

**REOPENING THE AMERICAN FRONTIER: REDUCING
REGULATORY BARRIERS AND EXPANDING
AMERICAN FREE ENTERPRISE IN SPACE**

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE, SCIENCE,
AND COMPETITIVENESS

OF THE

COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED FIFTEENTH CONGRESS

FIRST SESSION

APRIL 26, 2017

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ONE HUNDRED FIFTEENTH CONGRESS

FIRST SESSION

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WEDNESDAY, APRIL 26, 2017

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

The Subcommittee met, pursuant to notice, at 10:05 a.m. in room SR-253, Russell Senate Office Building, Hon. Ted Cruz, Chairman of the Subcommittee, presiding.

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

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

The CHAIRMAN. This hearing will come to order. Good morning.

In 1890, the Superintendent of the Census declared the end to the American frontier by stating, “Up to and including 1880, the country had a frontier of settlement, but at present, the unsettled area has been so broken into isolated bodies of settlement that there can hardly be said to be a frontier line. In the discussion of its extent, its westward movement, et cetera, it cannot, therefore, any longer have a place in the census reports.”

The American vision of westward expansion that had been initiated 86 years earlier through the Lewis & Clark Expedition had been successful in leading to the expansion of American commerce and settlement in a new territory that had not previously been chartered by American pioneers.

Today, this committee embarks on a series of hearings looking at reopening the American frontier with our sights set on the heavens, which President Kennedy referred to as the New Frontier. It is only fitting that the Nation born on the last frontier should continue to lead the way in the new frontier.

America must expand commerce and, ultimately, settlement into space, and we must do it first. This is an issue that not only impacts our global competitiveness, but also our national security. The world is much safer with America as the global leader on this planet, and the world will similarly be safer and stronger if the United States and our ideals of free enterprise and free speech are the driving force of commerce and settlement throughout the galaxy.

For nearly 60 years, NASA has granted the United States access to space and has made human spaceflight a reality. In recent years, commercial space companies have made enormous strides in technological advancements and the scope of their business activities that are leading to a new and dynamic renaissance in spaceflight. This is creating the real possibility that in the not too distant future, American private citizens will be able to reach space, hopefully, from a launch pad or a runway in the great state of Texas.

However, to ensure that this remains within the realm of the possible, Congress needs to continue to work to ensure that investment and innovation within the commercial space sector isn't chilled by obsolete regulations or overly burdensome requirements that may not naturally apply to new business models.

As we look to the future of American free enterprise and settlement in space, we should also thoroughly review the United Nations Outer Space Treaty, which was written and enacted in a very different time and era in 1967. It's important that Congress evaluate how that Treaty, enacted 50 years ago, will impact new and innovative activity within space as well as potential settlement throughout the galaxy.

Finally, we would be remiss if this committee did not also explore ways that the commercial space sector, academia, and NASA can look to build upon current partnerships and create new ones that can advance human spaceflight, research, and discovery. As we embark together on this series of hearings and potential legislation, I look forward to continuing to work in the same strong bipartisan manner that this subcommittee has always worked, working with Chairman Thune, with Ranking Member Nelson, with our Subcommittee's previous Ranking Member, Senator Peters, and, also, I want to welcome the new Ranking Member of this Subcommittee, Senator Markey. Welcome to this Subcommittee.

I will say at a time of significant partisan division on a great many issues, this subcommittee has been remarkable, under a Democratic Senate and Republican Senate, for being able to produce bipartisan legislation. We have produced not one, but two bills in the last couple of years, the Commercial Space Launch Competitiveness Act, which was signed into law by President Obama, and the NASA authorization legislation, which was signed into law by President Trump. In both instances, this committee was able to work together across party lines to achieve consensus and to move the ball forward.

I look forward to our working together to continue to do so and to continue working on new legislation to nurture, to create, and to expand a vibrant commercial space sector and a strong NASA so that America continues to lead the world in space exploration.

And with that, I'll recognize Ranking Member Nelson for an opening statement.

Senator NELSON. Well, thank you, Mr. Chairman, but I want to defer to the Ranking Member of the Subcommittee, and then I'll make some appropriate comments.

**STATEMENT OF HON. EDWARD MARKEY,
U.S. SENATOR FROM MASSACHUSETTS**

Senator MARKEY. Thank you, Mr. Chairman, very much, and I am thrilled here today as I launch into my new role as the Ranking Member on this very important subcommittee.

Investment in science and space has helped drive the American economy since World War II. It has unleashed American innovators and entrepreneurs to develop new technologies that have changed the world, and it has helped us understand the changes in the world caused by human activities that alter the environment and the climate. This subcommittee has an important role to play in ensuring that science and space activities continue to help America thrive.

Today's hearing title invokes the frontier. Next month, we'll celebrate the centennial of John F. Kennedy's birth. Science and space were an integral part of the new frontier that he saw in 1960. His challenge to land a man on the Moon opened up a new era, one in which humans travel and live beyond the Earth.

Now, there are few arenas of modern life in which space does not play a role. From satellite navigation to telecommunications to monitoring storms, we rely upon space. But in the next few years, there will be even more activity in space than we have ever seen in our history. In less than a lifetime, we have gone from one man circling the globe to contemplating settlement on Mars. Now, as space exploration and activities evolve, it is vital that we use the lessons of our past to guide us as we navigate this expanding territory.

Prior to major settlement of the American West in the 19th century, Congress funded a number of scientific expeditions to explore and understand the western territories. This government investment helped identify productive agricultural land and initiated a transportation revolution with the transcontinental railroads that allowed individuals and companies to succeed in the space age.

Government investment in science has gotten us to the Moon and has put a Rover on Mars, a satellite orbiting Saturn, and has gazed into the depths of the universe. The Cassini spacecraft just began its grand finale this week and is in the first of its orbits around Saturn right now. The James Webb Space Telescope is set to be launched next year.

Government investment in science has led the way for the private investment that is now flowing into space activities. Congress has a critical role to play to ensure that public and private investment is driving innovation and responsible development in space. And even as private companies expand their space activities, there is still an important role for public investment.

Today, the International Space Station serves as a national laboratory, which has dedicated space for science experiments from universities, Federal scientists, and small private research firms that could not otherwise be attempted. These experiments are varied and diverse and have the potential to solve some of the biggest problems humanity struggles with today, including improving the quality and quantity of our global food supply, finding new cures for cancer, understanding antibiotic resistance, and so much more.

We all stand to gain from supporting basic science research in space. We must also remember that space exploration and development is a global endeavor. It requires international cooperation and global standards, even as the space industry becomes more competitive.

So I look forward to hearing from our witnesses today on our growing American commercial space enterprise so that all of our country can begin to understand this incredible future that is about to unfold.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Markey. I would note that as we launch or relaunch a focus on the new frontier, it is altogether fitting that our new Ranking Member would evoke memories of President John F. Kennedy with that unique Boston brogue returning to this subcommittee.

Senator MARKEY. I will say this about my accent. It is not a Kennedy accent. That is a distinct and separate way of using the English language one family had that one privileged use of.

[Laughter.]

The CHAIRMAN. Well, and, thankfully, in my home state of Texas, none of us have accents in any way, shape, or form.

[Laughter.]

The CHAIRMAN. And with that, Senator Nelson.

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

Senator NELSON. Thank you, Mr. Chairman, and, indeed, it's fitting that the new Ranking Member of the Subcommittee is from Massachusetts, because it was the vision and the leadership of President Kennedy that picked a goal, and that goal was rather striking, that we were going to the Moon and back within a period of 9 years. The Nation marshaled the resources and met that goal. As a result of that "can-do spirit" of NASA and as a result of all of the spinoffs that came out of that technological revolution, particularly the microminiaturization, going to the Moon has dramatically improved the quality of our lives here on Earth.

I am looking forward to that happening again now that we passed the NASA authorization bill. The bill sets as its goal, going to Mars in the decade of the 2030s, and it builds on past NASA authorization bills. You talk about bipartisanship, that's exactly what happened with your predecessor, Senator Kay Bailey Hutchison, and this Senator in putting together the bill that set NASA off on the course that you see on the manned program. It's a dual course of the commercial as well as NASA and then getting out of low Earth orbit and going to explore the heavens.

I might say as a personal comment, Mr. Chairman, to your fitting remarks starting off about the frontier, that that frontier was always westward. That frontier is now upward, and it's inward, and as a part of that frontier, even though the official that you quoted in 1890 said the frontier had been achieved, that Homestead Act was still used for several years thereafter, and so it was with my grandparents.

In 1913, if you worked the land for four continuous years and could prove it, the Government would deed you 160 acres of land.

I have a copy of the deed signed by Woodrow Wilson in 1917. That 160 acres of land today is at the north end of the space shuttle runway at the Kennedy Space Center. So, needless to say, it was not lost on me that the first morning that we went to the launch pad, and as it turned out, we did several trips—five, after four scrubs—but that first morning, I just couldn't believe it.

I was the last crew member to crawl in and strap in, and as they were getting in, I wandered off on that launch tower by myself, looked in the direction of three miles away where the old homestead was, and just was overwhelmed, realizing that my grandparents, who I did not know, would have never believed that a grandson was going to literally leave the face of the Earth almost from the old homestead. So thank you for evoking the memories of the new frontier and that continuing frontier.

I'll just make a couple of other comments. As I have shared as I've visited with our witnesses, this Senator is so excited to see the abandoned launch pads at Cape Canaveral, which were alive with activity a half a century ago, coming back to life as a result of a lot of the activities represented in the panel that you have. It took getting agencies of the Government, who had been in stovepipes, to finally come together. There had to be a little prayer session, and we had to drag them to the altar to have that prayer session, but between the Air Force and NASA and the FAA, they got their acts together, and the proof is in the pudding, and we see what is happening.

And, now, in this recently completed NASA authorization bill, the standards were set. It brings that cooperation of all those agencies together in the commercial space sector, living alongside the necessary government launches plus the NASA launches that will be from Pad 39B. So it's going to be an exciting future.

The transformation of the Cape is illustrative of the broader impacts that the space industry has to offer this country, and we're just getting going. Both of you happened to mention the telescopes. I have behind my desk in our office here, a compendium of 5 years of photographs taken by the Hubble Space Telescope, which is millions and millions of light years away, showing the birth and death of stars. With the new Hubble that we're going to launch next year, we're going to look back further in time, almost to the beginning. That's going to bring new discoveries in addition to the excitement that we've already seen of other suns that actually have planets revolving around them.

So the challenges are there and we're ready to meet those challenges. The key to success is continuing a balanced space program, one that does not neglect science nor aeronautics, and along with the private space endeavors, balanced between cooperation and competition, as well as between risks and public safety. And for that, I think we're going to have a very exciting future.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Nelson, and I thank you also for sharing the story of your grandparents and homesteading. And just as your grandparents could not imagine their grandson being launched into space, perhaps sometime in the future, your grandkids will be homesteading 160 acres on the Moon or on Mars.

Senator NELSON. Well, Mr. Chairman, I still have two children that are not married, and—

The CHAIRMAN. I can't help you there.

[Laughter.]

Senator NELSON. And my wife and I are worried that we're going to be on oxygen before we have grandchildren.

The CHAIRMAN. Well, that gives us time to get back to the Moon and get to Mars.

[Laughter.]

The CHAIRMAN. With that, I want to welcome this distinguished panel of witnesses today. Thank you, gentlemen, for being with us this morning.

