market would be enormously more attractive to industry than the ISS alone could ever be.

The Moon is not just a physical destination but also a means of answering questions, creating capabilities, training organizations, and forging new relationships that serve the interests of the United States and its allies.

Through authorization and appropriation bills, the Congress should provide clear direction for NASA on an exploration mission for the 2018–2025 timeframe, as SLS, Orion, and other exploration systems currently under development begin operation.

The Congress should, in my view, direct NASA to develop mission concepts for an international return to the Moon with private-sector partners, in anticipation of a new administration in 2017.

The United States is crucially reliant on space systems, and the future sustainability and governance of space activities are key strategic interests for us. If we are to have an effective American space strategy, we need to align our policies, programs, and budget priorities with enduring national interests, for that will be the way they will be sustainable.

This means looking beyond individual missions and seeking to determine what future humanity might have beyond the Earth and what values will be part of that future. I would like those values to include the things we value today: democracy, human rights, rule of law, free markets. The rules on a frontier are made by the people who show up, not by the people who stay behind. And if those values are to be on a human future in space, then we need to be there to ensure them.

I close with a quote from Oliver Wendell Holmes. Quoting, "I find the great thing in the world is not so much where we stand as in what direction we are moving. We must sail sometimes with the wind, sometimes against it. But we must sail and not drift nor lie at anchor."

We need the confidence to choose what course offers the greatest advantage to our Nation and our values. And for that, I commend this hearing today.

Thank you.

[The prepared statement of Mr. Pace follows:]

PREPARED STATEMENT OF DR. SCOTT PACE, DIRECTOR, SPACE POLICY INSTITUTE, ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS, GEORGE WASHINGTON UNIVERSITY

Thank you, Chairman Cruz, Ranking Member Udall, and members of the Committee, for providing an opportunity to discuss the important topic of the future of human spaceflight and the strategic national interests served by international leadership in such endeavors. My testimony today is based on previous writings and presentations, most notably, my 2014 Durand Lectureship in Public Services sponsored by the American Institute of Aeronautics and Astronautics.

American Space Strategy Adrift

I would like to talk to you today about American space strategy and the choices before us. Space activities today play critical roles in U.S. national security, economic growth, and scientific achievements. Satellite communications link the world.

The Global Positioning System (GPS) is an integral part of several critical infrastructures, and enables functions ranging from survey and construction, to farming, finance, and air traffic management—not to mention critical support to U.S. military forces worldwide. Less well understood is that the GPS time signal provides a global time base for encrypted communications—including point-of-sale transactions. Without GPS, much of today's economy would come to a halt. We have rovers on the surface of Mars, and a probe that has left the solar system. The International Space Station represents a unique collaborative partnership between the United States, Europe, Canada, Japan, and Russia. New national entrants, some of them potential adversaries, may pose risks to the long-term sustainability and security of space activities as a result of increasing orbital debris and the proliferation of space capabilities.

While space touches every aspect of modern life, I would like to focus on human space exploration, as that topic is the one whose future is most in doubt today. This is unfortunate, as human space activities are among the most interdisciplinary of enterprises, requiring skills from every field of technical endeavor. Their successful accomplishment requires a degree of systems engineering skill found only in the most complex and demanding programs. The ability and willingness of a nation to lead such endeavors conveys much about the nature and intentions of that society. Thus, human spaceflight continues to possess enormous symbolic value, leading directly to important political, economic, and scientific consequences, both domestically and internationally. Human spaceflight is therefore a matter of considerable interest to policymakers, and should be.

It is my argument that international space cooperation, space commerce, and international space security discussions could be used to reinforce each other in ways that would advance U.S. interests in the sustainability and security of all space activities. At present, however, these activities are largely conducted on their individual merits and not as part of an integrated national strategy. I will return to this point later.

The International Space Exploration Coordination Group (ISECG) is a coordination mechanism among the major space agencies created in response to the Bush Administration's Vision for Space Exploration. The ISECG has been able to combine previously separate "Moon First" or "Asteroid First" approaches for going to Mars into a single scenario where cislunar space is the next step for human explorations beyond low Earth orbit. This is a major accomplishment, in that it has been the inconstancy of U.S. policy choices that have made attaining an international consensus so difficult in recent years.

The central elements of the current U.S. approach toward human spaceflight are found in the President's 2010 National Space Policy, which says that the NASA Administrator shall "set far-reaching exploration milestones. By 2025, begin crewed missions beyond the moon, including sending humans to an asteroid." This declaration came as a surprise to domestic and international space communities, following as it did upon the heels of two prior Congressional Authorizations Acts in 2005 and 2008 in which a human return to the Moon was specifically set forth as the next focus of U.S. space exploration. The international space community in particular, which had been shifting attention to the Moon as the completion of the International Space Station (ISS) drew near, felt blindsided. Countries in Asia, such as Japan, India, China, and South Korea, saw the Moon as a challenging but feasible destination for robotic exploration and a practical focus for human space exploration, a goal offering missions in which they could reasonably expect to play a part. The lack of U.S. support during the present Administration for a program to return to the Moon made it difficult for advocates of human space exploration in the United States, Europe, Japan, India, and elsewhere to gain funding for any efforts beyond the ISS.

While the United States continues to be officially uninterested in leading a human return to the Moon, the Moon is the next logical target for all of our potential international partners. Russia has made several presentations at various international conferences endorsing human missions to the Moon. China has not made an official decision to send humans to the Moon, but is proceeding with a steadily advancing robotic program that is putting in place the technical pieces necessary to conduct more ambitious missions when they so choose. They have landed a nuclear-powered rover on the Moon, unveiled designs for a Saturn 5-class heavy-lift launch vehicle, and are building a space station that will be open to international participation. Growing space powers such as the Republic of Korea and India have their own unmanned lunar ambitions, and even the private sector is looking to the exploitation of lunar as well as asteroid resources.

Europe is more cautious about human missions to deep space. They would almost certainly join in a U.S.-led effort, but would not lead one without us. Unfortunately,

there is no real U.S. plan or intent for human space exploration beyond the International Space Station, as there is no longer any real funding or any defined architecture for such endeavors. There is, however, a clear policy to create new U.S. providers of cargo and crew services to low Earth orbit to replace government capabilities. Using the ISS as an early market, the hope is that these new providers can provide lower cost services to meet government needs, be able also to compete for non-government payloads, stimulate new demand with lower prices, and thus contribute to U.S. economic growth. Cargo capability has been demonstrated, while crew capabilities are a work in progress. In addition, cost reductions are not yet evident in out-year projections of ISS funding needs.

There are risks in the current U.S. approach to human spaceflight. The United States finds itself reliant on the economic success of private service providers, and, through the intergovernmental agreements pertaining to the International Space Station our partners must now share this reliance. The companies themselves are also at risk. Should there be a "bad day" on the Station, this would be not only a disaster for NASA, but would also put an end to the near-term market for the so-called "commercial crew and cargo" companies. It would be very difficult to restart a U.S. human spaceflight effort without the pull of either the ISS partnership or the follow-on goal of a lunar return, and it is unlikely that private firms would, or even could, recreate a human spaceflight capacity without U.S. government demand and support.

Even assuming no accidents with the ISS, it will likely be impossible to operate the facility beyond 2028 due to life limitations on crucial station elements, obsolescence, and a lack of replacement parts. Political commitments may fade even earlier, as there is not yet a consensus among the partners to operate the facility beyond 2020.[1] Without commitments from the partners, it will continue to be difficult to induce scientific investigators to invest years of their career in carrying out an experiment which might fly once, if at all, before the facility is closed. And despite the promise of space tourism, it is also unlikely that the market will be large enough and stable enough by 2020 to replace the demand for human spaceflight now generated by the ISS partnership and NASA in particular.

Human space exploration and U.S. human spaceflight for the next decade will continue to be driven by U.S. space policy as reflected in the NASA budget. That budget is itself a political choice—it is a reflection of what we value as a society. NASA's budget has been declining in constant dollar terms for decades. If NASA today had the same budget in constant dollars that it did in 1992, it would be $24 billion. To the question of affordability, it should be understood that—in constant dollars—the Administration's stimulus program was greater than NASA's budget from 1958 to 2008. To emphasize: the United States sent humans to the Moon, built and operated a Space Shuttle fleet for 30 years, completed the initial robotic exploration of the solar system, built and operated several space telescopes, and contributed its share of the International Space Station for less than the cost of the American Recovery and Reinvestment Act.

That being said, fiscal limits are real and harsh. The performance requirements for getting humans safely to other worlds remain constant and demanding. As budgets are pushed down, schedules slip and risks increase. We cannot, however, focus solely on cost, as funds spent on any space activity have to compete successfully against other budgetary demands. If we are to sustain discretionary expenditures for civil space exploration, we must develop a clearer rationale linking such efforts to national interests that can be supported in a bipartisan manner over many years. In the absence of any larger strategic context for a human spaceflight program, ambitious mission concepts are insufficient to justify the required levels of effort.

Budget Volatility

There is a line from the movie "The Right Stuff" in which the actor playing Gordon Cooper says: "You boys know what makes this bird go up? FUNDING makes this bird go up." I would go further and say: "What creates funding? Bipartisan support creates funding."

Bipartisan agreement was reached in the aftermath of the tragic loss of the Space Shuttle *Columbia* that the United States should continue to explore beyond Earth orbit, returning to the Moon and then voyaging to Mars. President Bush called the Vision for Space Exploration "a journey, not a race" and one that would not be done by the United States in competition with other nations, but in partnership with them. The Congress passed two successive NASA authorization bills in FY 2005 and FY 2008 with strong bipartisan majorities endorsing this direction.

[1] The White House and NASA announced on January 8, 2014 that the United States would extend its participation in the ISS until at least 2024.

The Obama Administration decision to overturn that consensus led to the protracted battle over the FY 2010 NASA Authorization Act. The future of human spaceflight and the role of U.S. leadership were at the center of the debate between Congress and the White House. The result of this conflict was budget volatility as well as policy uncertainty, two factors that have burdened the U.S. human spaceflight effort for several years now. In addition to the flawed policy direction of focusing on an asteroid mission in the near term and an unknown path to Mars in the long term, the Administration's unstable budget requests for NASA have created immense challenges for the Agency's managers, scientists, and engineers. As an illustration of budget volatility, see Figure 1 below. It shows enacted budgets for NASA as well as the five-year budget request for FY 2010–20016. The FY 2010 budget had a "pause" in human spaceflight in the out-years while the Augustine Committee was working. The FY 2010 budget top-line returned but internal Agency priorities were greatly different, leading to the conflicts with Congress. FY 2011 saw a dramatic drop and flattening of the NASA budget request, creating more uncertainty for planning. The situation worsened in FY 2012, FY 2013, and FY 2014—leading to the wry comment at NASA that "flat is the new up." This year, the FY 2016 request shows a significant increase, but without changes in policy priorities to know if this change will be stable going forward.