Our first witness is Mr. Robert Bigelow, who is the Founder and President of Bigelow Aerospace, which manufactures and develops expandable space station modules. Bigelow Aerospace has designed BEAM, the first ever expandable space station module to occupy humans while in space. Prior to founding Bigelow Aerospace, Mr. Bigelow founded the hotel chain, Budget Suites of America.

Our second witness, Mr. Rob Meyerson, is President of Blue Origin, where he has overseen the steady growth of the company since 2003. Prior to Blue Origin, Mr. Meyerson worked at Kistler Aerospace and as an aerospace engineer at NASA's Johnson Space Center. Mr. Meyerson earned a B.S. in aerospace engineering from the University of Michigan and a Master's degree in engineering management from the University of Houston. It's always good to see someone who has been a Houstonian.

Mr. George Whitesides is the CEO of Galactic Ventures, which is developing a fleet of commercial space vehicles as well as a small satellite launch capability. Prior to joining Galactic Ventures, Mr. Whitesides served as Chief of Staff at NASA, where he provided policy and staff support to the agency's administrator and received the Distinguished Service Medal, the highest award the agency confers. Mr. Whitesides is an honor graduate of my alma mater, Princeton University's Woodrow Wilson School, and holds a Master's degree from the University of Cambridge in England.

Mr. Andrew Rush is President and CEO of Silicon Valley-based Made in Space, which specializes in the engineering and manufacturing of three dimensional printers for use in microgravity. Made in Space's 3D printer, the Zero-G printer, was the first manufacturing device in space. Prior to joining Made in Space, Mr. Rush was a partner at the PCT Law Group.

Thank each of you for joining us.

Mr. Bigelow, you're the first witness.

**STATEMENT OF ROBERT T. BIGELOW, FOUNDER AND
PRESIDENT, BIGELOW AEROSPACE, LLC**

Mr. BIGELOW. Mr. Chairman and members of the Subcommittee, thank you for the opportunity to speak to you today and present my views on the subject of this hearing: Reopening the American Frontier for Free Enterprise in Space. First, let me thank the Committee for the work it has done to support the commercial space industry.

For over 17 years, I have personally funded the development of space habitat stations at Bigelow Aerospace, and I have spent, per-

sonally, over about \$350 million in that endeavor. Commercializing space habitat systems will dramatically lower costs to NASA and other customers.

To date, we have successfully launched three habitat station prototypes. These new technologies comprise the basis for the structure of our spacecraft and in full scale provide superior radiation, debris, and micrometeorite protection, as compared to the modules of the ISS.

In 2006 and 2007, we launched the Genesis I and Genesis II prototype spacecraft from the Yasny missile base in Siberia, Russia. The Genesis program was the first test of these new technologies in the space environment. Both spacecraft exceeded our expectations. In April 2016, the Bigelow Expandable Activity Module, or BEAM for short, was launched to the International Space Station under a partnership agreement with NASA and has undergone continuous testing attached to the Tranquility module of the ISS.

Today, we are focused on our primary goal, which is to provide customers with an affordable and safe station that can be augmented and outfitted for almost any type of mission, to almost any practical destination. Bigelow's primary spacecraft, the B330, offers 330 cubic meters of pressurized volume, volume that traditional metallic structures, including the ISS, cannot match in terms of total up mass per launch and at significantly less cost. A single fully deployed 330 expandable habitat provides approximately one-third of the current pressurized volume of the International Space Station.

Bigelow Aerospace's business model is built on time sharing volume and other assets. We should view future low Earth orbit locations and businesses as a wellspring for deep space capabilities. Commercially available habitat stations like the B330 provide affordability and potential access to space that otherwise has been out of the reach for most all nations and companies of the world.

NASA took the first step to address its destination deficit recently when it instituted the NextSTEPs program. Part of the NextSTEPs program is to develop the necessary technology for NASA to transition to deep space activities. This is achieved through cost savings by partnering with commercial entities to assist NASA's efforts to get out of low Earth orbit, return to the Moon, and open up other new American frontiers across the solar system. We at Bigelow have worked hard to keep production on schedule so that we can produce two flight-ready B330s by the end of 2020. While I hope that Congress and President Trump will work together to provide NASA the necessary financial resources it needs to succeed, I am moving ahead with the B330 program.

Now let me briefly describe some of the risks and threats I see. First, I believe that the United States is quickly approaching a crossroad. There are no destinations for American transportation systems besides the ISS. Where shall NASA and this Nation go once the ISS is no longer available?

NASA will always need training and testing facilities in low Earth orbit and beyond. Commercially affordable facilities where the customer is king is the practical answer. To that end, NASA needs to be a strong and diverse customer of the commercial space industry. Bigelow Aerospace continues to develop partnerships with

launch providers and other companies to ensure that NASA and other potential customers have alternative choices for the utilization of affordable habitat stations.

But in order to achieve a truly free enterprise in space, NASA is too vital a customer to ignore. NASA needs the necessary funding and policy direction to transition from the ISS to supporting space missions based on utilization of commercially supplied space habitats and other transportation assets.

China has created in their quest to develop their own national space program, a program that is not disconnected from its military. The Chinese government has made it known that it wants to offer free access to other countries to utilize their national space station in the near future. To that end, the Chinese and ISS partner states have discussed international space cooperation and partnerships. While our allies consider partnering with China, we should be mindful of strategic consequences that an engaged China could have on the future of American enterprise in space.

I have had innumerable discussions about the future of space exploration with many people. One thing I think is clear is that NASA is too focused on just transportation systems to the ISS. Everyone wants to know what are NASA's plans to transition out of the ISS. Whether the ISS continues or not, additional destinations besides the ISS are vital to sustain a viable space crew and cargo enterprise with new markets that eventually replace the ISS.

Moreover, I believe that if initiated soon, Bigelow Aerospace and other companies could provide a lunar depot using a B330 habitat station that would enable NASA and commercial entities access to the Moon and cislunar space in a 4-year program. If we truly commit to an initial destination in low Earth orbit, then following quickly to cislunar space, I believe that expandable habitats can offer NASA and others the ability to test and gain experience for future missions to the Moon and Mars.

That concludes my written remarks. Thank you, and I look forward to your questions.

[The prepared statement of Mr. Bigelow follows:]

PREPARED STATEMENT OF ROBERT T. BIGELOW, FOUNDER AND PRESIDENT,
BIGELOW AEROSPACE, LLC

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to speak to you today and to present my views on the subject of this hearing: Reopening the American Frontier for Free Enterprise in Space. First, let me thank the Committee for the work it has done to support the commercial space industry. The Committee has been an invaluable leader in providing coherent space policy and supporting the private sector's ability to compete to make America a leader in human spaceflight once again. However, over the next two years, Congress will need to address a variety of *risks* and *threats* to free enterprise in space. Congress has the important role to establish the business and regulatory environment necessary for the viability of low Earth orbit and cislunar economies to develop. Much work is left to do.

For over seventeen years, I have personally funded the development of space habitat stations at Bigelow Aerospace. I am proud of the accomplishments my company has made in the development of expandable habitat systems, architecture that Congress forced NASA to abandon in the 1990s. I personally have spent over \$350 million designing, manufacturing, testing, and launching hardware because commercializing expandable habitat systems will dramatically lower costs to NASA and other customers, providing affordable destinations, and thereby enabling the growth of new markets in space.

To date, we have successfully launched three habitat station prototypes. These new technologies comprise the basis for the structure of our spacecraft and in full-scale provide superior radiation, debris and micro-meteorite protection as compared to the modules of the ISS. In 2006 and 2007, respectively, we launched the Genesis I and II prototype spacecraft from the Yasny missile base in Siberia, Russia. The Genesis program was the first test of these new technologies in the space environment. Both spacecraft exceeded our expectations and we achieved invaluable data from those test flights. In April of 2016, the Bigelow Expandable Activity Module, or BEAM, was launched to the International Space Station (“ISS”) in the trunk of the SpaceX Dragon cargo vehicle under a partnership agreement with NASA. BEAM was expanded in May of 2016 and has undergone continuous testing attached to the Tranquility module of the ISS. The BEAM program helps NASA and Bigelow Aerospace understand and demonstrate the strong viability of these new technologies that make up the base architecture of expandable habitats. And I would like to note that the BEAM exemplifies the first time the ISS has been augmented with habitable volume since the end of the shuttle program in 2011.

Today, I am focused on our primary goal, which is to provide customers with an affordable and safe station that can be augmented and outfitted for almost any type of mission to almost any practical destination in space. Bigelow’s primary spacecraft, the B330, offers 330 cubic meters of pressurized volume; volume that traditional metallic structures—including the ISS—cannot match in terms of total up mass per launch at significantly less cost. A single, fully deployed B330 expandable habitat provides approximately one third of the current usable volume of the ISS. We have the ability to dramatically increase the usable volume in space, to double and triple that of the ISS, with single digit launch rates. This illustrates the advantages that Bigelow Aerospace’s habitat technology provides to the market and to NASA. The opportunities my company can enable through our habitat architecture will help revolutionize the commercial space industry provided that the regulatory environment remains minimal, transparent, and clear.

What Bigelow Aerospace seeks to achieve is to offer the market affordable, safe, and robust habitat technology. While NASA early on envisioned the original architecture of expandable habitat technologies through the Transhab program in the 1990s, Bigelow Aerospace has created many innovations and is now marketing the concept. The Bigelow Aerospace business model is built on time sharing volume and other assets. As a long-time real estate developer in the United States southwest, I know something about selling volume and time. We should view future low Earth orbit locations and businesses as the wellspring for deep space capabilities because it makes affordable the operational experience, increases performance efficiencies, provides for more robust technologies, and supports novel applications necessary for deep space missions. Commercially available habitat stations like the B330 provide affordability and potential access to space that otherwise has been out of reach for almost all nations and companies of the world. Whether the volume and time are used for traditional science, manufacturing, on-orbit servicing, or tourism, to list a few uses, we cannot get the necessary economies for free enterprise unless we start to address some of the existential and near-term issues that will affect America’s future in space.

NASA took the first step to address its destination deficit recently when it instituted the Next Space Technology for Exploration Partnerships program, also known as NextSTEPS. Part of the NextSTEPS program is to develop the necessary technology for NASA to transition to deep space activities. This is achieved through cost-savings by partnering with commercial entities to assist NASA’s efforts to get out of low Earth orbit, return to the Moon and open up other new American frontiers across the Solar System. As a Phase I and II awardee of the NextSTEPS habitation program, we have worked hard to keep production on schedule so that we can produce two flight-ready B330s by the end of 2020.

While I hope that the Congress and President Trump will work together to provide NASA the financial resources it needs to succeed, I am moving ahead with the B330 program. As noted, we are on schedule to have two flight-ready B330s completed by the end of 2020 for any customer. Therefore, as this Committee deliberates over the creation of a new commercial space bill, I believe that the Congress should concern itself with the necessary business and regulatory environment for habitats to serve as the backbone for all activities in space. Commercial space station development is underway now. I do not believe that we need more reports on space activities. What we need is forward-thinking on how to ensure that America is leading the way to commercial space stations as well as the means by which to permit our customers to achieve the full value of space. The Congress has already enacted the right for Americans to obtain space resources. Now it is time to consider how to give life to those rights. Not only in the form of title, but laying out the conditions for

space commercialization in the ways that Americans have always substantiated their rights to commerce—through registry and notice of business activities. This will be essential to provide operational safety, integrity of revenue streams, and evidence in future litigation regarding commercial rights to operate and use space resources in situ. I believe addressing the issue of registry and notice will help grow investor confidence in space activities enabling the large capital investments needed to provide certainty in the market as it develops over time.

Now let me briefly describe some of the risks and threats I see the Congress needing to address. First, I believe that the United States is quickly approaching a cross-road where opportunities will rapidly arise from the innovative space technologies Bigelow Aerospace and other companies are currently developing. There are no destinations for American transportation systems besides the ISS. Where shall NASA and this Nation go once the ISS is no longer available? NASA will always need training and testing facilities in LEO and beyond. Commercially affordable facilities, where the customer is king, is the practical answer. We should not repeat the mistakes of the past to move on without a plan. We should not move ahead by allowing others to lead. This nation should recommit itself to returning to the Moon and then on to Mars because it is the only practical way to guarantee that future space activities will have a foundational infrastructure capable of growing and maintaining stable economies to ensure NASA and American enterprise can continue to explore and utilize space. To that end, NASA needs to be a strong and diverse customer of the commercial space industry.

Second, Bigelow Aerospace is committed to playing a vital role to ensure that there is no “space station” gap like there was a “shuttle gap” that cut-off American independence in human spaceflight. Bigelow Aerospace continues to develop partnerships with launch providers and other companies to ensure that NASA and other potential customers have alternatives and choices for the utilization of affordable habitats. My company is ready to provide the means to achieve the twin goals of exploration and the development of a sustainable space economy. Bigelow Aerospace is ready to take the next step in human spaceflight to ensure that America regains its leadership role in the exploration of space. But in order to achieve a truly free enterprise in space, NASA is too vital a customer to ignore. NASA needs the necessary funding and policy direction to transition from the ISS to supporting space missions based on utilization of commercially supplied space habitats and other transportation assets.

Third, regulatory processes should be streamlined, transparent, fair, and appealable. The proliferation of commercial activities in space has led to many challenges for the industry and government. That is why in 2013 Bigelow Aerospace asked the Federal Aviation Administration’s Office of Space Transportation (FAA AST) if there would be any regulatory obstacles to launching and landing a Bigelow habitat on the surface of the Moon. As a result of this trailblazing effort, FAA AST, in consultation with the Department of State (DOS), NASA, and several other relevant Federal entities, adopted a major policy change regarding how to evaluate private sector missions to the Moon. Through FAA AST leadership, the Federal government has begun to understand that the commercial space industry needs a workable framework to enable and support innovative commercial space activities in space and on planetary bodies. I especially applaud the tremendous efforts of FAA AST Associate Administrator George Neild, DOS Director of the Office of Space and Advanced Technology Ken Hodgkins, and DOS Attorney-Advisor Brian Israel in achieving this most productive policy change. I know that Congressmen Brian Babin and Jim Bridenstine are working hard to achieve the regulatory balance of liberty, safety, and international obligations. We are grateful for all their efforts because American leadership in space policy will be essential to expand the American principles of free enterprise and self-determination into space, enabling the same successes in space that these principles have realized domestically.

Fourth, the Committee should take note of the strong international competition China has created in their quest to develop their own national space program—a program that is not disconnected from its own military. As I understand it, the Chinese seek to develop their own commercial space industry—I assume commercial with Chinese characteristics. The Chinese government has made it known that it wants to offer “free access” to other countries to utilize their national space station in the near future. To that end, the Chinese and ISS partner states have discussed international space cooperation and partnerships. Among others, I am aware that the governments of China and Italy have signed a memorandum of understanding regarding space cooperation, and that many pressurized space modules are manufactured in Italy. As a successful businessman, I know nothing is free. And while our allies consider partnering with China, we should be mindful of the strategic consequences that an engaged China could have on the future of American enterprise

in space. I urge the Committee to consider the disruptive strategic role China will likely play as NASA and the commercial space sector expand beyond low Earth orbit especially in light of the Chinese launch of its first cargo spacecraft to its unmanned space station to conduct a refueling mission last week.

I have had innumerable discussions about the future of space exploration with many Americans, foreign officials, and business people. One thing I think is clear, is that NASA is too focused on just transportation systems to the ISS. Everyone wants to know: what are NASA's plans to transition out of the ISS? Whether the ISS continues or not, additional destinations besides the ISS are vital to sustain a viable space crew and cargo enterprise with new markets that eventually replace the ISS. NASA must transition out of low Earth orbit and into deep space. I therefore urge the Committee to acknowledge that developing new habitat systems that can carry humans, experiments, cargo, and other technologies for the exploration of the Moon, Mars, and other destinations must begin in low Earth orbit and then proceed to cislunar space. Moreover, I believe that if initiated soon, Bigelow Aerospace and other companies could provide a lunar depot using a B330 habitat station that would enable NASA and commercial entities access to the Moon and cislunar space in a four year program. If we truly commit to an initial destination in low Earth orbit then following quickly to cislunar space, I believe that expandable habitats can offer NASA and others the ability to test and gain experience for future missions to the Moon and Mars.

I believe that this country has an opportunity in the very near term to re-inspire our citizens and begin developing and marketing new innovative space products and services to the American people and the world. I believe that the next five years will be consequential to the future success and health of a commercial space industry in LEO and beyond LEO. I am eager to work with the Congress to find ways in which we can ensure cost-effective, robust, and safe habitation systems that will enable America to lead space exploration and commercialization to make America great again in space!

This concludes my written remarks. Thank you and I look forward to your questions.

The CHAIRMAN. Thank you, Mr. Bigelow.
Mr. Meyerson.

**STATEMENT OF ROBERT MEYERSON, PRESIDENT,
BLUE ORIGIN**

Mr. MEYERSON. Chairman Cruz, Ranking Member Markey, Ranking Member Nelson, and members of the Subcommittee, thank you for the opportunity to speak with you today about reopening the American frontier and Blue Origin's place in this future.

Blue Origin was founded to bring about a future where millions of people are living and working in space, which would certainly equate to a large expansion of the American frontier. We believe that the backbone of this vision is to achieve full operational reusability to lower the cost of access to space and increase safety and reliability. We've recently made great progress flying our fully reusable *New Shepard* vehicle to space and back five times in less than 12 months and are now building *New Glenn* which will launch people and payloads to low Earth orbit and beyond.

The passage of the Commercial Space Launch Competitiveness Act in 2015 helped lay the groundwork for much of what we plan to do in the coming years, and for that, I would like to thank you for your leadership. As you prepare to take the next step, we would like to offer a few suggestions.

The FAA Office of Commercial Space Transportation, or AST, does a good job of balancing its requirement to protect the uninvolved public with its statutory mandate to promote the commercial spaceflight industry. AST's budget has remained flat for sev-

eral years while the number of launches has continuously increased. We join the rest of the commercial spaceflight industry in urging Congress to increase funding for AST to allow the office to operate as a responsive and effective agency.

That said, we encourage Congress to ensure that AST is prioritizing its resources on its current statutory mission. We believe AST's resources are insufficient to meet its existing obligations and do not believe AST should take on new authorities now, such as on-orbit authority, space situational awareness, or space traffic management. We want to work with AST on the impending licensing traffic jam before they start taking on orbital traffic jams.

As Blue Origin initiates the application to license our *New Glenn* reusable launch vehicle, we are encountering conflicting expectations on the regulatory process between FAA and the Air Force. This conflict stems from the lack of a Federal adaptation to the market, which is transitioning from expendable rockets to reusable rockets. In contrast to those for expendable rockets, the Air Force and AST licensing requirements for reusable rockets are completely different from each other.

While pursuing an FAA launch license for our *New Glenn* launch at a Federal range, we simultaneously have an entirely different but equally rigorous set of deliverables for the Air Force, all for the exact same vehicle. This is duplicative and onerous and will increase costs, delays, and uncertainty. In his previous role as Commander of Air Force Space Command, General Hyten wrote a Commander's Intent Memorandum in March 2016 which highlights the necessity for the Air Force to work with the FAA to eliminate duplicative requirements and approvals.

The leadership of the 45th Space Wing understands the need to transition to a commercial model and has begun working with Blue Origin and the rest of the industry to adapt processes to facilitate these partnerships. That said, the leadership's vision has not yet been fully adopted at all levels of the Air Force. As a result, the Air Force has not yet realized its full potential to move at the velocity required to support commercial operators. We are hopeful that with continued leadership from the Air Force, FAA, and this subcommittee, this issue will be fully addressed in the near term.

Ultimately, we want AST to be the single point of contact within the Government for all commercial launches. We would like AST to have sole authority over launches and re-entries without regard to location or type of launch. At Federal ranges, commercial launches now require duplicative government approvals, delaying launch activity and burdening launch providers. This area is primed for increased efficiency in government operators.

Finally, I'd like to express our strong support for NASA's use of Other Transaction Authority Agreements and other innovative contracting mechanisms, such as those used in Commercial Crew and Cargo and the NextSTEP programs. Public-private partnerships allow government and industry to work toward common goals in a more efficient, agile, and cost-effective manner and expands the resources available for space exploration.

In March of this year, we announced the Blue Moon Lunar Lander to land large amounts of payload on the lunar surface. Blue Origin is willing to significantly invest in this development as part of

a public-private partnership with NASA in the interest of achieving a return to the Moon, which we believe to be a worthy national goal.

Thank you for the opportunity to testify before you today. I look forward to working with you on an updated Commercial Space Launch Act this Congress, and I look forward to answering your questions.

[The prepared statement of Mr. Meyerson follows:]

PREPARED STATEMENT OF ROBERT MEYERSON, PRESIDENT, BLUE ORIGIN

Chairman Cruz, Ranking Member Markey, Chairman Thune, Ranking Member Nelson, and members of the Subcommittee, thank you for the opportunity to speak before you today about reopening the American frontier, and Blue Origin's place in this future.

Lewis and Clark's preliminary exploration of the Pacific Coast in 1805 initiated 85 years of exploration and discovery of the American Frontier. Following in their footsteps, settlers spread throughout the Western territories, expanding American opportunity and realizing the region's potential up until the Frontier's "declared" closure in 1890. Much like that 19th century expedition, NASA has been trailblazing the space frontier for nearly 60 years, yet the same expansion of American opportunity seen in the 1800s has not been fully realized in space.

Jeff Bezos founded Blue Origin to bring about a future where millions of people are living and working in space, which would certainly equate to quite a large expansion of the American frontier. As the company's president, it is my job to make this vision a reality for humanity, our customers, and our now more than 1,000 people working tirelessly for Blue Origin across the Nation. We believe that the backbone of this vision is to achieve full operational reusability with our launch vehicles which will lower the cost of access to space, at higher flight rates and higher levels of safety and reliability. We will get there through practice, and we've recently made great progress flying our fully reusable *New Shepard* vehicle to space and back five times in less than 12 months. We are now building *New Glenn*, our next-generation reusable rocket which will launch people and payloads to low Earth orbit and beyond.

Our near-term goal is to compete in the commercial market—whether suborbital, orbital, or beyond—selling launch services and technologies. We are building the next generation of transportation infrastructure: reliable, affordable, frequent rides to space for everything from suborbital tourism to long-range exploration, from resource mining to microgravity manufacturing.

We recently entered into agreements with our first two commercial satellite launch customers for our *New Glenn* vehicle. We are prepared to partner with NASA for crewed and uncrewed space missions, including a return to the Moon within the next four years. We are ready to help end the military's reliance on Russian engines for our national security launches. What makes us most excited about building this infrastructure—this backbone—is the American entrepreneurialism that will undoubtedly flourish in space.

The passage of the Commercial Space Launch Competitiveness Act in 2015 helped lay the groundwork for much of what we plan to do in the coming years, and for that I would like to thank Chairman Cruz, Chairman Thune, Senator Peters, Ranking Member Nelson, Senator Udall, and the other members of this Subcommittee in the previous Congress for your leadership. As you prepare to take the next step, we would like to offer a few suggestions.