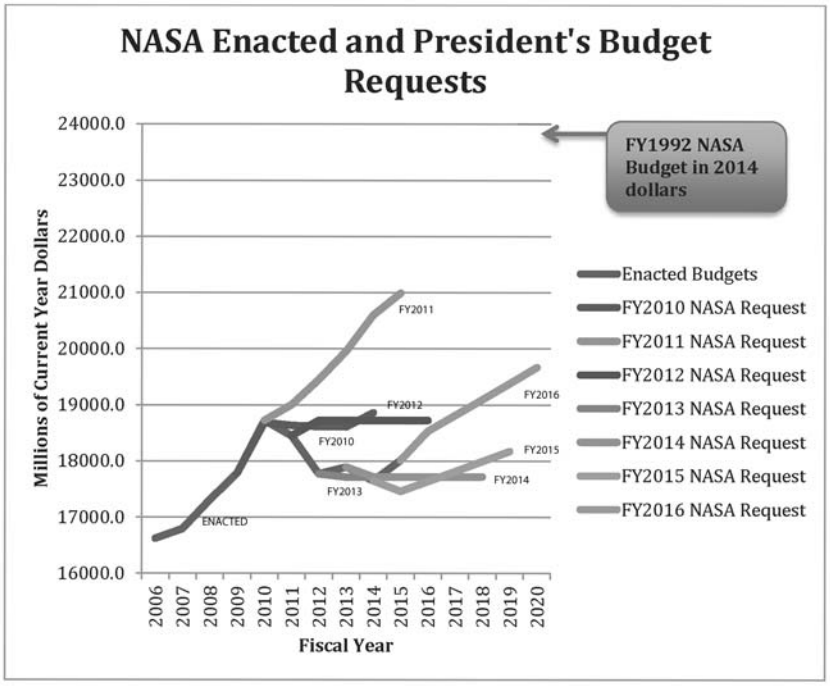

Figure 1—NASA Enacted Budgets and Presidential Budget Requests FY 2010–16

Global Space Competition

The uncertainty and drift attending human spaceflight efforts today have consequences beyond our borders. Working in a school of international affairs, it is easy to see the importance of cross-national "functional" issues such as security, trade, development, and technology to U.S. foreign policy. Of particular importance are debates over areas beyond traditional definitions of sovereignty, such as the high seas, international air space, the Polar Regions, space, and cyberspace. These are today's frontiers, and are thus areas of potential conflict and cooperation among state and non-state entities that impact U.S. interests. As with past frontiers, it is those who show up, not those who stay home, who create the rules and establish the norms in new areas of human activity.

In a world in which space capabilities are increasingly global, no one state will be in a position to impose rules unilaterally for the exploration and development of space. Similarly, the diversity of competing national interests in space make it un-

likely that a single international space authority or even a new space treaty will emerge anytime soon. Thus, the task for the United States, if it wishes to influence how space is developed and utilized, is to create attractive projects and frameworks in which other nations choose to align themselves, and their space activities with us, as opposed to others. Just as the United States shaped the postwar world with a range of international institutions, so we should look to the creation of new arrangements to advance our interests, values and freedoms in space.

There is nothing inevitable about U.S. leadership in space unless we make it so. I attended the International Astronautical Congress in Beijing in 2013. As might be expected, U.S., Russian, and Indian attendance was light. Nonetheless, the Chinese did a good job hosting the conference with welcoming remarks from Li Yuanchao, Vice President of the People's Republic of China, and a display of their three-man Shenzhou 10 capsule. There were also displays of Brazilian, Ukrainian, and South African cooperation with China, and one could easily see what a global space community might look like without the United States. It was in effect a picture of a post-American space world, with a full range of manned and unmanned space activities, but without American leadership or even, in many cases, an American presence.

China is planning to deploy its own space station in less than a decade, about the same time that the International Space Station may be ending. If China is able to offer pragmatic opportunities for space cooperation on its own space station or as part of efforts to send humans to the Moon, and the United States cannot, then other countries will likely find it attractive to forge closer relationships with China. Such a shift in international space influence away from the United States and toward China will, no doubt, impact a wide range of U.S. national security and foreign policy interests, both in space and in other arenas.

The United States retains several advantages in space, however. We have decades of experience and close relationships with almost every spacefaring nation on a wide range of projects. The entrepreneurial energy of the private U.S. space community, both large and small, is a source of admiration by and occasional puzzlement to the international space community. At the same time, a proud history and a nascent private industry cannot alone substitute for national and international leadership in space, and likely cannot survive, much less thrive without it. Both international cooperation and private sector initiative are necessary aspects of any effective American strategy in space, but are not by themselves sufficient. A focused national strategy is also needed to provide a coherent context for both cooperative agreements and private ventures.

Choosing a Direction

It is crucial to remember that international space cooperation is not an end in itself, but a means of advancing national interests. Those interests can be for security, commerce, science, international influence, or any combination thereof. A human space exploration effort driven by geopolitical interests and objectives provides the historic model and rationale for the United States. The United States undertook the Apollo program in the 1960s to beat the Soviet Union to the Moon as part of a global competition for Cold War prestige. The Apollo-Soyuz program symbolized a brief period of détente in the 1970s. The Space Station program was established in the 1980s, in part, to bring the developing space capabilities of Europe and Japan closer to the United States and to strengthen anti-Soviet alliances. Russia was invited to join a restructured International Space Station in the 1990s to symbolize a new post-Cold War, post-Soviet relationship with Russia.

The next steps beyond low Earth orbit will require international partners for practical and political reasons. Therefore, it makes sense to ask what our partners would like to do, and what they are capable of doing in the future. The answer is the Moon—with Mars and other destinations in the distance. A U.S. commitment now, to lead a multinational program to explore the Moon would be a symbolic and practical first step as well as a means of creating a broader international framework for space cooperation. At the same time, the geopolitical benefits of improving relations with growing space powers through greater U.S. engagement could support more ambitious space exploration efforts than science alone might justify. Providing commercial cargo delivery to the lunar surface would be an attractive post-ISS market for U.S. industry; the volume and duration of that market would be enormously more attractive to industry than that for the ISS could ever be. The Moon is not just a destination, but also a means of answering questions, creating capabilities, training organizations, and forging new relationships to serve the interests of the United States and its allies.

The United States is crucially reliant on space systems, and the future sustainability and governance of space activities are key strategic interests for us. U.S.

human space exploration today is "capability driven," with ambitious goals in the distance that are not well connected to other national interests, notably in international relations and commerce. If we are to have an effective American space strategy, we need to align our policies, programs, and budget priorities with enduring national interests. This means looking beyond individual missions and seeking to determine what future humanity might have beyond the Earth, and what values will be part of that future. I would like those values to include the things we value today—democracy, human rights, the rule of law, and free markets.

I will close with a quote from Oliver Wendell Holmes, Sr. "I find the great thing in this world is not so much where we stand, as in what direction we are moving—we must sail sometimes with the wind and sometimes against it—but we must sail, and not drift, nor lie at anchor." We need the confidence to choose what course offers the greatest advantage to our Nation and our values.

Thank you.

Comments on the President's FY 2016 Budge Request for NASA[2]

The President's FY 2016 budget request contains a 7 percent ($74 billion) increase over the FY 2015 Omnibus spending level, with NASA receiving $18.5 billion—a nearly $500 million increase above the FY15 Omnibus and nearly $1 billion above the President's budget request last year.

The proposed increase to NASA's budget largely benefits two of the Obama Administration's top priorities: Earth Science (+175M) and Commercial Crew development subsidies (+438M). These increases come at the expense of Exploration systems under development, including the super heavy lift Space Launch System (SLS) and the exploration crew spacecraft, Orion, which completed a successful inaugural test flight in December 2014.

The proposed cuts to SLS and Orion almost directly correspond with the budget's nearly half billion jump in funding for the Commercial Crew program. In September 2014, NASA announced the selection of Boeing and SpaceX to continue development of spacecraft for crew launches to the International Space Station by 2017–2018. Congress has repeatedly sought to constrain spending for this program and to narrow the number of program participants. SLS and Orion are the systems that will enable human exploration of space beyond low-Earth orbit. Of particular concern are potential reductions to the funding of SLS core stages that would further delay the program and increase total costs.

Overall, space technology budgets fare well in this year's request: the budget again proposes a $128+ increase to the Space Technology mission directorate and the Advanced Exploration Systems account, which funds exploration systems like habitat and landers, receives an increase of $48 million. While modest, funding for AES is important to ensure that systems are developed which leverage NASA's SLS and Orion capabilities enabling a return to the surface of the Moon.

For the third year, the budget continues to propose funding for an Asteroid Redirect Mission, which has been widely panned by the Congress, the scientific community, and NASA's international partners. The administration is again proposing to divert funding in the Advanced Exploration Systems and Space Technology accounts to pay for this mission.

The budget also continues efforts by the administration to cut programs favored by Congressional stakeholders, like Planetary Science and Aeronautics. Both programs are cut by approximately $80+ million relative to the recently enacted FY 2015 Omnibus.

Although the President's budget violates sequestration budget caps and makes unrealistic assumptions about new revenue to allow for increases in discretionary spending, the topline increase for NASA is welcome and should be encouraged within the allocation provided by the House and Senate budget resolutions. Republicans and Democrats in Congress both approved funding for NASA that was well above the President's request last year and should be encouraged to prioritize investments in the space program. For example, the Congress should enforce balance in the science portfolio to ensure that programs like Planetary Science and Earth Science receive funding consistent with their scientific merit.

The appropriations process should prioritize investments in NASA's Exploration program by fully funding SLS, Orion and Advanced Exploration Systems, while restricting spending on the Asteroid Redirect Mission. A heavy-lift capability of 130 mT (*e.g.,* Saturn V class) is highly beneficial for a human return to the Moon and a necessity for eventual human missions to Mars. Lacking such a capability would

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[2] Adapted from *The Hay Bulletin,* Issue 34, The John Hay Initiative, February 12, 2015, p. 7

mean doing multiple orbital assembly flights at substantial additional cost and risk. The upper stage necessary to reach the 130 mT capability continues to be underfunded.

As a possible offset to the administration's proposed increase for Commercial Crew, Congress could direct NASA to adopt a "leader-follower" approach with the final level of funding provided for the program. Under this approach, NASA would provide full funding to the primary crew award winner to ensure the development of domestic access to ISS by 2017, while the second crew system would come online later, pending the availability of resources and the progress made by the "leader" and an evaluation of the market for these services.

Through authorization and appropriations bills, Congress should provide clear direction for NASA on an exploration mission for the 2018–2025 time-frame as SLS, Orion, and other exploration systems currently under development begin operations. The Congress should direct NASA to focus on the mission concepts for an international return to Moon, with private sector partners, in anticipation of a new Administration in 2017.

SCOTT PACE

Dr. Scott Pace is the Director of the Space Policy Institute and a Professor of the Practice of International Affairs at George Washington University's Elliott School of International Affairs. His research interests include civil, commercial, and national security space policy, and the management of technical innovation. From 2005–2008, he served as the Associate Administrator for Program Analysis and Evaluation at NASA.

Prior to NASA, Dr. Pace was the Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy (OSTP). From 1993–2000, Dr. Pace worked for the RAND Corporation's Science and Technology Policy Institute (STPI). From 1990 to 1993, Dr. Pace served as the Deputy Director and Acting Director of the Office of Space Commerce, in the Office of the Deputy Secretary of the Department of Commerce. He received a Bachelor of Science degree in Physics from Harvey Mudd College in 1980; Masters degrees in Aeronautics & Astronautics and Technology & Policy from the Massachusetts Institute of Technology in 1982; and a Doctorate in Policy Analysis from the RAND Graduate School in 1989.

Dr. Pace received the NASA Outstanding Leadership Medal in 2008, the U.S. Department of State's Group Superior Honor Award, *GPS Interagency Team,* in 2005, and the NASA Group Achievement Award, *Columbia Accident Rapid Reaction Team,* in 2004. He has been a member of the U.S. Delegation to the World Radiocommunication Conferences in 1997, 2000, 2003, and 2007. He was also a member of the U.S. Delegation to the Asia-Pacific Economic Cooperation Telecommunications Working Group, 1997–2000. He is a past member of the Earth Studies Committee, Space Studies Board, National Research Council and the Commercial Activities Subcommittee, NASA Advisory Council. Dr. Pace is a former member of the Board of Trustees, Universities Space Research Association, a Corresponding Member of the International Academy of Astronautics, and a member of the Board of Governors of the National Space Society.

Senator CRUZ. Thank you, Dr. Pace. And I would note that in an afternoon where we are listening to learned scientists, as a lawyer, I appreciate your throwing a Supreme Court justice in there.

Mr. Stallmer?

STATEMENT OF ERIC W. STALLMER, PRESIDENT, COMMERCIAL SPACEFLIGHT FEDERATION

Mr. STALLMER. Thank you.

Thank you, Chairman Cruz, Ranking Member Nelson, and members of the Subcommittee and staff. I want to thank you for holding this hearing and for providing me the opportunity to testify as President of the Commercial Spaceflight Federation.

CSF is an industry association of leading businesses and organizations working to make commercial spaceflight a reality. NASA and the commercial sector are partners in America's great national

enterprise in space. Since the dawn of the space program, cooperation between the government and the private sector has been critical to our tremendous accomplishments in space.