AST Focus/Resources

The FAA Office of Commercial Space Transportation, or AST, does a good job of balancing its requirement to protect the uninvolved public with its statutory mandate to promote the commercial spaceflight industry in the United States. AST's budget has remained essentially flat for several years, while the number of launches has continually increased, and is likely to continue growing. We join the rest of the commercial spaceflight industry in urging Congress to increase funding for AST to allow the office to operate as a responsive and effective agency.

That said, we encourage Congress to ensure that AST is prioritizing its existing, and any new resources, on its current statutory mission. As discussions continue on authorities that may be granted to AST in the future, we believe that AST's resources are already insufficient to meet its existing obligations; licensing launches, reentries and spaceports. We recommend that AST not attempt to handle on-orbit

authority, space situational awareness, or space traffic management at this time. We do not believe that AST should take on these new authorities now, but we take no position here on whether any of these roles may be appropriate for AST in the future.

Furthermore, Blue Origin strongly supports the continuation of both the current launch indemnification regime and the learning period on human spaceflight regulations. We encourage permanent indemnification as well as ongoing Congressional advocacy and extensions of the learning period. These policies allow the industry to focus on continued maturation of innovative technologies without unnecessary burdens.

Expendable v. Reusable and the Need for Streamlining

One specific example of the need for a single point of access and a streamlined regulatory process is the transition from expendable rockets to reusable rockets. Blue Origin is a leader of this transition, having launched and landed the same rocket five times.

The licensing requirements for reusable rockets differ from those for expendable rockets. In the case of expendable rockets, the Air Force's requirements match AST's requirements almost word for word. This means that a company can create a set of deliverables for the Air Force and essentially provide the same information to AST to satisfy launch license requirements. It is duplicative, but not onerous.

In contrast, the Air Force and AST licensing requirements for reusable rockets are completely different from each other. Blue Origin is seeking an AST reusable launch vehicle license for an orbital class booster operating at a Federal Range. While pursuing our FAA launch license, we simultaneously have an entirely different but equally rigorous set of deliverables for Air Force certification—all for the exact same vehicle. This is duplicative and onerous.

The government is placing a requirement on Blue Origin and other commercial companies that will increase costs, delays, and uncertainty. Instead of encouraging and rewarding companies that are innovating and driving launch costs down, the current process is punishing those companies with red tape, and creating excessive barriers to launch.

In his previous role as Commander of U.S. Space Command, General Hyten wrote a memorandum in March of 2016 on "Commander's Intent on Range Support to Commercial Space Launch." The memo highlights the necessity for the Air Force to work with the FAA to eliminate duplicative requirements and approvals in order to support "a more stable, predictable and efficient interaction with commercial space activities." To effectively accomplish this mission, General Hyten recognized the need to "actively seek opportunities to adapt range operations, processes and policy to flexibly accommodate all users."

The leadership of the 45th Space Wing at Patrick Air Force Base in Florida understands the need to transition to a commercial model, and has begun working with Blue Origin and the rest of the industry to adapt processes to facilitate these partnerships. That said, the leadership's vision has not yet been fully adopted at all levels of the Air Force. As a result, the Air Force has not yet realized its full potential to move at the velocity required to support commercial operators. We are hopeful that with continued leadership from the Air Force, FAA, and this Subcommittee, this issue will be fully addressed in the near term.

AST Licensing

Ultimately, we seek streamlined deliverables, irrespective of vehicle type, in alignment with the structure of 14 C.F.R. Part 431, "Launch and Reentry of a Reusable Launch Vehicle". This means we want AST as the single point of contact for any commercial spaceflight company interactions with the government. We would like AST to have sole authority over launches and reentries, without regard to location or type of launch, consistent with the National Space Transportation Policy. When operating our *New Shepard* reusable launch vehicle at our private launch site in West Texas, the licensing process is much more efficient since we deal only with the FAA. At Federal ranges, however, licensing the same commercial launches requires duplicative government approvals delaying launch activity and burdening launch providers—this area is primed for increased efficiency in government operations.

Government Overreach

Recently Blue Origin and a number of other companies in the industry received a notification from the U.S. Department of Commerce, Bureau of Industry and Security that they are conducting a "survey and assessment of organizations responsible for the research, design, engineering, development, manufacture, test, and integration of rocket propulsion-related products and services." The survey is intended to

assess the health and competitiveness of the rocket propulsion industrial base, and is apparently being shared with 400 propulsion related organizations. The survey contains several hundred extremely detailed questions, and we have some concerns with sharing our proprietary and confidential information. Blue Origin is a private company that is currently not participating in major government contracts, and we are hoping to work with Congress and the Department of Commerce to identify a reasonable path forward to share information.

NASA Public-Private Partnerships

The U.S. Government seeks to become more efficient, agile and cost-effective through public-private partnerships. NASA's use of Other Transaction Authority, Space Act Agreements, and other innovative contracting mechanisms has produced incredible results while reducing government spending. The unique risk-and-cost-sharing regimes, such as those seen in the Commercial Crew, Cargo, and NextSTEP Programs, enable true collaboration toward national space priorities.

We believe that the national goal should be to return to the Moon, this time to stay. NASA has identified cislunar space as the strategic high ground, an enabler of grander exploration into our solar system, and a source of critical resources. In March of this year we announced our Blue Moon Lunar Lander Mission, the capability to precisely soft-land large amounts of payload on the lunar surface. Such capability is a necessity for future lunar settlement and exploration. Blue Origin is willing to significantly invest in this development as part of a public-private partnership with NASA, in the interest of achieving this ambitious national priority.

NASA Enhanced Use Leasing/In-Kind Consideration

NASA's Enhanced Use Leasing (EUL) authority allows NASA Centers to lease underutilized NASA real property to private sector entities, academic institutions, and state and local governments. The authority helps preserve unique assets that NASA may want to use in the future, rather than allowing them to fall into disrepair. EUL authority also allows for a more productive use of the land that NASA must retain as a "buffer zone" around its launch and test sites. Revenues received under EULs cover NASA's full costs in connection with the leases. Any remaining proceeds must be used for maintenance, capital revitalization, and improvement, thereby positioning the Agency to reduce operating costs, incrementally improve facility conditions, and improve mission effectiveness. The NASA Transition Authorization Act of 2017 extended NASA's EUL authority to the end of 2018.

We support extending EUL authority an additional five years, and expanding the agency's authority to accept "in-kind" contributions toward the lease. This will help NASA cultivate public-private partnerships to transform underutilized real property, including launch and test infrastructure remaining from the Apollo and Space Shuttle eras, to serve broader science, exploration, defense, and commercial interests. As an example this authority has been critical in helping NASA's Kennedy Space Center create a multi-user spaceport environment that is drawing commercial launch and satellite enterprises to efficiently use once vacant buffer space while creating a thriving commercial space nexus. Of course, any expansion of the authority should protect against possible abuses, particularly for leases involving in-kind contributions.

New Shepard Suborbital Research & NASA Flight Opportunities

Starting in 2016, Blue Origin began flying research payloads on our *New Shepard* vehicle, allowing university researchers, corporate technology developers, and even K-12 STEM programs to access the space environment at lower cost and with lower barriers than ever before. The results from these studies are changing the way we understand fields as varied as fluid physics, spaceflight medicine, and planetary science.

Examples of payloads flying on *New Shepard* include:

- Purdue University in Indiana, characterizing effective tank geometries for in-space propellant management
- Orbital Medicine, Inc. of Virginia, developing devices for critical spaceflight medical care
- A collaboration between the University of Central Florida, Southwest Research Institute in Colorado, and the University of Braunschweig in Germany to examine rock and particle collisions in low-g environments, such as asteroids and the early solar system
- High school students in Washington State, studying the ways that liquids of different densities behave in microgravity

- NASA centers in both Ohio and Texas, characterizing suborbital flight environments to support the agency's broader research portfolio.

Today, the majority of Blue Origin's payloads are funded by NASA's Flight Opportunities Program within the Space Technology Mission Directorate (STMD). They serve to develop technologies for Earth-based applications, orbital satellite missions, and ISS investigations. This program has been critical in facilitating the use of emerging suborbital commercial vehicles, like *New Shepard*, and we support full funding for the Flight Opportunities line item in future NASA appropriations. Additionally, we strongly encourage NASA's efforts to widen this aperture beyond STMD to include the broader agency's science and education objectives.

As we enter the era of frequent private human spaceflight, Blue Origin looks forward to taking both tourists and researchers aboard *New Shepard*. We ask that Congress direct NASA to remove the barriers that exist today for experts seeking to conduct hands-on research aboard suborbital vehicles. Furthermore, we advocate for human-tended suborbital research to be treated in the same manner as other challenging laboratory environments, such as undersea and Antarctic outposts, and not as equivalent to commercial orbital crew.

Ultimately, as the cost and frequency of space access dramatically improves with vehicles like *New Shepard*, spaceflight R&D is growing beyond its cradle at NASA. We are entering an era where every Congressional district and every Federal agency should evaluate how it can take advantage of the space environment for discovery-based science, technology breakthroughs, inspiring STEM learners, and catalyzing American business innovation. We hope Congress will join us in this broader view, and will consider how this new era supports not only NASA's objectives, but those of the wider government and the entire nation.

National Security

Air University recently published a report that highlights the necessity for the Department of Defense to take advantage of commercial spaceflight capabilities to increase Air Force resiliency in space and extend the service's reach. Doing so will allow the government to leverage fast, low-cost access to space. While we recognize that it may be many years before the Air Force is prepared to use a flown rocket, Blue Origin has stepped in to assist the Air Force in assuring access to space with our BE-4 rocket engine. A 550,000lbf thrust liquid oxygen, liquefied natural gas engine, the BE-4 is in full-scale testing and is the fastest path and lowest cost option to end American reliance on Russian rocket engines.

Conclusions

Blue Origin was founded to bring about a future where millions of people are living and working in space. With low-cost, safe, and frequent access—achieved through reusable launch technology—an entrepreneurial explosion can begin in space, irreversibly expanding the American Frontier.

Addressing the below recommendations will allow the government and industry to interact more efficiently, develop stronger partnerships towards shared goals, and work toward America's full potential in space.

- *AST Focus/Resources*—Increasing funding for FAA AST and encouraging prioritization of their current mandates will allow the office to continue operating as a responsive and effective agency.
- *AST Licensing*—Designating AST as the single point of contact for commercial space companies will eliminate duplicative approvals and streamline the launch process.
- *Expendable vs. Reusable*—Embracing and readying for the next generation of reusable vehicles will allow the government to fully realize a new era of low-cost launch for its most valuable payloads.
- *Public-Private Partnerships*—Increasing the pursuit of innovative public-private partnerships, like the proposed Blue Moon lunar lander mission, will allow us to collectively achieve ambitious national priorities at the lowest cost.
- *NASA Enhanced Use Leasing (EUL)*—A five-year extension of NASA's EUL authority and "in-kind consideration" will reinvigorate and preserve underutilized property, often of vast historical national significance.
- *Suborbital Research*—Renewed and ongoing support for suborbital research will not only change the way we understand fields like science and medicine, but will also grant students unprecedented, low-cost access to space.
- *National Security*—The Blue Origin BE-4 American made engine is the fastest path and lowest cost option to end American reliance on Russian rocket engines.

Thank you for the opportunity to testify before you today. I look forward to working with you on an updated Commercial Space Launch Act this Congress.

The CHAIRMAN. Thank you.
Mr. Whitesides.

**STATEMENT OF GEORGE WHITESIDES, CEO,
GALACTIC VENTURES**

Mr. WHITESIDES. Chairman Cruz, Ranking Member Markey, Ranking Member Nelson, and members of the Subcommittee, thank you for the opportunity to testify today about how our companies can help reopen the American frontier in space.

Space represents the best of America: discovery, inspiration, cooperation, but also courage, competitiveness, and resolute determination. The women and men in our company, as in others, I consider among the American explorers of the 21st century.

I'm the CEO of Virgin's Galactic Ventures, and I'm here to represent our human spaceflight program as well as our small satellite launch capability. We have three commercial space companies within the Virgin space portfolio: Virgin Galactic, Virgin Orbit, and The Spaceship Company. Together, our team employs over 800 direct staff and many more contractors and suppliers across virtually every state in the nation, and we look forward to commercial operations in Senator Udall's state soon.

Virgin Galactic will operate SpaceShipTwo, a suborbital spaceflight system that is manufactured and tested by The Spaceship Company. SpaceShipTwo is a rocket plane that is deployed from a carrier aircraft called WhiteKnightTwo and is designed to safely transport people and payloads to space on a frequent basis. Ultimately, we aspire to evolve this technology to provide high-speed, point-to-point transportation services between continents.

Galactic's sister company, Virgin Orbit, is developing and manufacturing a dedicated orbital rocket for small satellites called LauncherOne. LauncherOne is a two-stage, liquid propulsion rocket deployed from a Boeing 747 that we ultimately plan to operate weekly.

Today, hundreds of companies around the world as well as many important parts of the U.S. Government are developing small satellites for everything from communications to remote sensing applications. LauncherOne will offer a flexible and affordable launch service for such satellites beginning in 2018. Both SpaceShipTwo and LauncherOne will operate under an FAA operator's license issued by the Office of Commercial Space Transportation, or AST.

The U.S. has always been a global leader in space, in part because Congress has created a regulatory and policy environment that supports commercial space companies by prioritizing safety without stifling private sector innovation. The regulatory learning period is a great example of this.

However, to continue our Nation's supportive policies as launch providers go from test to operations, it is important to adapt and address new issues facing the industry. For example, AST must have sufficient resources to successfully undertake its current responsibilities in an era of increased space launch activity and the ability to adjust its policies and practices to respond to industry developments.

As the Government seeks to develop new and innovative space capabilities, whether for civil or defense purposes, it should encourage partnerships with the commercial space sector through firm fixed price contracts and efficient acquisition strategies. Above all, the Government should refrain from using taxpayer dollars to fund programs that directly compete with commercially available or emerging services and strive to leverage its taxpayer dollars by using commercial services wherever possible. NASA is already doing this in efforts such as the Flight Opportunities Program that purchases capacity on reusable suborbital vehicles for research payloads and in its Venture Class Launch Services program that uses small launchers to place cubesats in orbit.

The Government should support policies that allow for domestic industry growth and increased capture of global market share. For example, the Government should vigorously continue its export control reform efforts. Domestically, Congress should work to ensure that disparate state laws and regulations do not create unanticipated barriers to innovation and growth.

Finally, the Government should continue its longstanding policy forbidding the commercial use of excess ICBM assets or else risk a catastrophic impact on the U.S. launch industrial base that would undermine national security and civil space objectives. Since multiple new privately developed vehicles will be entering the marketplace over the next 2 years, there is no reason to change this longstanding policy.

Our companies are dedicated to providing frequent, reliable, and safe transportation to space for humans and payloads. Our vehicles, along with other commercial space companies, will continue to push Earth's economics sphere outward. This subcommittee is helping to ensure that the U.S. continues to play a leading role in exploring and democratizing the next great frontier. We look forward to working with you on these and future issues.

[The prepared statement of Mr. Whitesides follows:]

PREPARED STATEMENT OF GEORGE WHITESIDES, CEO, GALACTIC VENTURES

Chairman Cruz, Ranking Member Markey, and Members of the Subcommittee, thank you for giving me the opportunity to provide testimony for your hearing on "Reopening the American Frontier" I am here representing Virgin Orbit, Virgin Galactic, and The Spaceship Company. I will provide an overview of our current activities and our thoughts on the present and future environment for commercial space operations in the U.S.

I am the CEO of Galactic Ventures and in this role, I am responsible for guiding all aspects of building the world's first commercial spaceline which includes both our human spaceflight program as well as our small satellite launch capability. Galactic Ventures has three privately-funded commercial space companies within its portfolio:

- Virgin Galactic, which will operate a suborbital spacecraft for the purpose of space tourism and research
- The Spaceship Company, which designs, manufactures and tests our suborbital human spaceflight system
- Virgin Orbit, which is developing, and manufacturing a dedicated, small launch platform for satellites which they will also operate

Three separate companies, but one shared vision for providing frequent, reliable and safe access to space for all. In the past few years, our companies have collectively grown from a handful of employees to providing roughly 1,000 direct jobs, and supporting another 1,000 indirect jobs in the aerospace sector.

Thank you for holding this important hearing about the U.S.'s role in exploring the next important frontier. The U.S. has always been a global leader in space. In part because Congress has worked diligently to create a regulatory and policy environment that is supportive of commercial space companies. The United States is, quite literally, undergoing a renaissance in space science and technology. New companies are introducing satellites technologies that allow for increased capabilities in smaller, more affordable, packages. A new, globally competitive domestic launch industry is looking to make space transportation more frequent, reliable, and safe. This new marketplace even reaches beyond the confines of our planet and serious ideas are in development to better link private sector energies with the NASA exploration vision. This industry is not only important for our future in space, but it is contributing to high-tech jobs and inspiring a new generation of scientists, engineers, and entrepreneurs in our country today.

In my written remarks, I will go over some key issues that are currently contributing to our leadership in space, as well as those that still need to be addressed such as:

- The current regulatory environment for our industry that prioritizes safety without over-reach, including:
 - The continued need to regulate based on data rather than analysis.
 - The need for a permanent indemnification regime for launch competitiveness overseas.
 - Streamlining the licensing of hybrid vehicles—those that include elements of both aircraft and spacecraft—and their operations.
 - The need for legal clarity for informed consent through the requirement of cross-waivers.
- The continued need to mature and expand our concept of public private partnerships to ensure that commercial space sector plays a pivotal role in both civil and national security programs.
- Continued support for Government policy that restricts the use of ICBMs for commercial purposes. Allowing ICBMs into the commercial marketplace will irreparably damage an emerging domestic launch sector.
- Support for the Ex-Im bank and other policies such as export control reform that will keep the commercial space sector a global leader in space transportation and applications.

Virgin Galactic

Virgin Galactic is at the forefront of an important emerging market that is developing suborbital spaceflight experiences for humans, commonly referred to as “space tourism,” as well as for research payloads. Founded by Sir Richard Branson and based in Mojave, California, we are opening access to space to change the world for good. Virgin Galactic’s voyages will allow people to experience true microgravity, and to see the Earth from space. In addition, Virgin Galactic will also provide access to the microgravity environment for research, education and other industrial applications to develop and test new applications.

Based on the historic SpaceShipOne vehicle built by Scaled Composites—which safely carried human beings into space in 2004, claiming the Ansari X PRIZE and becoming the only privately-operated human spaceflight vehicle to do so to date—Virgin Galactic’s vehicles have been designed with the intention of opening up frequent access to space while setting new standards for safety, frequency, flexibility, and cost. Our suborbital spaceflight system consists of two vehicles: WhiteKnightTwo (pictured in *Figure 1* below) is a four-engine, dual-fuselage jet aircraft capable of high-altitude heavy lift missions, including but not limited to fulfilling its role as a mothership for SpaceShipTwo (shown in *Figure 2*), a suborbital spaceplane designed to safely and routinely transport people and payloads to space and back. SpaceShipTwo will carry two pilots and as many as six spaceflight participants or about 1,000 pounds of science and technology payloads to space altitudes, where they will have exposure to 3–4 minutes of a high-quality microgravity environment.



Figure 1: WhiteKnightTwo Carrier Aircraft, VMS EVE



Figure 2: SpaceShipTwo, VSS Unity manufactured by The Spaceship Company

The current SpaceShipTwo, named the *VSS Unity*, is currently undergoing flight test, and was manufactured in Mojave, California by Virgin Galactic's manufacturing wing, The Spaceship Company. Commercial operations will be based in New Mexico at Spaceport America, the world's first purpose-built commercial spaceport.



Figure 3: WhiteKnightTwo and SpaceShipTwo in their mated configuration during a test flight in March 2017

The Spaceship Company

Virgin Galactic's manufacturing wing is The Spaceship Company, which is made up of an experienced team that designs, manufactures, tests and supports unique and innovative aerospace vehicles. They offer an extensive set of capabilities through the full lifecycle of high and unique performance vehicles through preliminary vehicle design, manufacturing, ground testing, propulsion, flight testing and post-delivery support. They manufacture the fleet of SpaceShipTwos and WhiteKnightTwos for Virgin Galactic, and are currently flight testing VSS Unity.

Virgin Orbit

In addition to human spaceflight, Virgin Galactic's sister company, Virgin Orbit, will provide dedicated, responsive, and affordable launch services for small satellites. Today, hundreds of companies around the world are developing small satellites for everything from communications to remote sensing applications. To help this small satellite revolution, Virgin Orbit is developing LauncherOne, a flexible launch service for commercial and government-built satellites. The LauncherOne platform is dedicated to the task of lowering the cost and increasing the frequency of space access for payloads in the 150 kg–500 kg weight range.

LauncherOne (shown in *Figure 4*) is a two stage, liquid propulsion (LOX/RP) rocket launched from a carrier aircraft. The carrier aircraft is a modified 747-400 (shown in *Figure 5*) that will carry the launch vehicle under the port side wing between the fuselage and inboard engine to the appropriate altitude before launch. Once released from the carrier aircraft, LauncherOne will fire its single main stage engine, a 73,500 lbf, LOX/RP-1 rocket engine. After stage separation, the single upper stage engine, a 5,000 lbf LOX/RP-1 rocket engine will carry the satellite (or satellites) into orbit. At the end of this sequence, LauncherOne will deploy our customers' satellites into their desired orbit.

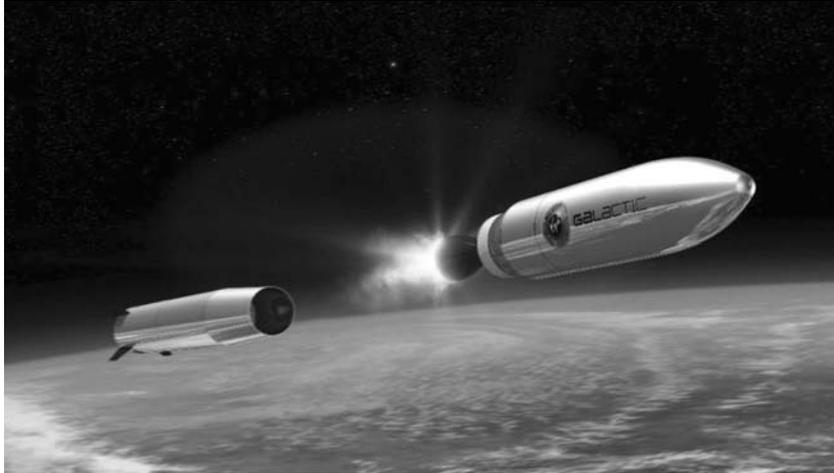


Figure 4: LauncherOne vehicle



Figure 5: Modified Boeing 787-400 carrying the LauncherOne rocket

Currently, Virgin Orbit is working towards initial test flights of the LauncherOne system. Virgin Orbit will operate LauncherOne under a FAA AST license and will initially launch from Mojave Air & Space Port, but will eventually operate from other licensed sites.