This cooperation continues to enable us to achieve great things, but the relationship has evolved over time. The relationship that once defined the United States' nascent space program have given way to a more modern and innovative approaches to procure a wide variety of necessary capabilities and services.

My written testimony provides detailed examples of these successful commercial partnerships, but I would like to quickly highlight a few of these areas where this new alliance has helped move our Nation's space exploration goals forward and areas where we can help with it in the future.

The pioneering COTS and CRS programs have led to affordable and robust domestic cargo access to the International Space Station, increasing its utilization for scientific research, technology, and development. A variation of this model is being applied in the Commercial Crew Program, which is developing safe, reliable, and also domestic access to and from low Earth orbit for our astronauts.

Finally, private companies are working on building a variety of capabilities to help explore destinations beyond low Earth orbit, of which NASA should leverage this support in its future exploration efforts. Further expansion of the commercial spaceflight industry will create a self-reinforcing ecosystem that will make space ours, and it will enhance and strengthen our leadership in space.

For the past 6 months, I have made it my priority to personally visit all of our member companies all over this great country of ours, from Midland to Mohave, from Seattle and the Florida space coast, and here is what I have seen: U.S. suborbital companies are leading the development of reusable vehicles, creating versatile platforms to service diverse markets for research, space tourism, education, and other applications. Orbital providers are increasing access to space for a wide variety of customers, including small-sat, national security payloads, and geostationary communications satellites.

This is a positive trend for the United States. After decades of decline, we are finally recapturing market share in the commercial launch sector. In order to support the growth in the launch activities, states, I should say, states have been competitively investing in commercial space supports to ensure their state economies have a key role in this 21st century business.

Finally, within our grasp in space are nearly limitless resources of great commercial value here on Earth. These resources can also be used to help us press onward as explorers deep into the cosmos. Several companies are working to unlock these resources.

As you can see from this growing commercial ecosystem, it is not a surprise that we are experiencing private sector investment unlike anything we have seen in history. But to continue this progress, we need thoughtful commercial procurement policies and regulatory certainty. Congress must set policies that encourage growth and innovation in the industry and maintain the U.S. space sector's competitive advantage.

As you prepare to reauthorize the Commercial Space Launch Act, you can help provide critical updates: extending the regulatory learning period that helps our industry innovate rapidly toward ever safer vehicles in practice; solidifying launch indemnification, which is critical to the competitiveness of our launch industry in the global marketplace; and addressing the questions of how to handle government astronauts in commercial vehicles and so forth.

These and other important issues are addressed in my written testimony. Codifying these policies increase our global competitiveness, promote industry growth, and strengthen our Nation's industrial space base and keep the United States at the forefront of space technology.

The commercial space sector is and will continue to be a valuable partner in America's ever more ambitious missions to expand our reach in space. I have three young children who regularly ask me, "Daddy, when can we go to space?" And I am confident, from working in this industry, that the answer is, "Very soon."

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

[The prepared statement of Mr. Stallmer follows:]

PREPARED STATEMENT OF ERIC W. STALLMER, PRESIDENT, COMMERCIAL SPACEFLIGHT FEDERATION

Chairman Cruz, Ranking Member Udall, and Members of the Subcommittee, thank you for holding this hearing and for providing me the opportunity to testify as President of the Commercial Spaceflight Federation. The Commercial Spaceflight Federation (CSF) is the industry association of leading businesses and organizations working to make commercial spaceflight a reality. Our mission is to promote the development of commercial spaceflight, pursue ever higher levels of safety, and share best practices and expertise throughout the industry.

I hope to provide three main take-aways from my testimony today providing insight on the sector's past, it's present, and how lessons learned from these eras can be applied to the future for the growth of America's space program.

First, NASA and the commercial sector are partners in America's "great national enterprise" in space. Since the dawn of the space program, the partnership between government and the private sector has been a testament to our accomplishments in space. The partnerships early in the U.S. space program were different than the partnerships we see and encourage today, but this is owed to the evolution of our Nation's space program and the continued evolvement from both parties. Later in my testimony, I will discuss successful commercial partnerships and how these can be applied to our Nation's space exploration goals moving forward.

Second, further expansion beyond the government will create an ecosystem that will make space ours, and will enhance and strengthen U.S. leadership in space. Many of CSF's member companies are working to push Earth's economic sphere outward from Low-Earth orbit and beyond. Suborbital platforms will provide an avenue for space tourism and research that could not be conceived otherwise. Orbital vehicles will increase utilization of the International Space Station (ISS) for industry and research institutions in addition to increasing destinations in low-Earth orbit (LEO). Beyond LEO activities span the spectrum from mining celestial bodies for resources valuable to Earth to habitats on the Moon. All of these activities and more are creating a market in space that will continue to grow.

Finally, policies must be in place to encourage growth and innovation in the industry and keep the U.S. space sector competitive. Tools such as contracts using Other Transaction Authority (OTA) can continue this trending growth. The Commercial Space Launch Amendments Act (CSLA) and export control are other policy areas ripe for reform that will shape the advancement for the industry. Later in my testimony, I will discuss how Congress and industry can work together on these important policies to encourage progress and not hinder it.

Public-Private Partnerships

The Federal Government and the commercial space sector have worked together in various capacities since the beginning of America's space exploration program. From Mercury through Apollo, NASA's success in the space race was not without

the help of commercial companies such as Bell, North American Aviation, and what was then known as the Grumman Aircraft Engineering Corporation. This era saw collaboration with industry in which NASA engineers would design the systems and competitively bid out portions of the project. While this proved to be a successful method for developing specially-designed systems, it has become clear that there are a wide variety of necessary capabilities and services that do not fit that template.

Since the 1990s, a new wave of public-private partnerships has emerged to complement traditional contracting methods. "Commercial Procurement" now allows the government to assume the role of customer while still being involved in the development of the system. However, the government is no longer the sole customer and its role changes from top-down control to promoting and stimulating the development of commercially-owned capabilities. By spreading costs across multiple users, prices can be reduced, saving the government money while also increasing space's economic return. This approach allows NASA and the commercial sector to become true partners in America's "great national enterprise" in space. The public and the private sector together will collectively advance our Nation's reach into the cosmos.

Suborbital

The NASA-commercial partnership starts in the shallow waters of space, in the suborbital realm. Initiatives such as NASA's Flight Opportunities Program (FOP) use commercial reusable vehicles for technology development that will allow and enable future missions to new destinations, keeping the U.S. at the forefront of exploration technology. In addition to robustly testing new technologies, these platforms offer brief access to the space environment for scientific data collection. Many researchers see them as stepping stones to using the International Space Station (ISS), increasing its utilization and raising its commercial success. Made In Space, a company based out of Silicon Valley, used FOP to test its 3D printers operation in microgravity for a fraction of the price of an orbital mission. After testing and building confidence on Earth, the company sent one of its printers to the ISS where it is currently operating. To date, the company has printed 14 objects from a calibration coupon to a ratchet. This perfectly exemplifies the success of a public-private partnership developing technology for future exploration, where astronauts could create a spare parts to support ambitious new missions.

Low-Earth Orbit

The ISS has been described as the crown jewel of the United States space exploration enterprise; it's a platform to perform a wide variety of experiments focused on life and physical sciences, human research, exploration research, and technology development. Almost a decade ago, in the NASA Authorization Act of 2005, Congress codified a new agreement between NASA and the U.S. commercial space industry to better achieve the Nation's space exploration goals together. Congress designated the U.S. segment of the International Space Station a national laboratory, no longer the sole domain of NASA, but rather a shared resource to be utilized by both the Federal Government and private industry. An excellent example of the ISS being used in this fashion is the Bigelow Expandable Activity Module ("BEAM"), which will be launched and attached to the ISS later this year. Bigelow Aerospace has invested hundreds of millions of dollars in bringing expandable habitat technology to fruition, and, in partnership with NASA, the ISS will be utilized as a platform to demonstrate this vital new technology. Additionally, in anticipation of the Space Shuttle's retirement, Congress directed NASA to partner with the commercial space industry to develop cargo transportation capabilities to the International Space Station.

To that end, NASA created the Commercial Orbital Transportation Services (COTS) Program to stimulate efforts within the private sector to develop safe, reliable, and cost-effective transportation capabilities to the ISS and LEO. COTS competitively funded two commercial companies—SpaceX and Orbital ATK—through cost-sharing, milestone-based, Space Act Agreements to help develop these capabilities. The program tied payments to the successful completion of contractually agreed upon milestones, and incentivized companies to contribute a significant amount of their own funds towards development. Following up on the success of the COTS program, NASA entered into a separate set of FAR-based, firm-fixed-price contracts with the companies to supply a series of cargo missions to the ISS through at least 2016. As of last month, 8 resupply missions have successfully been completed, with 12 more to come.

The pioneering COTS and CRS partnership has benefited American human spaceflight efforts in several ways, including:

1. Providing timely critical supplies to ISS crew members;

2. Increasing the utilization of the ISS for research experiments and technology development;
3. Developing affordable, fixed-cost domestic access to the ISS; and providing
4. Dissimilar redundancy to assure continued critical access through the life of the program.

A variation of this model is being applied in the Commercial Crew Program (CCP), which is enabling American companies to develop reliable and cost-effective human access to LEO, and will return human launch capabilities back to U.S. soil. NASA is currently paying more than $70 million per seat for rides to the ISS for our astronauts on Russian Soyuz vehicles, and the price increases every year. Commercial Crew will allow NASA to purchase cost-effective domestic flights for their astronauts while eliminating dependence on the Soyuz. These transportation systems will also allow NASA to expand the ISS' crew size to its planned seven persons, roughly doubling U.S. crew time for utilization. This will allow much more scientific research and technology development activities to be conducted on our national lab. Additionally, with the private sector providing more economical transportation to LEO, NASA's budgetary resources will be freed up to pursue additional avenues for the further exploration of space.

Beyond Low-Earth Orbit

As the commercial space industry has taken a larger partnership role in exploring LEO, it has enabled NASA to focus on extending human presence beyond LEO. NASA has continually stated that the United States' long-term human exploration goal is to send humans to Mars, with precursor missions along the way to prepare for trips to the Red Planet. To that end, NASA is building a new heavy lift rocket, the SLS, and Orion crew capsule, to take astronauts beyond LEO in the early 2020s. The development of a heavy lift launch vehicle and crew capsule are important pieces of the United States beyond LEO human exploration plans, but other complementary pieces are needed as well. I'd like to reference NASA Office of Inspector General's *2014 Report on NASA's Top Management and Performance Challenges* on this matter. The November 2014 report states:

> "even after the SLS and Orion are fully developed and ready to transport crew, NASA will continue to face significant challenges concerning the long-term sustainability of its human exploration program. For example, unless NASA begins a program to develop landers and surface systems, NASA astronauts will be limited to orbital missions. In the current budget environment, however, it appears unlikely that NASA will obtain significant funding to begin development of this additional exploration hardware anytime soon, effectively delaying such developments into the 2020s. Given the time and money necessary to develop landers and associated systems, it is unlikely that NASA would be able to conduct any manned surface exploration missions until the late 2030s at the earliest."

I highlight this not because I believe it is a problem for our beyond LEO exploration goals, but rather because I believe it is an opportunity that should be leveraged. While the audit correctly surmises that there is unlikely to be enough resources in the near- or mid-term for NASA to develop a lander and surface systems through traditional approaches, it fails to recognize the significant contributions that the commercial space industry is making in these areas. Private companies like Moon Express, Bigelow Aerospace, Masten Space Systems, and Golden Spike are all building capabilities to explore and commercially develop the Moon. These companies, and others, are interested in the Moon because it offers the potential to support near-term opportunities for economic growth. To NASA's credit, it has begun exploring public-private partnerships for beyond LEO exploration via the Advanced Exploration Systems (AES) program which is supporting initiatives such as Lunar Cargo Transportation and Landing by Soft Touchdown (CATALYST). In the FY 2015 appropriations bill, Congress included language that strongly reaffirmed the importance of the private sector contributing landers, habitats, and propulsion systems to beyond LEO human spaceflight through public-private partnerships as is occurring via the AES program. Hardware developed by AES will serve a critical role in ensuring that NASA can utilize the transportation capacities of SLS and Orion to conduct surface missions to the Moon and eventually Mars. We believe that including the commercial space industry as an early partner in reaching U.S. human exploration goals beyond LEO is a logical extension of the successful COTS and CRS partnership model proven in LEO, and can help alleviate budgetary constraints and compliment the Agency's investment in its transportation systems.

Commercial companies are also exploring other destinations beyond LEO, like asteroids. For example, Planetary Resources is working to identify, track, analyze, and eventually interact with near-Earth asteroids. While these companies and others work to supplement NASA programs for exploration, even more importantly, they are working to create a sustainable ecosystem in space. NASA continues to play an invaluable role in creating early markets for and in the support of American entrepreneurial companies at the edge of competitive technology areas such as spaceflight but much more can be done to incubate markets in space.

To conclude, Congress can further support the growth of the commercial space industry by promoting a true partnership between the Government and private sector. Government investment in leading edge launch technologies will remain essential, but it is vital to the industry that taxpayer dollars not compete with private investment. The industry acknowledges that decisions regarding when to exit Government funded programs and when to rely on commercial capabilities are difficult ones. In light of this, the commercial space launch industry would like to maintain an ongoing dialogue with Congress and with the leading U.S. Government R&D agencies on the most effective way for government investment to ensure U.S. leadership without competing with commercial operators.

Commercial Space as a Business

This economic model is not a new one. When one looks through the 20/20 lens of history, you will find that a flourishing commercial industry enables the long-term well-being of a nation's strategic goals. In the eighteenth and nineteenth century, Great Britain was the leader of the open seas. It was home to the largest mercantile marine afloat, more than half a million tons of shipping, and a Royal Navy that fielded a force larger than the fleets of Spain and France combined.[1] This was by design, not accident. By thoughtfully passing maritime laws that encouraged the growth of its commercial shipping industry, the British built the crucial foundations of a sustainable maritime power: a thriving shipbuilding industry and the maintenance of a pool of experienced seamen. As Alfred Mahan more succinctly put it, a thriving commercial shipping industry is the force that naturally produces a healthy navy.[2]

In the 1980s President Reagan and leaders in Congress shared a similar vision for American commercial leadership in space. Mr. Chairman, it will probably not surprise you that the first commercial launch in the United States was conducted in Texas, from Matagorda Island in 1982. Two years later, in 1984, the Reagan Administration created the Office of Commercial Space Transportation and then Congress enacted the Commercial Space Launch Act to centralize the function of licensing and promoting the new commercial space launch industry. Since its establishment, the commercial spaceflight industry has grown tremendously to include a diverse range of companies and applications. The commercial space sector is an emerging high-tech industry that has continued to make significant progress in the past few years in terms of growth in revenue, employees, and capability. Orbital companies such as SpaceX, Sierra Nevada Corporation, Blue Origin, and Boeing have begun testing their crew vehicles that will fill the gap in U.S. human spaceflight capability to LEO. SpaceX has already docked a version of its Dragon capsule to the ISS several times under NASA's CRS program. Additionally, reusable technology will have the potential to further disrupt the launch industry to bring even more business to U.S. soil.

U.S. suborbital companies are leading the development of reusable manned vehicles. Virgin Galactic is working on the second version of its SpaceShipTwo vehicle and XCOR Aerospace has begun assembling its Lynx suborbital vehicle and is conducting tests on its propulsion system. Blue Origin has also successfully conducted a test of its pusher escape system for its orbital and suborbital crew capsule. Late last year, the StratEx team broke Felix Baumgartner's record skydive through technology development and advancements that will be incorporated into World View's future commercial balloon platform. These and other suborbital platforms are gearing up to offer flights to private individuals and researchers, and their scientific, industrial and educational payloads to altitudes that were previously unachievable for the everyday consumer. Each month brings new accomplishments for these companies, and each stride forward builds the robust market for research, space tourism, education, and other applications.

Going beyond public-private partnerships with NASA, the commercial launch industry's activities continue to grow rapidly. In Fiscal Year 2013, Federal Aviation

[1] Sugden, John (2011). Nelson: A Dream of Glory. Pimlico.

[2] Cropsey, Seth, & Milikh, Arthur. Mahan's Naval Strategy: China Learned It. Will America Forget it? World Affairs (March/April 2012).

Administration's Office of Commercial Space Transportation (AST) licensed and permitted 18 commercial launches, a six-fold increase over the previous year. To support this growth, states have been competitively investing in commercial spaceports to ensure their state economies have a key role in this 21st century business. States who have developed or are developing commercial spaceports include, Alaska, Texas, New Mexico, Florida, Virginia, Colorado and California. These facilities provide competing venues to test equipment, launch orbital and suborbital missions, and train crew and spaceflight participants in the types of environments they will experience in space. Companies around the country are also supplying spacecraft parts and subsystems, ranging from screws and fasteners to environmental control systems, engines and spacesuits.

These and other entrepreneurial activities in the commercial space sector are reinvigorating our space industrial base. Domestic launch competition is lowering the cost and increasing the reliability of our access to space, vital for launches needed for national security. Additionally, the private sector is working towards replacing international dependence for national security, evidenced in the work being done by Blue Origin and United Launch Alliance in their BE–4 engine, a replacement for the Russian RD–180 engine.

While strengthening our Nation's industrial base, the commercial sector is creating new cost-effective applications for exploring space and creating a better life for people on Earth. The commercial space industry is creating new opportunities for humanitarian applications in addition to commercial business. Planet Labs' fleet of small satellites will be providing daily images of Earth that can be used to evaluate project sites, monitor crops, as well as observe forest fires for early detection and warning. Other companies such as OneWeb and SpaceX are planning to provide broadband Internet access to even the most rural parts of the world through the deployment of affordable small satellite constellations.

Other companies are looking to use space for resource utilization to further space exploration and to better life here on Earth. While the price tags on platinum metal groups remain high, they are used to manufacture 1 of 4 goods we use every day, from electronics to medical devices. The major sources of these metals are concentrated overseas in regions of Africa and Russia. One company aimed at mining asteroids has the potential to increase our access to the resource. Planetary Resources is currently developing a platform to detect and mine platinum-rich asteroids. Just one of these asteroids contains more platinum than has been mined in the entire history of humankind. This technology will also play a critical role in detecting near-Earth asteroids in the future for science and the safety of our planet.

The industry is also providing new opportunities in research, science, and resource utilization. Little is known about the mesosphere, often called the "ignorosphere," which lies above the maximum altitude for aircraft and balloons and below the minimum altitude for orbital spacecraft. New suborbital reusable platforms that will come online in the next few years will provide access for in-situ data for this portion of our atmosphere, allowing us to increase our understanding of phenomena such as red sprites and noctilucent clouds that occur in that realm.

Finally, the commercial space industry itself is creating thousands of high-tech jobs in the U.S. In addition, the sector is creating a renewed interest in STEM careers. The industry is exciting the next generation and allowing them to personally participate in the Nation's journey into space. With new commercial space platforms, students can build and fly their experiments into space on suborbital platforms, build and launch their own satellites, and even use flight hardware already in space for classroom projects. Inspiring the next generation is inspiring our future problem-solvers and the entrepreneurs that will shape our lives in the coming years. As Jeff Bezos, the founder of Amazon and Blue Origin, so eloquently put it:

> "Millions of people were inspired by the Apollo Program. I was five years old when I watched Apollo 11 unfold on television, and without any doubt it was a big contributor to my passions for science, engineering, and exploration."

In order to continue this trend of technological advancement, we must provide the best possible environment for the burgeoning commercial space sector.

Policy

Other Transaction Authority

Policies that have shown success in the past should continue to be used to encourage growth and success in the future. The COTS model, which enjoyed bipartisan support under NASA Administrator Mike Griffin, is representative of the successful public-private partnership that uses mechanisms to encourage private sector innovation while still satisfying the strict requirements of government procurement. The program used milestone-based Space Act Agreements through its Other Transaction

Authority (OTA) rather than the traditional Federal Acquisition Regulations (FAR) to keep costs low and performance high. Traditional, cost-plus FAR contracts can, in some instances, focus too much on needless bureaucracy and take attention away from performance and safety. Conversely, firm fixed price agreements allow the objectives of the contractor and the agency to be aligned in an affordable fashion, shifting the burden of cost overruns onto the private sector. With these performance based payments, the contractor is highly incentivized to be efficient and keep costs low in its development. Additionally, the agency is restricted from changing the direction mid-program, which tends to cause delays and increase the program's lifetime as well as the cost to the taxpayer.

At the same time, we support Congressional transparency measures regarding Space Act Agreements (SAAs). Creating a database of SAAs (with proprietary information redacted) that companies and the public can access allows for both NASA officials and private sector entities to learn from past agreements and improve the future use of SAAs.

For these reasons and reflections of past success, I urge Congress to encourage the continued use of OTAs to allow commercial companies to create future partnerships and products that will enhance government capabilities, safety, and affordability.

Federal Regulations

Policies in Federal regulations must also be taken into account to continue the trend of innovation and growth from the commercial space sector. Congress has been very cognizant of the needs for these policies dating back to 1984 when the Commercial Space Launch Act authorized the Secretary of Transportation to license and promote commercial launch activities. Since its inception, the office's mandate was to promote the commercial space industry and ensure the safety of the uninvolved public. It has been years since its last full reauthorization and consequently, CSF believes that the regulatory processes to ensure a favorable and safe development of industry need to be revisited. I will talk about a few of those regulatory issues next.

Congress approved the Commercial Space Launch Amendments Act in 2004, instituting a human spaceflight regulatory "learning period" to allow for both industry and FAA AST to learn, quickly and jointly, how to best promote safety. The stated learning period gave the Federal Aviation Administration's Office of Commercial Space Transportation (AST) freedom to regulate with the stipulation that all regulations for the safety of passengers must be based on an event that led to serious injury or that had the potential of serious injury. In addition, commercial human spaceflight operators use an informed consent regime that requires them to inform spaceflight participants of the inherent risks of spaceflight and the specific safety record of the vehicle type for their flight. Participants are also informed that the government has not certified the vehicle as safe, and must sign a consent form before flight.

The initial learning period put in place was 8 years from the enactment of the CSLAA of 2004, expiring in December 2012. Congress expected that commercial operations would immediately follow the flights of SpaceShipOne, and this eight-year period would be filled with commercial launches that would help develop a knowledge base from which FAA could regulate intelligently. However, because of the due diligence of the companies in designing and building the safest possible vehicles, and their efforts to raise private investment, there were no commercial human spaceflights in that eight-year period. Recognizing the important purpose served by the learning period, in 2012 the FAA Modernization and Reform Act extended it to October 1, 2015 (the duration of the broader FAA reauthorization). The importance of the learning period is to create a regulatory regime based on data from actual flights, rather than speculative analysis based on other vehicles or technologies. Initial test flights of crewed suborbital vehicles began in 2013 and regular operational flights are expected in the next couple of years. Additional time and data are required to determine appropriate regulations for the industry and we ask that the original eight-year learning period be restored to allow for innovation to grow and for safety to improve in the long term.

The Commercial Space Launch Act separates space transportation service customers and their liability responsibilities. For example, customers who purchase a launch for their payload, or who sponsor the launch of a spaceflight participant, are required to be protected by the obligatory third-party damage insurance policy and are required to execute a mutual waiver of claims against all other parties. These customers are also indemnified from excess claims by the Federal Government. However, spaceflight participants are explicitly excluded from this regime.

The launch of a human spaceflight vehicle that carries only one participant could in fact be entirely funded by that person, and therefore the participant could be exposed to third-party claims. It is not logical for the law to put spaceflight participants at greater financial risk for partaking in human spaceflight activity, as many of them could be researchers, employees of the customer, or winners of a promotional contest and would not otherwise have substantial resources to pay excess claims should they arise. The spaceflight participant should be protected by insurance and, if needed, government risk-sharing from third party claims that may arise due to their flight. Moreover, the participants should be included in the mutual waiver of claims that protects all other parties in the launch from each other. For these reasons, CSF believes that the spaceflight participant should be included in all parts of the liability regime.