The Regulatory Environment

Virgin Galactic, The Spaceship Company, and Virgin Orbit are a part of a robust and growing domestic commercial space industry. This U.S.-based space sector is made up of companies with private financial backing working on a myriad of missions from rocket launch, human spaceflight, satellite constellations, to beyond Low-Earth Orbit (LEO) operations such as asteroid mining, lunar landers, and in-space habitats. The commercial space industry is well underway and poised to continue its growth.

The Commercial Space Launch Act as amended and re-codified at 51 U.S.C. Ch. 509, §§ 50901–23, authorizes the Department of Transportation, and by delegations the Federal Aviation Administration’s office of Commercial Spaceflight (AST), to oversee, authorize, and regulate commercial launch and reentry vehicles. FAA AST’s regulatory authority over commercial launch and reentry is expansive when it comes to protecting public safety, national security and U.S. foreign policy interests, but is limited outside of those areas. This is significantly different than how the FAA regulates aviation activities today. However, this regulatory approach is necessary to encourage the emerging commercial space industry while prioritizing the safety of the uninvolved public. Recognizing the importance of these principles for the development of the commercial space industry, we applaud Congress for reaffirming them in the Commercial Space Launch Competitiveness Act of 2015.

As we look to the future, Congress has an opportunity to build on the success of the Commercial Space Launch Competitiveness Act (CSLCA) in several areas:

The Regulatory Learning Period

Congress has long recognized that the commercial spaceflight industry is too dynamic and too early in its development cycle for the kind of full-scale regulation that characterizes air travel. Congress also recognized that it is impossible for regulators to know enough yet, about how to regulate a group of vehicles as diverse and innovative as our industry is developing. The solution was to create a statutory regulatory learning period, during which AST may regulate for the safety of the uninvolved public, or in response to an incident, but not prospectively otherwise.

This learning period was initially enacted in 2004 to allow the commercial space industry to create a sufficient database of knowledge on which to base future commercial space regulations. However, due to technical and economic challenges and industry’s emphasis on safety, commercial space companies did not progress as quickly as was once envisioned. Congress correctly acknowledged that the learning period had not yet accomplished its intended purpose and extended the learning period to 2023 in the CSLCA. The learning period gives AST the opportunity to collaborate with industry so that both AST and industry better understand how to operate safely. The learning period also enables commercial spaceflight companies to innovate for safety more quickly than they could if regulations were in place. Any update of CSLCA should maintain the learning period.

Indemnification

Since 1988, U.S. law has included a third-party risk-sharing regime for FAA-licensed commercial space launches and reentries that allows U.S. companies to compete more effectively with their foreign competitors. Passed by multiple Congresses, this “indemnification” regime requires companies to buy commercial insurance or demonstrate available financial resources to cover any third-party damages up to the Maximum Probable Loss, which is calculated by the FAA pursuant to Federal regulation (and which is calculated to be exceeded in only one in a million launches). In exchange, the Secretary of Transportation commits to seek funds to pay third-party claims above that level, up to a statutory cap—which would require another separate action by Congress. However, no claim to date has ever been triggered. Without these means of limiting catastrophic risk, both the industry and the Federal government would be subject to significant legal risk. The CSLCA extended indemnification to 2025. We encourage this Subcommittee to study and consider a permanent indemnification regime for the U.S. launch industry. The Congressional Budget Office has scored indemnification as no cost to the government. The government receives the benefit of indemnification for all claims up to the Maximum Probable Loss.

The current regulatory regime should continuously adapt as the industry continues to grow and deploy new technologies. While we appreciate and applaud Congress’ tremendous efforts on the CSLCA of 2015, there are still outstanding regulatory issues facing our industry today—such as:

Cross-waivers

Under the Commercial Space Launch Amendments Act (CSLAA), Commercial human spaceflight operators operate under an informed consent regime, requiring them to inform spaceflight participants of the inherent risks of space flight and the specific safety record of the vehicle type for their flight. In general, spaceflight participants must state in writing that they understand that the U.S. Government has not certified the space launch or reentry vehicle as safe and they must be informed of the risks of the vehicle they are boarding. Six states, each home to existing or proposed spaceports, have passed varying levels of informed consent requirements to protect vehicle operators from claims from spaceflight participants. All state laws exclude injuries sustained by spaceflight participants that are the result of gross

negligence or intentional misconduct. While these statutes all require that a licensee obtain informed consent from each spaceflight participant, state courts have yet to discuss and interpret the application of this statute to their current body of law. As a result, it is possible that different jurisdictions will arrive at different interpretations of these rules.

This lack of legal consistency between the CSLAA and local state law could undercut the Federal statutory mandate to promote the health of the commercial space transportation industry. To encourage the successful growth of the U.S. commercial spaceflight industry, and its operators, manufacturers, and suppliers, Congress should implement a predictable and consistent national legal environment.

Streamlining Hybrid Regulations

Virgin Galactic and Virgin Orbit's vehicles form a hybrid launch system involving both an aircraft and a rocket-powered vehicle. WhiteKnightTwo operates under an Experimental Airworthiness Certificate (EAC) issued by FAA's office of Aviation Safety (AVS). When the WK2/SS2 vehicle pair perform test flights where SS2's rocket motor is not used, the pair operates under an EAC. However, if the vehicle pair takes flight with the intention of lighting the rocket motor, they operate under an AST Operator's License. Virgin Galactic received its Operator's License for SpaceShipTwo from FAA AST in July of 2016. The license was the culmination of years of interaction with the AST and required in-depth reviews of the vehicle's system design, safety and flight trajectory. Both AVS and AST have tremendous expertise in their respective fields and in our case, have been willing to work with us to meet our flight test schedule. However, while looking to the future as more vehicles and flights come online, streamlining the regulatory environment for hybrid vehicles—in a manner that keeps pace with the industry's rapid tech advancement without overly complex procedures—would be a welcome improvement to the current process.

Space Support Vehicles

Operating WK2 and SS2 under the EAC for certain flight operations restricts use of the vehicles to flights not for-hire. WhiteKnightTwo's primary purpose is to enable the launch of SpaceShipTwo. However, due to the capabilities of WK2, there has been interest in using the aircraft for spaceflight participant training purposes, and for research payloads as WK2's ceiling is higher than most commercial aircraft. We are currently unable to do those types of commercial activities without filing for a waiver. We recommend Congress address the issue of the use of "Space Support Vehicles" for hire either through streamlining the licensing for these types of vehicles or implementing new regulatory guidelines.

AST/ATO Coordination / Commercial Space Integration into the Air Space

We represent only two of several different commercial space launch vehicles operating today and while all are different, commercial space operations are not currently a large user of the NAS. Furthermore, because both their speed and their direction of flight are so different from aircraft, rockets and spaceplanes typically occupy the NAS for only a few minutes or even seconds per flight, rather than lingering or passing through the airspace for hours at a time. However, as the industry's launch cadence increases, it drives the need for efficient and streamlined processes for continued seamless integration into the airspace. For example, as part of the AST license issuance, Virgin Galactic coordinated with the FAA Air Traffic Organization (ATO) and the local Air Traffic Control (ATC) to receive Letters of Agreement (LOA) to define operations in the national airspace. The current process used to get a LOA is lengthy and requires conversations with multiple elements within the FAA. A much more streamlined process should be in place for future operations.

The number of commercial launches has been increasing over the past few years and will continue to do so in the years ahead as the industry continues to grow. This drives the need for an efficient, defined process as well as technical tools, like the Space Data Integrator Prototype being developed by the FAA's Tech Center. The Space Data Integrator, when fully developed, will automate the current manual processes used by the FAA to monitor launch and reentry operations and will be able to respond to off-nominal scenarios to ensure the safety of the National Airspace System (NAS). Automated data flow also provides opportunities for more dynamic and efficient airspace management.

The CSLAA built the foundation for a regulatory regime that protects public safety while allowing for rapid innovation and continuous improvements in the launch vehicle industry. The legislation correctly recognized that regulatory uncertainty or over-reach can strangle the American commercial space business. As industry continues to grow, the regulatory environment must allow for continuous improvements and innovations as well. However, to effectively do so, AST needs sufficient re-

sources to support increased commercial space launch activity as well as incorporate next-gen technologies for ever increasing safety of operations. Virgin looks forward to continuing our work with the FAA to keep the skies ever safer while reaching new heights for commercial space operations.

Public Private Partnerships/Use of Commercial Services

As the Government seeks to develop new and innovative space capabilities, whether for civil or defense purposes, it should encourage partnership with the commercial space sector through firm-fixed price contracts and efficient acquisition strategies. The success of public private partnerships was recently exemplified through the achievement of NASA's Commercial Cargo Resupply Program. Public private partnerships and the use of commercial services will be key in furthering our space exploration program to reach new destinations.

The Government should refrain from using taxpayer dollars to fund programs that directly compete with commercially available or emerging services. In fact, in a tight budgetary environment, the U.S. Government should strive to use commercial services wherever possible. NASA is already doing this in its programs such as the Flight Opportunities Program that purchases capacity on commercial reusable suborbital vehicles for technology development and research payloads, as well as its Venture Class Launch Services program that uses commercial small launchers to place cubesats in orbit to conduct research for the Science Mission Directorate in which Virgin Orbit was awarded a launch. This allows the government to leverage already invested private sector capital to meet their agency goals while supporting the U.S. space industrial base. We strongly support both programs.

However, current acquisition processes and requirements are seen by the commercial space sector as contributing to increased costs, extended mission timelines and reduced capability due to heavy requirements that prefer reducing risk at all cost. The Government should review and revise acquisition processes for commercial services with an emphasis on rapid procurement of innovative capabilities for both civil and national security purposes.

Damaging Impact of Potential Commercial ICBM Use

Finally, to continue the growth of U.S. domestic launch capability, the Government should maintain its longstanding policy forbidding the commercial use of excess ICBM assets. Releasing ICBMs for use as commercial launch vehicles would have an adverse impact on the U.S. launch industrial base and would undermine national security and civil space objectives. Since multiple, new, privately developed vehicles will be entering the marketplace over the next two years, there is no reason to change this longstanding policy.

International Competitiveness

Financing from export credit agencies is often a critical competitive factor in international satellite sales and launch service deals. Many countries that are active in the global launch and satellite marketplace offer this kind of financing in some capacity. In 2014, financing support for the space industry started becoming the fastest-growing sector at the Export-Import Bank of the United States (Ex-Im). Ex-Im helped to level the international playing field for U.S. companies, and the Bank's prudent lending practices have led it to consistently be a net positive contributor to the U.S. Treasury. However, since July of 2015, the Ex-Im bank has been unavailable to U.S. exporters due to delayed congressional reauthorization and currently, vacancies on the Bank's Board of Directors. International competitors have access to credit that U.S. companies do not without the Ex-Im bank, which essentially tips the playing field in favor of our foreign competitors to the detriment of the U.S. space industrial base.

Finally, I would be remiss if I did not mention the importance that export control, and more importantly, export control reform, has on our competitiveness overseas. The commercial spaceflight industry recognizes the important national security interests at stake, but overly restrictive export control regulations can obstruct an industry from capturing global market share while failing to prevent proliferation. As technologies continue to develop and enter the commercial marketplace, the International Traffic in Arms Regulations must be reviewed and updated to adequately control the flow of technology and information without stifling American innovation or business. This includes modernizing the Missile Control Technology Regime regulations to accommodate 21st century space systems such as commercial space tourism.