In 1988, Congress put in place a "risk sharing regime" to prepare for any damage caused to uninvolved third parties from FAA-licensed commercial space activities. This regime requires commercial space operators to take on stringent financial responsibilities by purchasing insurance or demonstrating available financial resources to cover any third-party damages up to the Maximum Probable Loss (MPL), calculated by the FAA pursuant to Federal regulation. In exchange, in the event of an extremely unlikely event of an accident that causes damage above the MPL, the Federal Government agreed to seek an expedited appropriation to cover damage above the insured amount. This "risk-sharing" regime has never been activated since its enactment in 1988. However, it is a necessity for U.S. launch companies to more effectively compete with foreign launch companies whose own governments provide even stronger protections. CSF strongly urges Congress to permanently extend the risk-sharing regime.

With the rapid growth in the number of state spaceports, which are owned and operated by state governments much like regional commercial airports, it is also important that the Commercial Space Launch Act be updated to extend the scope of property insurance coverage expressly to the property of State and local governments associated with licensed spaceports. This change would provide much needed clarity to the insurance coverage for state spaceports and encourage more investment in space launch infrastructure throughout the U.S.

Commercial launch operators are highly focused on developing concepts of operation that offer maximum operational flexibility to launch when needed, as well as to maximize affordability. In order to accomplish this, it is essential to avoid parallel coordination and approvals among multiple agencies wherever possible. In addition, there is a compelling need to streamline the regulatory process and utilize commercial practices to the greatest extent possible. Finally, commercial launch providers must have the opportunity to avoid the dictated use of mandatory range services, and be provided the opportunity to self-perform or subcontract to the most efficient provider that is able to meet the requirements. These attributes are what will ultimately draw commercial customers to establish launch operations at existing launch ranges.

Export Control Reform

We commend Congressional authorization to modernize the United States Munitions List (USML) and the Administration's prompt use of that authority. Placing items deemed 'dual-use' on the Commerce Control List (CCL) will allow them to be more appropriately regulated. Commercial communications satellites will especially benefit from being regulated under the Export Administration Regulations (EAR) due to their broad civilian applications. With this reform, the American commercial satellite industry will become more competitive in the international market, grow our Nation's space industrial base, and bring high-tech jobs back to the US. However, the devastating impact that ITAR restrictions had on the well-established commercial satellite industry over the past fifteen years is a demonstration of the damage that overly broad ITAR regulation could do to the commercial human spaceflight industry. As I stated previously, this industry, much like the satellite industry, has the potential to greatly contribute to our space industrial base, a major asset to our national security.

The U.S. is currently a leader in commercial spaceflight and to continue this leadership, we must take a look at adapting our export control environment with the evolution of commercial technologies. Companies that wish to operate their vehicles from allied countries are running into a major hurdle due to the "presumption of denial" policy for MTCR Category I items. The Missile Technology Export Committee, a Department of State agency that presides over the export of MTCR equities, has stated that their primary concern is ensuring appropriate safeguards are put in place to protect missile technology, regardless if an item is controlled on the ITAR or the EAR. Because of this position, we believe the MTCR "presumption of

denial" policy is an issue that must be addressed in addition to those pertaining to ECR ITAR revisions. The MTCR Guidelines state that their purpose is to limit the risk of non-proliferation of weapons of mass destruction (WMD) by controlling transfers that could make a contribution to delivery systems of those weapons. The Guidelines are "not designed to impede national space programs or international cooperation in such programs. . ." Since the MTCR has been established, space programs have expanded beyond the governmental domain into the commercial domain, and the regime is now currently impeding international collaboration for a strong global space economy. The difficulties incurred to offer U.S. commercial spaceflight services abroad, will birth foreign domestic competitors which could ultimately replace America's leadership in the commercial space sector and hurt U.S. national security interests.

For this reason, I urge Congress to encourage the Administration to perform continued regular reviews to reform USML categories and other proliferation measures to adapt to the quickly changing environment of commercial technology today in order to enhance both national security and the domestic economy.

Conclusion

When I took over as President of the CSF six months ago, I made it a priority to personally visit our member companies all over this great nation, from Midland to Mojave, to Seattle and the Florida Cape. I am energized and beyond enthused about what I have seen. The Commercial Space Industry is alive and well and the United States is leading the way. We are experiencing a level of private sector investment unlike anything we have seen in history, and its because these investors see that the expansion of the economic sphere into space is real and very close.

As you debate legislation this year, I would implore you to think of the commercial space industry as a valuable and tremendous partner that will continue to help the United States achieve its ever-more-ambitious missions in space, and codify the competitive policies that will maintain the domestic commercial space industry's global leadership for years to come.

I have three young children that constantly ask "when can we go to space?" I am very confident from working in this industry that the answer is, "very soon."

Senator CRUZ. Thank you very much.

And I am going to begin by deferring to Senator Nelson for the opening questions.

Senator NELSON. Thank you, Mr. Chairman.

And, Mr. Stallmer, my congratulations to your commercial spaceflight sector, because they are being very successful

Mr. STALLMER. Thank you very much, sir.

Senator NELSON. Indeed, now with the competition proceeding for the commercial crew, we are seeing a lot of innovation coming out, and it is going to be exciting, and this will all be coming more and more into the focus of the American public over the course of the next couple of years.

I wanted to ask you, how important do you think extending the ISS beyond its existing termination date in law, which is 2020, how important is that?

Mr. STALLMER. It is certainly an important step forward. It is our gem of a national laboratory. The amount of research that has taken place on the ISS is incomparable. I was talking to my colleague Mr. Elbon today of some of the things in his testimony. On the scientific and medical research that is being conducted up there, the practical applications here on Earth are just incalculable.

The other great aspect of the International Space Station, as it is today, is the partnership that it has with the commercial sector on the experiments that we are doing.

I was tremendously inspired recently by a trip out to the West Coast, a company called Made in Space, who, through several NASA programs, through the Flight Opportunities Program, was able to build and test 3D printers, first on the suborbital level and

then these 3D printers are up in space right now on the International Space Station.

And it came to a point where the astronauts on the International Space Station needed a five-eighths inch ratchet, didn't have it. And they were able to, on the ground from Ames, California, send up the image of this ratchet, and they were able to print it right there on the Space Station. Fantastic.

That is the kind of technology, that is the kind of innovation that we are seeing through these partnerships through the International Space Station, but the commercial-public partnerships. So I am very inspired by that.

Senator NELSON. Dr. Pace, how could we encourage our international partners to help us continue the Space Station beyond 2020?

Dr. PACE. Thank you.

I think, first of all, the U.S. has already taken the first really important step, which is to have itself propose to lead the effort to go to 2024 and to work with the other partners to make that possible. So I think it was very important for the U.S. to move first on that. We are, I think, the indispensable nation in that regard.

The second thing I think we can do is we can help our partners show how to improve utilization on the Station, in part by some of the innovative things that the commercial industry is able to do.

At my university last week, we had a workshop—when the Federal Government was closed by snow, our university was open—for a company called NanoRacks, which is putting small CubeSat-size payloads aboard the Space Station. And what was very interesting about it is there has been this creation of, as Mr. Stallmer put it, kind of an ecosystem around the reality of the government facility—stable, available. Then a whole bunch of other commercial people had been able to build around it, so that a small education establishment was able to go from signing a contract to deploying a small satellite in the space of less than 9 months. That is an absolutely amazing turnaround time, but it was made possible by the private-sector innovations working with a stable essentially government facility.

When the Antares vehicle was lost at Wallops, the company was able to work quickly to re-manifest virtually all of those payloads and is able to find ride-share opportunities for some other satellites.

So the innovation that has gone on with the private sector is aiding and supporting the conduct of research and utilization aboard the Station, which I believe, in turn, will help our partners see benefits from continuing to 2024.

I would also have to say that that continuation is not guaranteed. Our partners are under great pressure within Europe, Canada, Japan, and we all know the volatility in Russia. So it is by no means an assured thing; it is very fragile. And we need to be looking at what is going to come beyond Space Station in order to assure people that they can continue on Space Station today.

Senator NELSON. And, Mr. Elbon, you are right in the middle of it. We are counting on you to be one of those means of transportation for crew to get us up there. You have a proven workhorse

that launches a lot of cargo into orbit. And so are you very positive about this whole commercial sector maturing as we are going forth?

Mr. ELBON. I am.

I will put it in this light: Boeing is going through its 100th-year anniversary as a company. And during that, kind of, reflection of that 100 years, you can see the aviation industry grow from just a starting, beginning industry to the incredible industry that it is today. And I think commercial space is at that same pivot point now. The effort that is being done to have NASA serve as the foundational customer for that growth is similar to the way the government participated in airmail in the early days of aviation.

And so I think that, as we develop vehicles to meet those needs, that capability will grow as we go forward.

Senator CRUZ. Thank you very much.

I would now like to shift to asking each of you, what do you see right now as the greatest impediments to the continued development and expansion of our commercial crew and commercial cargo capacity?

Mr. ELBON. I would say that having the market develop is important. Commercial industries follow the market. So extending ISS, continuing the research on ISS, which by itself is a great thing independent of commercial crew, provides that kind of a foundation and a starting point going forward.

It is important that we maintain the industry in such a way that it is safe and reliable and don't let public opinion erode because we have accidents that could have been avoided, for example. So we need to keep it as a robust industry moving forward.

Things like the CSLA legislation that helped with the cost of insurance for launches are important, that we maintain that going forward.

We need to develop working relationships with regulatory agencies like the FAA, similar to the way we do that in commercial airplanes. It is a really good partnership today, and keeping that going, I think, is important.

So those are, kind of, things to stimulate the growth of the commercial sector, I believe.

Senator CRUZ. Dr. Pace?

Dr. PACE. Sir, two things: market demand and a predictable environment for investment.

Right now, that demand is predominantly driven by government. To the extent that we can see nongovernmental demand come for a lot of these activities, things beyond the Space Station, then it will be more sustainable.

But that begs the question of, what comes, really, after the Space Station? Although we are talking about extending to 2025, in aerospace terms, that it just right around the corner.

And I think one of the things that I worry about, which contributes both to the fragility of our political relations with other countries as well as the fragility in the commercial industry, is, if you are not planning today as to what you are going to be doing next, what you are really doing is planning to go out of business.

And so we need to have, I think, very thoughtful discussions and decisions very soon as to not only ISS extension but also, post-ISS, what does that look like, whether in LEO or beyond, because with-

out that, there won't really be that investment environment, nor will there be the international partner environment.

So that uncertainty, I think, is the greatest thing we could address.

Senator CRUZ. And, Mr. Stallmer, you mentioned in your testimony also some suggested reforms in reauthorization of the Commercial Space Launch Act. I would welcome your elaborating a bit on those reforms.

Mr. STALLMER. Certainly. Thank you, Senator.

I think regulatory uncertainty is a major barrier that the launch industry could face. With indemnification, it is critical for our global competitiveness. Right now, China, France, Japan all indemnify far more than the U.S. So that is critical right now.

Extending the learning period. The learning period currently is 8 years. If we want to foster this economy, this space economy that we have right now and the launch industry, we really need to extend that and continue to work together as partners, right now with the FAA. Because nothing is more paramount to the commercial companies than safety, to developing a safe product. If you don't have a safe product, you are not going to have a commercial product, a commercial business to that extent.

So the regulatory uncertainty is critical, but also the funding, knowing for Commercial Crew. Like yourself, I find it completely unacceptable that we have to depend on the Russians to launch U.S. astronauts to the International Space Station. So any sort of disruption in the Commercial Crew Program, I think, would be a tremendous setback.

I know how much it pained the NASA administrator to have to extend those flights on to 2018 for contingency purposes. But I think if we continue with the prudent budgetary measures through the Commercial Crew program, I think that is one of the best ways we can move forward, and especially with the Commercial Space Launch Act.

Senator CRUZ. You mentioned concerns about safety. And, obviously, there is an element of risk that is inherent in space exploration. The safest option would be never to go into space.

And so what is the right way for regulation to balance those safety concerns with the desire to continue expanding our capability and exploring new frontiers?

Mr. STALLMER. You have to test and learn. You have to test and learn. And we found that out the hard way this past October with an experimental test flight. But, as Americans, I think we are going to continue to push the envelope. This is what we want to do, and we have mentioned our westward expansion goals and the manifest destiny of the United States.

Safety will always be an issue. As my colleague, my predecessor once told me—you know, I went down to the Orion launch. He goes, you have to remember that 10,000 things can go wrong and only 1 thing can go right. And that is something you always have to keep in mind.

But it is the redundancy of safety, of testing, evaluating, learning from the testing that you are doing and the data that you collect to move forward. And I think the commercial spaceflight industry is doing that in spades.

Senator CRUZ. Let me ask the panel a different question. What is the shortest time-frame we can reasonably no longer be dependent on the Russian Soyuz and also the RD–180? And what would be required to accelerate that timeframe to the soonest date possible?

Mr. ELBON. So I will address that from the perspective of launching commercial crew.

We are on a path with CST–100 to be able to launch crew in 2017. That path is paced now by the internal work that we are doing with our suppliers, with our integration and test, going through the certification process that will allow us to certify that vehicle based on the lessons that we have learned on shuttle, on station, so that it is certified and ready to fly.

Our program at the moment is not being paced by dollars, so if the question was hinting at could we apply more money to go faster, at this point we need to apply the level of funding that we proposed in our contract, and we will be able to achieve that on the pace we are on.

Relative to the RD–180, there has been a lot of discussion about the RD–180 today. I would say this. The Atlas V is an incredibly dependable launch vehicle as a system. It has had 53 successful launches, and, in fact, that is the reason we selected it as our launch vehicle to get going.

It would seem that over time it would make sense to work to transition away from dependence on the Russians. I would hope that we don't do that in a very abrupt way that would cause us to impact our national security as a country and also our commercial launch industry. So I am hopeful that that is a thoughtful process and that we work through that in a way that addresses the geopolitical concerns that are out there but also the technical concerns of being able to keep launching that vehicle.

Senator CRUZ. So how would you define a thoughtful process? Because there is always the risk geopolitically——

Mr. ELBON. Right.

Senator CRUZ.—that particularly if things escalate with Mr. Putin, that he decides to use access to space as a weapon. And were he to cutoff access to either the Soyuz or the RD–180, that would impose significant hardships on the United States.

So how would you propose we deal with that potential threat?

Mr. ELBON. Well, certainly, we have an inventory of existing engines that are available to use. And there are more engines on order that are coming. And so, you know, keeping that pipeline open as long as is reasonable is good.

I don't have insight into exactly where it is going, but ULA has announced that they are working with another company, maybe other companies, for a replacement engine for the RD–180.

And so, you know, working through that in a way that doesn't just declare, "OK, that is enough, no more," but using the assets that we have and keeping those assets and that pipeline open as long as we can to facilitate a transition.

Senator CRUZ. Dr. Pace, Mr. Stallmer, do you have thoughts on these questions?

Dr. PACE. I think the question depends on when you think the immediate risks are.

If you thought there was a risk tomorrow or even today, then the answer is, you know, we have the inventory, you know, we have.

Beyond that inventory, your next bet is you have a very expensive option but a very doable option, which is manifesting on the Delta.

Looking beyond that, the answer ultimately, of course, is to have a U.S. source. And the proposals, I think, that have been put forward for building a replacement engine, a LOX/kerosene, LOX/methane engine, the numbers that I have heard have been on the order of, like, 3 to 4 years that it would take to do that. Perhaps that could be accelerated a little bit on money, but I think there probably are some parts that you can't accelerate, and you are talking 3 to 4 years.

So if you think that the crisis with Russia is not going to go away and is going to be with us for some time to come, then the answer, in my view, is to begin development of that engine and to do so now. If it turns out that everything works out great or we have other options come up, that is fine. But if we don't have that option, then we will find our negotiating leverage much reduced.

Mr. STALLMER. Senator, I would add that, as Mr. Elbon was saying, one of our companies, a company called Blue Origin, founded by Mr. Bezos, they are working right now on developing a new engine, I think, to help alleviate the RD–180 problem, the BE–4 engine.

I have been to that facility in Seattle. It is tremendously impressive what they are doing out there. As well as traveling to the SpaceX facility and what SpaceX is doing with their engine technology and as well as with the commercial crew vehicle.

I think they would like to be on line and get us off our Russian dependence as soon as possible, but, unfortunately, I think that date is no sooner than 2017.

Senator CRUZ. Well, thank you very much, gentlemen. I appreciate the testimony you have given. I appreciate your being here today. This was, I think, a very productive hearing.

I would note for each of you the question of regulatory uncertainty. It was a question I believe all three of you raised. That is a significant concern of mine. And in moving forward with reauthorization of the Commercial Space Launch Act, regulatory reform is going to be a component that we are going to look at.

And so I would welcome from each of the witnesses your specific ideas on reforms that would provide greater certainty, accelerate the development of either commercial crew or commercial cargo, and expand the commercial capacities we have.

I will also note that the hearing record will remain open for 2 weeks. During that time, Senators are asked to submit any questions for the record. And, upon receipt, the witnesses are requested to submit their written answers to the Committee as soon as possible.

And, with that, I want to thank each of you for being here, I want to thank our witnesses on the first panel, and the hearing is concluded.

[Whereupon, at 4 p.m., the hearing was adjourned.]

A P P E N D I X

Response to Written Questions Submitted by Hon. Tom Udall to Michael J. Massimino, Ph.D.

Question 1. Mr. Massimino, your testimony notes the importance for NASA of continuing to build and expand its international partnerships. You note that the International Space Station, for example, helps bring nations together around a common goal of scientific inquiry and space exploration. Yet today, the United States obviously has significant challenges when it comes to our overall relationship with Russia, a key partner for the International Space Station. What is the best way to ensure continued cooperation on space issues when our relationship with some international partners may make this more and more difficult?

Answer. If a common goal is shared by the U.S. and an international partner then the people working toward that goal will work together. Political differences can melt away when a common science or exploration goal is shared by two countries. I have seen this to be the case at the working levels at NASA where astronauts, cosmonauts, instructors, scientists, engineers, and program managers can work very effectively together. Stressing the science, engineering, and exploration goals that are shared can lead to a better working relationship not only in space, but I think in other areas as well because we get to know and understand each other better by working together.

Question 2. More generally, how can U.S. space policy help support our Nation's broader diplomacy goals?

Answer. Having a clear shared goal in space exploration, as the ISS program has shown for example, can give two countries something they can clearly agree on. It gets rid of distractions and lets us focus and work together. I think international space projects can be great building blocks upon which other agreements and common goals can be identified in areas outside of space exploration.

Question 3. Mr. Massimino, I would like to ask if you could respond to criticism from fellow astronaut Walter Cunningham about NASA's role in climate research. Mr. Cunningham's written testimony states that NASA compromises its scientific credibility by, quote: "participating in the politics surrounding one of the great scientific hoaxes in history." Do you share this view of NASA participating in a great scientific hoax?

Answer. No I do not. I think we don't have all the answers but I think it is an area worth looking into further. It is a large enough concern to many scientists who study our climate and to explorers who interact with it that it deserves attention. There may be differences of opinion and conflicting evidence, but there is enough of a concern and the outcome could be devastating. We owe it to future generations to take it seriously and determine what we can do to protect our planet for our children.

Question 4. Do you see value in having NASA continue to gather climate-related data from space-based observations of the Earth?

Answer. Yes I do. I think if we consider this to be an issue of national importance then I think any agency of our government with the ability to help should help. NASA has experts and assets that can help to better understand this problem, and determine the extent and reality of it as well as what can be done if action is warranted.

Response to Written Questions Submitted by Hon. Roy Blunt to John Elbon

Question 1. Former NASA Deputy Administrator Lori Garver has made multiple public statements that the Space Launch System is "wasteful and old technology," and that it and Orion should be cancelled. One of her quotes was, "Would you really go to Mars with technology that's 50 years old? That's not what innovation and our

space exploration should be all about." This statement is concerning coming from a former NASA deputy administrator. Can you comment on her statement? Are we spending tax dollars on outdated technology?

Answer. The referenced statements by former NASA Deputy Administrator Lori Garver are both misguided and inaccurate.

The claim that SLS and Orion technologies are outdated is a great misrepresentation. These systems are being developed to transport astronauts further into the solar system than ever before imagined. It is incomprehensible that the NASA and contractor teams, with a well-known reputation to ensure astronaut safety, would compromise this core value by not fielding the most technically advanced systems.

While these systems have ties and resemble heritage systems, the employed technologies are state of the art. Where applicable, heritage system designs are being updated with advanced design practices, materials, manufacturing processes, computer controls. These programs represent the cutting edge in human space transportation.

Question 2. Ms. Garver also said SLS and Orion are jobs programs in Congressional members' states and districts—specifically Texas, Florida, Colorado and Alabama. Can you discuss the number of companies and suppliers involved in SLS and Orion, and how many states play a role?

Answer. The SLS and Orion programs have more than 2,000 suppliers in 48 states. This supplier network was developed through competitive procurements and each supplier bringing unique technical capabilities at the component level. The attention to detail at this level in turn enables a highly reliable human space transportation capability.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. BILL NELSON TO JOHN ELBON

Question. Commercial human space travel is only just beginning to become a reality. Many of the issues faced by the commercial human spaceflight industry seem analogous to those faced by the early commercial aviation industry. Drawing on Boeing's nearly 100 years of experience in commercial aviation, what steps can the Federal Government take to help rapidly mature a safe and viable commercial human spaceflight industry?

Answer. Boeing has a long-standing relationship with the Federal Aviation Administration (FAA) for the regulation of aircraft safety regulations. This relationship has provided the necessary regulatory frame work to ensure the level of public safety is maintained to sustain the industry's viability. Given the human space transportation commercial services market is a fledgling market with a high profile and public awareness, ensuring passenger safety will be a critical factor governing market growth and success.

The current approach initially tasks NASA to establish and verify safety requirements for the initial commercial crew demonstration flights with a transition of these responsibilities to the FAA for the follow-on crew transport services. FAA regulation is essential to ensuring new commercial entrants to the market will be held to the same requirements and standards as those developed for the NASA missions.

There should be a joint NASA/FAA team established to ensure a seamless transition of knowledge between these two government agencies until a mutually agreeable regulatory structure is in place. It will be necessary to ensure NASA safety protocols are maintained and enforced during the transition of NASA sanctioned demonstration flights, and the following commercial services flights that FAA will be responsible to regulate.

The Commercial Space Launch Act currently delays the FAA's involvement beyond the initial NASA commercial transportation service missions. Delaying this regulatory window opens the door to individual company judgment regarding safety and unnecessarily jeopardizes this industry at the most critical juncture. FAA regulatory involvement will protect the fledgling commercial space transportation market which could be irreparably damaged by a single flight incident.

Continued involvement of the Federal Government is needed to ensure commercial human spaceflight will rapidly mature into a safe and viable industry. Government investments and contracts through NASA to develop human transportation capabilities have been solely responsible to drive the current progress to realize a commercial space transportation market.

The market for these human transportation services is currently limited to two flights per year to the International Space Station (ISS) through 2024. This relatively short window of opportunity appears insufficient to establish additional market opportunities to sustain such capabilities after the retirement of the ISS. It is

envisioned that after the initial human transportation capability becomes operational, additional commercial investment for in-space capabilities will significantly increase. Bigelow Aerospace, for example, has been developing in-space habitation modules, but has paced their investment/development on the availability of commercial transportation services. An extension of the ISS operations through at least 2028 would provide a larger window of opportunity to sustain these fledgling capabilities and allow commercial ventures to mature to the point where they could sustain a commercial transportation capability post ISS.