Our companies are dedicated to providing frequent, reliable, and safe transportation to space for humans and payloads. Our vehicles, along with other commercial space companies working to provide services in LEO and beyond will continue to push Earth's economic sphere outward. This Subcommittee is helping to ensure that

the United States continues to play a leading role in exploring and democratizing the next great frontier. We look forward to working with you on these and future issues.

The CHAIRMAN. Thank you.
Mr. Rush.

STATEMENT OF ANDREW RUSH, CEO, MADE IN SPACE, INC.

Mr. RUSH. Chairman Cruz, Ranking Member Markey, Ranking Member Nelson, and members of the Subcommittee, thank you for the opportunity to speak with you today.

As CEO of Made In Space, I have the immense privilege of leading an incredibly passionate and talented team in pursuit of making the cislunar economy a reality. We want to see people sustainably commercially living and working in space. We're developing space-capable manufacturing technologies because we believe that manufacturing in space is a key enabler of the cislunar economy.

As a young company with no outside investment, our founding team started with small practical steps, a philosophy we still apply today. By working with a variety of groups and leveraging infrastructure I'll be talking about in a moment, we've made real progress.

After initially demonstrating 3D printing in microgravity via NASA's Flight Opportunities Program, Made In Space was granted a series of SBIR contracts allowing us to work with Marshall Space Flight Center to build and launch a 3D printer to the International Space Station. In 2014, that device produced the very first objects to ever be manufactured off the face of the planet.

This capability is paradigm shifting, because it allows us to produce spares, parts, and fixes, on demand, on the spot. Without infrastructure like the Flight Opportunities Program, the SBIR program, and the International Space Station, we could not have developed this capability at the price that we've developed it at nor in a step-by-step fashion.

We're now building on this foundation in other ways. In March 2016, under a user agreement with the Center for the Advancement of Science in Space, CASIS, our second generation 3D printer that we own and operate was launched to the International Space Station. This device, called AMF, has been operating profitably on the International Space Station for a year, producing parts for a wide variety of government and commercial customers. In fact, the very first customer was the home improvement giant, Lowe's.

Operating on the International Space Station is a crucial stepping stone to sustainable commercial activity in space because it allows for the refinement of technology and incubates cislunar economic business models. In late 2016, via a public-private partnership, a Made In Space-led team began work for NASA's Space Technology Mission Directorate to develop large-scale, in-space additive manufacturing and assembly technologies. We call this system Archinaut.

Archinaut enables the optimization of spacecraft structures for their operational environment, for the microgravity environment, rather than having to primarily design them to survive launch. This technology enables us to build large structures at lower cost

in space, enables the robotic manufacturing assembly of large reflectors, space stations, and other applications for civil, defense, and space customers. We applaud the use and expansion of public-private partnerships which focus on delivering capabilities which are useful to both the Government and the private sector.

American free enterprise in space can also be expanded via manufacturing of space-enabled materials. These are materials which, due to being manufactured in space, have emergent beneficial properties for use here down on the Earth. These materials are produced in space and then brought back to Earth for sale and utilization.

Now, on the International Space Station National Lab, Made In Space will soon be manufacturing ZBLAN, a space-enabled optical fiber which market research indicates can be profitably sold when launching raw materials from Earth. ZBLAN promises to deliver significantly better signal throughput than traditional fiber for telecommunications applications, a \$2 billion a year market.

We have self-funded the development of a pilot facility that we launched and operated on the ISS this year, and we intend to expand production further on the ISS and eventually move to commercial platforms in space, opening the door for the industrial production of thousands of kilometers of material a year. This would not be achievable without the infrastructure of the ISS National Lab and the research into ZBLAN's promise and properties performed by personnel at NASA Ames Research Center, NASA Marshall Space Flight Center, and other facilities.

In closing, we at Made In Space are grateful for the support that we have received. We encourage continued operation and expansion of the infrastructure that I've just described. It has allowed us and other companies to develop capabilities in a step-by-step fashion, creating solutions for both the public and the private sectors. We strongly believe that in-space manufacturing will be an anchor tenet of the cislunar economy and encourage this subcommittee to take steps to ensure that it flourishes.

Thank you.

[The prepared statement of Mr. Rush follows:]

PREPARED STATEMENT OF ANDREW RUSH, CEO, MADE IN SPACE, INC.

Introduction

Made In Space, Inc. (Made In Space, MIS), seeks to develop products and services that will enable and drive people to one day sustainably live and work in space. In 2014, Made In Space hardware successfully produced the first functional objects manufactured off the face of the planet. Today, Made In Space has several in-space manufacturing programs underway and is commercially manufacturing for customers aboard the International Space Station. This success would not be possible without the Small Business Innovation Research Program, NASA support, and access to the International Space Station National Lab.

Via in-space manufacturing, Made In Space is developing the first factories in space which will produce high-value goods for use on Earth. These factories may one day be the anchor tenants of commercial space stations.

Made In Space strongly encourages continued support of programs which enable the step-by-step development of new commercial space capabilities, including the SBIR program, NASA's Flight Opportunities Program, and the International Space Station National Lab. Made In Space believes that personal and intellectual property created by commercial enterprises in space and aboard the International Space Station should be owned by the commercial entity. Further, Made In Space encourages the creation of a transition plan to commercial space stations before the Inter-

national Space Station is decommissioned and expanded support for commercial activity aboard the International Space Station in order to effectively foster the birth of the cislunar economy as NASA's activities look deeper into space.

The Cislunar Economy Is Coming

This is a unique time in history. Although the creation of a cislunar economy has long been discussed and dreamed of, sustainable, space-based, commercial manufacturing, tourism, and research and development has long been elusive. Today, sustained progress is being made toward this dream because the basic technological and regulatory framework exists to allow growth of space-based businesses.

We are on the cusp of the next great American technological boom: the creation of a sustainable cislunar economy. This boom is not guaranteed. Investments must continue in order to properly germinate this boom. This boom will encompass commercial satellites leveraging the best technology the American semiconductor industry has to offer, consistent space tourism activity sending people on suborbital, orbital, and translunar adventures, space-based research and development discovering new drug and compound formulations which can be made on Earth, and space-based manufacturing of products for use on Earth which provide revolutionary capability due to being manufactured in the microgravity environment of space.

Like every boom that has come before, from the smartphone revolution, to the Internet boom, reaching back to the booms like the one brought on by the discovery of oil at Oil Creek, Pennsylvania the mid-19th century, many approaches will be tried, to varying success. In the creative destruction of progress, many will try. Some will fail. Some will succeed. Importantly, space entrepreneurs must be allowed to experiment, fail in small or grand ways, succeed in small or grand ways, and scale their businesses as the market demands.

Infrastructure enables and enhances economic booms. Without public and private investments in things like ARPANET and legislative actions to enable profit making via the Internet, the Internet boom would never have happened. Without investment, maintenance, and enhancement of the Global Positioning System, businesses and services like Yelp and Google Maps could not exist and our smartphones would be pale shadows of the powerful devices they are today. Going back further, without railway and eventually pipeline infrastructure created by public and private entities, transportation and refining of oil into kerosene and other products would have been severely constrained.

A boom in commerce in low Earth orbit and beyond will be no different. This space boom will be built upon infrastructure investments by both the private sector and the public sector. Some of this infrastructure exists already. The International Space Station (ISS), the International Space Station National Lab, and the regular human and cargo missions to and from that installation enable world beating scientific research and development, new understanding of the effects of space on the human body, and provide a platform for pathfinding the technologies and business models that may become the anchor tenants of future commercial space stations.

Crucially, the ISS allows deployment and operation of payloads to space at a fraction of the mass a free flying satellite would require to support the payload. Combined with the frequent cargo modules launched to the ISS, this creates an ecosystem which allows payloads to be flown to space and operated at a low price point and a frequency that is currently unattainable by the orbital launch industry. At a relatively low cost, this infrastructure allows commercial companies to develop technologies, test business models, and make profits that may one day support sustainable operations in commercial space stations or free flying satellites, where the full promise of sustainable commercial space industry will be realized and billions in revenues will be generated.

The ISS allows development, testing, and deployment of pilot commercial facilities for investments on the order of millions of dollars, amounts of money that can be realistically attained through private investment or public sources, such as the Small Business Innovation Research program. Without this infrastructure, such development and deployment would cost a hundred million dollars or more; an amount of money which is rarely invested in unproven space technologies by either the private or public sector.

Like the ISS and the ISS National Lab, other infrastructure supports the gradual, step-by-step transition of technologies which will enable a space-based economic boom from the drawing board to full scale operation in space. The increasing availability of parabolic aircraft flights and suborbital rocket flights provides very low cost to no cost testing of technologies in short bursts of microgravity ranging from twenty seconds to several minutes. This enables low-cost prototypes to be tested in their intended operational environment, without the enormous expense of orbital launch. NASA's Flight Opportunities Program has long provided these flights to re-

searchers and entrepreneurial companies, laying the groundwork for government and commercial payloads that have now been deployed to space.

On the operational end of the spectrum, we at Made In Space are ecstatic to see plans from commercial space station providers coming together to deploy modules to space within the next five years. Similarly, orbital launch providers bringing new, lower cost and reusable launch vehicles to market is a landmark achievement for commercial access to space. The combination of the ISS and future commercial space stations and frequent low-cost commercial launch gives companies at the forefront of the forthcoming commercial space boom somewhere to operate and a way to get there. Without somewhere to operate and a predictable way of getting there, operations are not possible and expansion of American free enterprise in space is stifled.

Made In Space, Inc. And The Emerging Cislunar Economy

Made In Space, Inc. (Made In Space, MIS) is a small business with offices in California, Florida, Alabama, and Ohio.

Made In Space was founded in 2010 with the goal of enabling people to sustainably live and work in space.

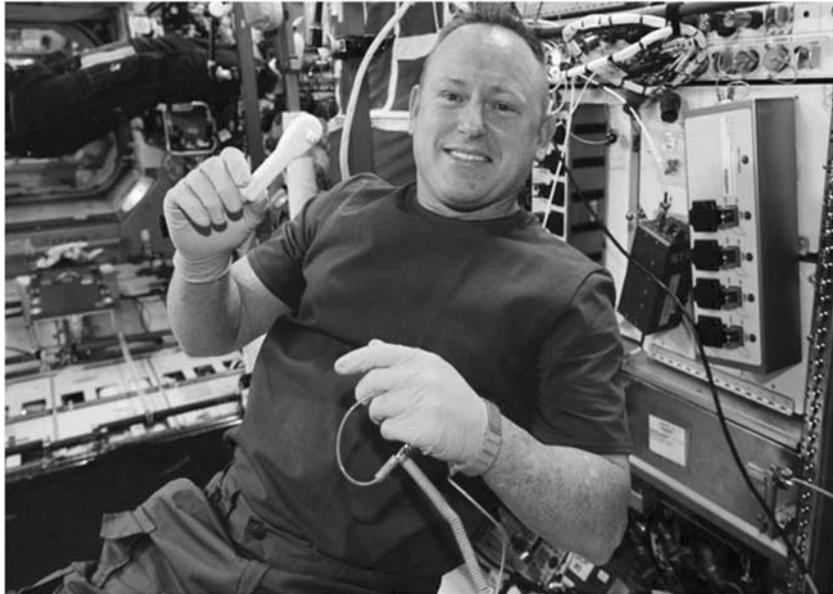


Figure 1. ISS Commander Barry "Butch" Wilmore holding a 3D printed ratchet manufactured in space. The ratchet was designed on the ground and manufactured in space one week later, making it potentially the fastest delivery to space ever. Image credit: NASA

This goal is shared by many in the space industry who believe in the economic promise the final frontier holds. Companies like SpaceX and Blue Origin are focused on building low cost launch vehicles, 21st century versions of the covered wagon. We at Made In Space are focused on developing the tools and manufacturing facilities that will fill those wagons to the stars, enabling a sustainable cislunar economy.