There are also yet to be identified opportunities for commercial crew and cargo transportation services to support NASA's deep space human exploration efforts. It would be in the best interest of the government to fund studies to develop a detailed deep space exploration roadmap. This road map could be used to identify potential opportunities for commercial services in support of the baseline SLS/Orion missions. These market opportunities are contingent upon the completion of the SLS and Orion system developments and an operational flight rate of at least one flight per year.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. TOM UDALL TO JOHN ELBON

Question 1. Mr. Elbon, I am keenly interested in ways that Congress can encourage smarter Federal procurement policies. Last year, I partnered with Sen. Moran to help pass the Federal I.T. Acquisition Reform Act ("FITARA," PL 113–291), which could lead to billions of dollars in taxpayer savings through greater use of "agile" or incremental approaches to procurement. Do you agree with Mr. Stallmer that NASA should have the ability to choose from different "tools" in its procurement "toolkit," such as using Other Transaction Authority where appropriate?

Answer. Yes, we believe NASA should have flexibility to select a procurement approach which aligns with the specific resources and needs for each procurement. However, there are advantages to a FAR-based contracting approach for large scale development programs which ensure proper insight and oversight of how government funds are spent. The FAR-based procurement also allows the government to impose requirements to ensure the delivered products meet the intended purposes. For this reason we believe that OTA's be limited to procurements for $50 million dollars or less.

Question 2. Would you like to share any additional thoughts on potential improvements to NASA procurement policies?

Answer. We have been investigating hybrid type contracts as a means to reduce overall costs while ensuring risk exposure is not sacrificed. This would allow contractors to perform low-risk work at minimal margins or on a fixed price basis, and the higher risk elements at higher margins or traditional cost plus contracting. Through this type of contracting, we believe we could offer the U.S. taxpayer savings while not exposing the programs to undue risk exposure.

A specific risk we currently face in the commercial crew contract is ensuring our designs and procedures meet NASA requirements under a fixed price contract environment. The aerospace culture is founded in cost plus contracting, where requirements were allowed to remain fluid with the associated risk covered through the contracting arrangement. Both Boeing and NASA are working to ensure requirements are managed in a manner which will allow development expediency without sacrificing safety.

Question 3. Mr. Elbon, your testimony highlights some of the science coming from the International Space Station, particularly related to medical research. Could you share your thoughts on some notable technology transfer and commercialization successes that came from our Nation's space program?

Answer. NASA has a long history of technology spinoffs and has a dedicated website of the many successes. An example of a well-known technology transfer/commercialization is cordless power tools. These were developed by NASA for the astronauts to construct the International Space Station, and have since become part of our everyday life. Other significant contributions to our medical industry include Magnetic Resonance Imaging (MRI), and ultra-precise human-robotic brain surgery. The International Space Station allows researchers to analyze medical specimen reactions to the microgravity environment, which provides unique insight of viruses and vaccines. For instance, when the Duchene's Muscular Dystrophy crystal was analyzed in microgravity, the fundamental structure became much more organized and led researchers to discover a previously undetected water molecule in the structure. This observation led researchers to develop an inhibitor, something that was not possible without the ISS. With the ISS as a National Laboratory, space is now

delivering intentional science and technology returns along with the traditional unintentional spinoff returns that have drawn much of the attention.

An often overlooked technology transfer from the space program is the human inspiration and talent generation created by our space endeavors. At Boeing we are constantly reminded by our new hires of their strong desire to work on the space exploration programs and how NASA inspired them to undertake a curriculum in Science, Technology, Engineering and Math (STEM). Another observation within Boeing is the number of leaders within the corporation which originated from the space exploration programs. We believe the great challenges associated with these programs inspire these people to push themselves to new heights.

In general the NASA mission continues to push the limits of capabilities and technologies to meet the ever increasing mission challenges. These challenges are the driving force to challenge our best and brightest to create new and unique solutions, and will continue to be a solid return on investment—both scientifically and also by opening up new commercial markets.

Question 4. What are the best technology transfer lessons from NASA that we could apply to other Federal agencies?

Answer. Perhaps not a lesson learned, but the ISS offers an opportunity to other Federal agencies to leverage the significant U.S. investment in the ISS National Laboratory. NASA has established Memorandums of Understanding to conduct microgravity research on the ISS with both the National Institute of Health and the Department of Agriculture. Initial discussions were held to identify potential scientific research of interest, but both agencies are without specific funding to undertake such research given the current workload and no additional funding for such research. This research would be possible if a small percentage of these budgets were directed to ISS research projects. This research represents potentially game changing technologies/capabilities, but there is a limited window of opportunity to conduct such research before the ISS is retired.

Question 5. Mr. Elbon, your testimony notes that the International Space Station is a model for international space cooperation. This helped bridge the diplomatic divide with Russia after the collapse of the Soviet Union. You also note that an American astronaut and Russian cosmonaut will fly to the space station next month. This joint mission will take place despite the obvious challenges when it comes to our overall relationship with Russia. What is the best way to ensure continued cooperation on space issues when our overall relationship with some international partners may make this increasingly difficult?

Answer. The best way to ensure continued cooperation on space issues is to engage their participation in a deep space exploration program based on the fundamental elements of the International Space Station, Space Launch System and Orion capsule. The relationships and working arrangements developed through the International Space Station Program have endured Administrations, sessions of Congress, and the up and downs of international relationships. These should be leveraged, adapted, and re-energized in support of a deep space exploration mission with a goal of sending humans to the Martian surface. This undertaking is beyond the financial capability of a single entity, but is realistic within a construct of the International Space Station agreements and arrangements. The U.S. has been the leader in space exploration, and the rest of the space faring nations look to the U.S. for direction and leadership.

Question 6. How can U.S. space policy continue to help support our Nation's broader diplomacy goals?

Answer. A significant lesson learned through the International Space Station program is the joint space mission has always transcended the international relationship status. At times the joint space activities have been the guiding principal to resolve diplomatic differences. It appears, with the high profile status of the space program and the prestige of participation, each country involved is unwilling or unable to take action which might damage one or both. With the ISS retirement currently scheduled for 2024, now is the time to engage this team on an even more challenging and inspiring mission with a goal to expand this community.

Question 7. Mr. Elbon, the Obama Administration is in the process of reforming our Nation's export control system. Your testimony discusses how smart reforms can not only improve national security, but also increase American exports and job growth. Could you discuss how to strike the right balance to ensure that we protect our national security while not inappropriately stifling the development of the U.S. space industry?

Answer. Since technology is advancing at great velocity, our classification of these technologies may, understandably, be behind. It's prudent for industry and government to partner in a re-examination of our domestic space products. The goal of the

re-examination is to ensure we aren't bundling domestic civil space technologies suitable for export with technologies we must protect for our national defense.

If we can segregate sensitive and non-sensitive technologies with more fidelity and precision, we can expand our ability to export additional space technologies without compromising our vital defense capabilities. This would not only provide additional jobs and economic benefits, but also increase the domestic space industry base, which will ultimately enhance our Nation's civil and defense-related space capabilities.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO DR. SCOTT PACE

Question 1. The 1967 Outer Space Treaty requires that the United States "authorize and supervise" the operations of U.S. companies on celestial bodies. Commercial companies are now considering activities on the Moon and other celestial bodies, such as asteroids. What level of government oversight is appropriate for regulating the operations of U.S. companies on celestial bodies and what agency would you suggest is best suited to perform that oversight?

Answer. In my view, the United States needs to create a stable, predictable and transparent domestic licensing process for new in-space operations in order to create a supportive investment environment and to fulfill U.S. obligations under existing international law. The United States has done so in the past in areas such as communications satellites, space launch, and remote sensing. While it is undesirable to create law and regulation for purely hypothetical activities, the rapid rate of change in private sector space activities makes it important that the law not lag far behind market realities.

Among the activities that should be addressed are in-orbit servicing, privately owned space facilities (manned and unmanned) in orbit or on the Moon and other celestial bodies, and the utilization and extraction of in-space resources for commercial purposes. There are numerous legal questions to be addressed in developing appropriate regulations. For example, if resources are intended for return from space, would the FAA require a payload review before launch (regardless of whether the launch was a U.S. vehicle or the U.S. was a launching state) since the return is now under their jurisdiction? What if the return is by parachute or means other than a "vehicle." Do we need a new or clearer definition of vehicle? Further, if a satellite that is licensed by another agency is to be deorbited (*e.g.,* a NOAA licensed remote sensing satellite) under rules established in law by NOAA/DOC, would that be a "payload" that is covered under FAA regulations per the Commercial Space Launch Act (CSLA)?

I believe it is premature to extend DOT/FAA's current jurisdiction into space activities that are not clearly related to transportation and transport vehicles. Instead, I would suggest a multi-step process:

1. Commission a study to provide appropriate recommendations for alternative assignments of regulatory responsibility to Federal departments and agencies, to include DOT/FAA as one option.
2. If there is a congressional finding that it is appropriate and within the authority Congress given to a particular department or agency, then regulations could be developed through the normal Administrative Procedures Act (APA).
3. If new authorities were needed either for a new private sector U.S. activity or for the regulation of that activity by a particular department or agency, then congressional legislation would be developed. After passage of legislation, the normal APA process would be used.
4. Formal rule adopted by the designated department or agency (*e.g.,* DOT/FAA, Commerce, or State).

Question 2. How would you suggest that the United States address its treaty obligations when regulating or establishing property rights for companies seeking to extract natural resources from celestial bodies?

Answer. Under international law (*i.e.,* the 1967 Outer Space Treaty) the United States is responsible for providing on-going supervision and authorization for the space activities of persons subject to U.S. jurisdiction or control (*e.g.,* U.S. companies). However, the United States lacks a defined licensing regime for in-space operations (*e.g.,* satellite servicing, private space platforms, resource extraction, etc.). This potentially leaves the United States vulnerable to foreign charges that the U.S. is not fulfilling its obligations with respect to emerging private commercial activities

and could encourage arguments for creating a binding international treaty that might try to constrain U.S. space activities.

The United States, as a launching state or state of registry, can be held internationally liable for third party damage for activities in outer space if found to be at fault in its activities. Presently, the United States has not imposed any insurance requirement on commercial companies involved in these in-orbit activities. Some companies do carry that type of insurance.

It would be helpful for the Congress to briefly and clearly recognize that the United States will meet its commitments under international law, but through appropriate national law and regulation of private space activities. It would not be necessary to define specific regulations as that would need to be the subject of separate hearings, legislation, and rule-making. Possible text:

> *"The United States will continue to meet its commitments under existing international law for the authorization and continuing supervision of all private sector space activities under its control or jurisdiction, including in-space operations, through appropriate domestic law and regulation."*

There are many different types and characteristics of property rights that could apply to the utilization and extraction of in-space resources. Some property rights (*e.g.,* claiming ownership in fee simple of in-situ resources) are likely incompatible with U.S. commitments under the Outer Space Treaty (*i.e.,* the rejection of claims of sovereignty) while "functional" property rights (*e.g.,* use of geostationary orbital slots) are consistent with U.S. treaty commitments. The most important consideration for supporting commercial development of space resources is that there be a stable and predictable long-term investment environment, subject to the rule of law. In this regard, international acceptance and recognition is crucial. A system of limited property rights in space, recognized by some if not necessarily all spacefaring states, can and should be developed through U.S. international leadership. A first step could be an internal U.S. process for accepting claims to space resources without prejudice to the final international recognition of those claims. A claims registry, open to U.S. and foreign non-governmental entities, could be authorized by the Congress and initially housed at an existing department or agency (*e.g.,* the Department of State). Such a registry should require evidence of actual activities in space or on a celestial body to support a claim.

Lastly, there continues to be a misunderstanding, domestically and internationally, that space is a global commons for purposes of international law. Some legal experts argue that the use of the term "common heritage of all mankind" in the Outer Space Treaty means that the United States accepts space as a global commons; with its space activities subject to international input and possible constraint. This is not accepted by the United States, as can be confirmed by the State Department's Office of the Legal Advisor. Today, the high seas and the air above the high seas may be considered a global commons, with certain exceptions, but not Antarctica (which is governed by a separate treaty), "cyberspace" or outer space. With regard to areas like space that lie beyond the traditional bounds of national sovereignty, international law does not preclude States from creating agreements to address specific issues of mutual interest (*e.g.,* resource utilization). Thus the use of the term "global commons" with respect to space creates misleading expectations. It would be helpful for the Congress to clarify this point. Possible text:

> *"The United States does not currently recognize outer space as "global commons" for purposes of international law."*

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO ERIC W. STALLMER

Question 1. The health of the commercial space industry depends on incentives to invest in space operations, both in low-Earth orbit and possibly beyond. Similarly, Federal agencies must consider the impact on investment planning of rules, regulations, and procedures. The Administration has proposed continuing International Space Station (ISS) operations through at least 2024. Current law permits extension through at least 2020. How would extending ISS beyond 2020 impact investment decisions within the commercial space industry?

Answer. As a general rule, bringing more certainty and uniformity to U.S. government space policy is a big positive for incentivizing greater investment in the commercial space industry. For example, the extensions of the ISS to 2024 is the current Administration's policy, but is not codified into law. With a new administration to be elected next year, if the extension is not codified into law, then the new administration could reverse the current policy; this creates unnecessary ambiguity and

doubt that could slow or reverse recent ISS investments. By codifying the extension, Congress would send a signal investors, and potential investors, that regardless of the election results, they continue to plan their investments through at least 2024.

With that said, codifying the extension of the ISS to 2024 is only one of the factors that investors will weigh when deciding whether or not to invest in the commercial space industry. If investors are going to invest in an orbital laboratory, rather than a terrestrial one, then they will want to know that there will be a continuity in orbital facilities—meaning no space station gap. So in concert with codifying an extension of the ISS to 2024, NASA, Congress, and the White House need to begin working with the private sector to ensure that a new facility is developed in time to avoid a space station gap in LEO. NASA's Advanced Exploration Systems ("AES") program has been entering into partnerships with the private sector to support new technologies such as next-generation habitats that will allow the U.S. to maintain a presence in LEO past ISS retirement. Congress should address this in their next NASA Authorization.

Finally, in addition to codifying policy uniformity and orbital facility continuity, Congress should increase support for programs that drive demand for ISS research experiments and technology development, like NASA's Flight Opportunities Program. The expense of the flights and the long lead-time required for orbital launches can present a big barrier to the maturation of new technologies, a barrier known as "The Valley of Death", where most new technologies end up on a shelf due to lack of available funding. The Flight Opportunities program provides a cheaper and more efficient path through the "Valley" by increasing timely access to affordable commercial available microgravity and high-altitude atmospheric environments. Many researchers see commercially available microgravity and high-altitude platforms as a stepping-stone to using the ISS, increasing its utilization and raising its commercial success. For example, Made In Space, a company based out of Silicon Valley, used Flight Opportunities to test its 3D printers operation in microgravity for a fraction of the price of an orbital mission. After testing and building confidence on commercial reusable platforms, the company sent one of its printers to the ISS where it is currently operating.

Question 2. How have restrictions on property rights to data and inventions developed on the ISS affected the attractiveness of the ISS as a commercial research platform? What, if any, amendments to the policies governing property rights on ISS would you suggest?

Answer. I agree with NASA's OIG September 2014 ISS report, which found that the current "Patent License and Data Rights Obligations" provision was deterring commercial stakeholders from conducting research on the ISS. Congress, NASA, and the commercial space industry should work together closely to expeditiously fix this issue and revise the current law.

Question 3. The 1967 Outer Space Treaty requires that the United States "authorize and supervise" the operations of U.S. companies on celestial bodies. How would you suggest that the United States address its treaty obligations when regulating or establishing property rights for companies seeking to extract natural resources from celestial bodies?

Answer. Through a "mission review". Below is our proposed language for a mission review:

- (1) Independent of or in conjunction with a payload review, the appropriate agency or agencies shall conduct and grant a mission review of the planned activities related to the payload to affirm that all planned activities are in compliance with United States' obligations under the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.
- (2) The President shall, as needed, identify the appropriate agency or agencies to conduct mission reviews of the planned payload activities as specified above. Such agency or agencies shall be authorized to require updates to the mission review if there is a material change in the planned payload activities.
- (3) The appropriate agency or agencies shall not review planned payload activities that are otherwise subject to regulation by other Federal agencies.

Question 4. Commercial space launch providers face a patchwork of regulations and regulatory oversight when obtaining launch site permits and launch licenses. What challenges do commercial launch providers operating on Federal property face? How do these challenges differ from those faced when launching from non-Federal sites?

Answer. I won't get into the weeds about the challenges, but I will outline the attributes that characterize a commercially friendly and operationally flexible

launch range. (1) Regulatory Confidence that enables a consistent and efficient regulatory environment; (2) Operational Efficiency which enables autonomous safety systems that reduce turn times between launches and minimize the range assets required to support a mission; (3) Schedule Assurance which minimizes schedule impacts caused by other launch operators, unanticipated site downtime, and range infrastructure outages associated with mandatory use of Federal range assets and; (4) Investment Confidence through streamlined real estate processes that allow for long term, exclusive use of real property, cost transparency which provides the ability to plan/budget/dispute charges for services, and the ability to operate in commercial enterprise zones or other tax advantaged areas.

Question 5. NASA is formulating a mission to capture an asteroid—or a boulder on an asteroid—and place it in a stable orbit near the Moon. This undertaking, along with follow-on missions to study the asteroid or boulder, would demonstrate many of the technologies needed for a crewed journey to Mars. How could commercial space companies take advantage of an asteroid or boulder that has been placed in a stable orbit near the Moon?

Answer. Responding more specifically, having an asteroid or boulder parked relatively close to the Earth, in cis-lunar space, could provide companies like Planetary Resources a testbed to mature technologies and operations necessary for future deep space resource utilization missions.

More generally, commercial space companies can help enable NASA to undertake future beyond LEO missions, like studying an asteroid or boulder that has been placed in a stable orbit near the Moon. For example, NASA has invested billions of dollars for vital next-generation deep space exploration transportation systems such as SLS and Orion; however, as the NASA Inspector General recently pointed out in its 2014 Report on NASA's Top Management and Performance Challenges, work must begin immediately on habitats, landers, and other systems or NASA will "face significant challenges concerning the long-term sustainability of its human exploration program." The best, and potentially only fiscally viable option to ensure that these new systems are developed in parallel with SLS and Orion is to leverage private sector investment. NASA's AES program recognizes that private sector partnerships create opportunities for utilizing the SLS and Orion transportation system to achieve our human exploration goals.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. TOM UDALL TO ERIC W. STALLMER

Question 1. Mr. Stallmer, your testimony makes a strong case for updating the Commercial Space Launch Act (CSLA). I would like to ask a few basic questions about CSLA for the benefit of the hearing record. As you know, the CSLA's indemnification protection will expire if Congress does not act to either update or extend it. What impact would that have on the U.S. commercial space industry?

Answer. Other nations presently indemnify their launch customers against any damages, usually at no cost to the launch company. If the U.S. government does not provide indemnification, industry will have to try and buy more insurance, and insurance costs may go up because the insurance company does not have the government as a backstop. The bottom line is the U.S. launch prices will become less competitive in the international market, and American jobs and prosperity will suffer.

Question 2. How would this affect the cost of launches for U.S.-based companies?

Answer. Cost likely rise for the reasons outlined above.

Question 3. Would this make U.S.-based launches less competitive than foreign launches?

Answer. Without Federal indemnification it makes it harder for U.S. commercial space launch companies to effectively compete with the Chinese, French, and Russian launch companies due to their strong domestic indemnification regimes which are much stronger than that of the United States.

Question 4. Mr. Stallmer, New Mexico plans to be a leader in suborbital space launch. Commercial spaceflights such as those from Spaceport America could dramatically expand access to space for researchers and help develop new technologies. Could you expand on the comments in your testimony on the role for suborbital spaceflights in our Nation's overall space program? How could NASA better support suborbital spaceflight through initiatives such as the Flight Opportunities Program?

Answer. CSF has long promoted the many benefits that accrue from NASA's Flight Opportunities Program. It enables access to suborbital and high-altitude atmospheric research platforms critical to the workforce development of our next gen-

eration of space scientists and engineers—our future Alan Sterns. It enables access to relevant environment testing to mature compelling space technologies and research at a small fraction of the costs required for orbital flights—keeping promising technologies from being shelved. Further, many researchers see access to these platforms as a stepping-stone to using the ISS; resulting in an increase in commercial usage of LEO, as well as maturing technologies needed for future human missions beyond LEO.

NASA could better support suborbital spaceflight by increasing the Flight Opportunities program from a $15 million program to a $30 million a year program. NASA should expand the Flight Opportunities program to enable agency wide and government wide access. For example, NASA's Science Mission Directorate could fly technology maturation flights to reduce programmatic risks to future science missions. In addition, NASA's Science Mission Directorate could more effectively develop and train their scientific workforce by flying research missions through the Flight Opportunities program, as highlighted by the National Academy of Sciences. "Small-scale experiments in suborbital research often serve as precursors to larger orbital missions and are important for training scientists and engineers to work on larger missions and for supporting the research base."—National Academy of Sciences, Revitalizing NASA's Suborbital Program, 2010.

Question 5. Mr. Stallmer, your written testimony notes that NASA can get better value for its procurement dollars through continued use of "Other Transaction Authority" rather than the traditional Federal Acquisition Rules (FAR). I am keenly interested in ways that Congress can encourage smarter Federal procurement policies. Last year, I partnered with Sen. Moran to help pass the Federal I.T. Acquisition Reform Act ("FITARA," PL 113–291), which could lead to billions of dollars in taxpayer savings through greater use of "agile" or incremental approaches to procurement. Could you expand on how the Commercial Spaceflight Federation thinks NASA can appropriately use Other Transaction Authority to get better procurement outcomes?

Answer. If the private sector can competitively provide a service that NASA is looking to acquire, then NASA should use OTAs to do so. For example, NASA should utilize OTAs to help acquire capabilities required for beyond LEO missions. Private companies like Moon Express, Bigelow Aerospace, Masten Space Systems, and Golden Spike are all building capabilities to explore and commercially develop the Moon. These companies, and others, are interested in the Moon because it offers the potential to support near-term opportunities for economic growth. To NASA's credit, it has begun exploring public-private partnerships for beyond LEO exploration via the Advanced Exploration Systems (AES) program, but this should be expanded. Hardware developed by AES will serve a critical role in ensuring that NASA can utilize the transportation capacities of SLS and Orion to conduct surface missions to the Moon and eventually Mars. Including the commercial space industry as an early partner in reaching U.S. human exploration goals beyond LEO is a logical extensions of the successful COTS and CRS partnership model proven in LEO, and can help alleviate budgetary constraints and compliment the Agency's investment in its transportation systems.

Question 6. NASA's commercial space program has a successful track record of providing launch services using fixed-price development agreements and contracts. How can NASA continue to encourage greater competition and thus lower costs for launch services without compromising safety?

Answer. To this point, NASA appears to be doing all the right things. I would only briefly highlight one possible concern. NASA and Congress should avoid prematurely selecting launch vehicles for future missions, unless that vehicle is the only one capable of meeting the mission's requirements. There should be competition for NASA science mission launches amongst U.S. commercial launch providers to ensure the best deal for the American taxpayer. Further, NASA owned launch vehicles should be fully reimbursed by the appropriate mission directorate for their launch cost.

Question 7. Mr. Stallmer, the Obama Administration is in the process of reforming our Nation's export control system. Your testimony discusses how smart reforms can not only improve national security, but also increase American exports and job growth. Could you expand further on how to strike the right balance to ensure that we protect our national security while not inappropriately stifling the development of the commercial space industry?

Answer. As noted by the COMSTAC, a cornerstone of the Department of Defense's general concern regarding the transition of spacecraft to the EAR is the potential inability of the national security community to track and grant approvals for EAR-controlled spacecraft. The adoption of orbital and suborbital human spaceflight sys-

tems' Export Control Classification Numbers will require the Department of Commerce to issue export licenses for all destinations. Further, piloted, unarmed, commercial suborbital spacecraft with thrust levels less than that of a SCUD A missile should be transferred to the CCL if such spacecraft have received a license or permit from the Office of Commercial Space Transportation.

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