We focus on two types of space-based manufacturing: manufacturing technologies that enable new missions in space; and manufacturing technologies which leverage the space environment to create high value goods for use on Earth. Both are crucial enabling technologies for the cislunar economy which will utilize the above described infrastructure and one day generate revenues sufficient to profitably sustain commercial orbital launches and space stations.

Made In Space has no outside investors and has been profitable since its inception. Currently, Made In Space has approximately forty employees, including several who began their careers in the aerospace industry via internships funded by the NASA Space Grant and Fellowship Program.

Manufacturing In Space For Use In Space

Utilizing multiple pieces of the space infrastructure described above to open up new sources of space-based revenue, Made In Space engineers initially internally

funded a prototype gravity-independent 3D printer. Through a grant from the NASA Flight Opportunities Program, that prototype was tested and successfully operated on board a parabolic flight aircraft in 2011. Building on this demonstration of viability, Made In Space was awarded SBIR contracts to develop the technology for demonstration aboard the ISS. Via an SBIR Phase III contract with NASA run out of the In-Space Manufacturing group at NASA Marshall Space Flight Center, Made In Space built and operated the first 3D printer to operate in space. In late 2014, via the 3D Printing In Zero-G Technology Demonstration experiment, this space-capable 3D printer was installed on the ISS and manufactured the first functional objects ever made off the planet Earth by humanity (see Figure 1).

Building on this initial on-orbit success, Made In Space built the Additive Manufacturing Facility (AMF, see Figure 2), a second-generation more capable 3D printer. The AMF was launched to the ISS in March 2016. Via agreements with NASA and the Center for the Advancement of Science In Space (CASIS), the managers of the ISS National Lab, Made In Space owns and operates the AMF, routinely sending print jobs to the ISS and manufacturing them on a weekly basis. The AMF print services business is profitable and has produced parts for NASA, the U.S. Navy, Lowe's, universities such as Texas A&M University, student groups, and even individuals. Parts manufactured include space optimized structures, hand tools for the ISS crew, prototype medical splints and ventilators, and adaptors for ISS equipment.



Figure 2. The Additive Manufacturing Facility (left) is the first ever commercial manufacturing facility deployed to space. A wide variety of customers have been served, including Lowe's who designed the first print on this facility, a space optimized hand tool (right). Image credits: NASA/Made In Space.

The capability to manufacture parts on demand during a space mission is paradigm shifting. 3D printing serves as a fast and inexpensive way to manufacture parts on-site and on-demand, reducing the need for costly spares on the ISS and other spacecraft. Long-term missions would benefit greatly from having onboard manufacturing capabilities. New parts may be manufactured to enable new scientific experiments or augment existing ones.

Further building on this success and internal research and development into manufacturing very large, space-optimized structures in space, Made In Space became a "Tipping Point" selectee by NASA's Space Technology Mission Directorate. Under a contract begun in late 2016, Made In Space is leading a team including Northrop Grumman and Oceaneering Space Systems to develop its Archinaut in-space manufacturing and assembly technology. During rocket launch, spacecraft are subjected to high g forces and large vibrational forces. Further, the entire spacecraft must fit within the limited volume of the launch fairing. Surviving this launch environment requires wasting mass to over engineer components to survive launch and engineering deployables which unfurl once the satellite reaches orbit, creating points of failure. Archinaut technology will enable optimization of spacecraft structures for their operational environment, rather than launch. Additionally, repair and reconfiguration of assets once they are on orbit will be possible. Further, this technology enables providing large structures at lower cost and enabling robotic manufacture and assembly of large reflectors, space stations, and other applications for civil, defense, and commercial space customers. Before operating in space, this technology will initially be demonstrated in NASA environmental testing facilities and aboard ISS via AMF, including manufacturing space-optimized structures in space.

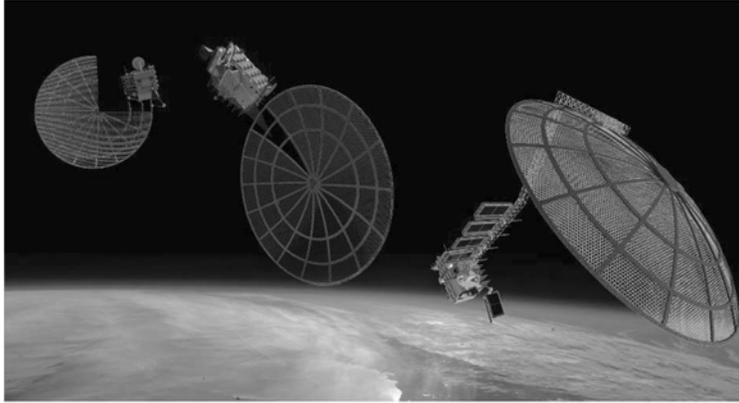


Figure 3. This artist's rendering depicts the Archinaut payload during its deployment in space. Via additive manufacturing and assembly, a large reflector is manufactured and integrated over time. Image credit: Made In Space

The Archinaut Development Program is a private-public partnership designed to develop a technological capability that is useful to both government and commercial customers. As part of its effort, the Made In Space-led team is contributing over 25 percent of the program cost. Made In Space believes that space technologies should be developed into products which are useful and sold to both government and commercial space customers. This expands their utilization and lowers costs for all customers.

Manufacturing Space Enabled Products

Space-enabled products are materials and products which are manufactured and/or processed in space which, due to being manufactured and/or processed in space, have beneficial properties. Because of space's unique properties like microgravity, in-space manufacturing enables the creation of new materials and products which cannot be duplicated via Earth-based manufacturing.



Figure 4. Made In Space will deploy a payload to ISS this year to manufacture high value optical fiber in space. Image credit: Made In Space

Some products have been well researched via government funding and determined to provide significant performance improvements when manufactured in space. For example, research indicates that space-manufactured ZBLAN optical fiber has ten to one hundred times better signal loss compared to traditional silica optical fiber. Due to this dramatic performance improvement, some government and private analyses estimate that space-produced ZBLAN optical fiber could generate over a billion dollars a year in revenue. Commercial manufacturing of ZBLAN in space would also represent the first industrial use of space, a key enabler of the cislunar economy.

Because of its unique expertise in microgravity manufacturing and the market potential of ZBLAN, Made In Space has privately funded the development and deployment of a ZBLAN manufacturing facility. Via an agreement with CASIS, this facility will be flown to the ISS this year, produce optical fiber there, and then be returned to Earth where the fiber will be characterized and delivered to customers. Made In Space plans to scale in-space production of ZBLAN quickly aboard the ISS with the ultimate goal to produce thousands of kilometers of ZBLAN optical fiber a year in space on a commercially provided platform.

Made In Space is taking a step-by-step approach with this program, leveraging government research, the ISS, and its own profits to deliver a commercial in-space manufacturing capability. The promise of in-space manufacturing is not limited to optical glasses. Government and private research indicates that many other products and materials can benefit from in-space manufacturing and close the business case at current launch costs or launch costs achievable in the medium term, making manufacturing of space-enabled products a potential anchor tenant of future commercial space stations in the cislunar economy and adding new launches to the industry.

Conclusion

Made In Space has benefited enormously from a virtuous cycle of technology development and operation enabled by the Small Business Administration, NASA, and CASIS. Made In Space is grateful to all those that have helped along the way and proud to continue working with NASA and other government agencies. The step-by-step technology development path that currently flows from lab development to parabolic flights through the ISS National Lab and eventually to commercial platforms in space has been critical to Made In Space's success. Made In Space strongly encourages continued support of the elements of this path as well as support and expansion of commercial enterprise aboard the ISS so that the cislunar economy is well positioned to blossom before the ISS is decommissioned. By actively supporting the growing commercial cislunar economy through the end of the ISS's life and supporting the creation of commercial platforms in LEO, the United States can expand its supremacy in space.

The CHAIRMAN. Thank you, Mr. Rush, and thank you to each of the witnesses for your very helpful testimony. We'll now move to the question portion of the hearing, and let me start out with this.

As Congress looks to build upon the Commercial Space Launch Competitiveness Act, what are the regulations that are most impacting your companies that need to be addressed by Congress or processes that can be streamlined to facilitate or accelerate the exploration of space?

Mr. MEYERSON. If I could start, as I stated in my oral and also in my written testimony, we think the designation of FAA as the sole lead agency for licensing commercial space launches, independent of the location of the range, is the single most thing that, as a launch operator, we would like to see to streamline space regulation.

Mr. WHITESIDES. Senator, two suggestions from Virgin's perspective. On indemnification, since 1988, U.S. law has included a third-party risk sharing regime for FAA licensed commercial space launches and re-entries that allows U.S. companies to compete more effectively with their foreign competitors. Without this means of limiting catastrophic risks, both the industry and the Federal Government would be subject to significant legal risk. The CSLCA extended indemnification to 2025. We encourage this subcommittee

to study and consider a permanent indemnification regime for the U.S. launch industry.

And if I could add one more, in terms of streamlining hybrid regulations, Virgin Galactic and Virgin Orbit's vehicles form a hybrid launch system involving both an aircraft and a space vehicle. Both AVS and AST within FAA have tremendous expertise in their respective fields and, in our case, have been willing to work with us to meet our flight test schedule. In the future, as more vehicles and flights come online, streamlining the regulatory environment for hybrid vehicles would be a welcome improvement to the current process.

Mr. BIGELOW. I'd like to suggest that staying with Space Act Agreements is a significant step forward as opposed to the far type of structure of contracting. We have used them with NASA, and they are expeditious. They are agile. They do not involve a lot of red tape. So to us, the Space Act Agreements should be maintained as a principal method of contracting between the commercial sector and the Government sector.

Mr. RUSH. As a company that operates in space, we would like to see a few things: An affirmation that intellectual property that's developed in space by companies operating in space, whether that be within a government facility or without, be retained wholly by the company that creates that intellectual property. Further, as a company that is seeking to manufacture goods on U.S. spacecraft and on U.S. modules, we would like to see those modules and spacecraft continue to be treated as U.S. soil, so that one day, when we're manufacturing a wide variety of high-value goods in space and bringing them back, there's no question that they're not subject to any sort of import or customs tax.

Further, in the more near term, simplifying the process for getting payloads to the ISS and operating those payloads there is something I think that all operators would like to see.

The CHAIRMAN. Well, thank you. Those are all helpful suggestions, and I'll note, Mr. Rush, on your last point, I certainly hope we would not trigger reciprocal tariffs from Mars. That would be a real problem.

Senator NELSON. Nor a border adjustment tax.

[Laughter.]

The CHAIRMAN. Mr. Meyerson, Blue Origin and SpaceX are both making terrific strides in changing human spaceflight and lowering the price of access through the use of reusable rockets, a notion that not too long ago would have been almost unthinkable. What's the difference in the licensing requirements set by the Air Force and set by the FAA's Office of Commercial Space Transportation, and when it comes to using a reusable rocket compared to an expendable rocket?

Mr. MEYERSON. So the reusable licensing machine has not been utilized yet, so it's a relatively new regime within the FAA, and that's one that we're now exploring with our *New Shepard* and our *New Glenn* vehicles. The current regime requires—when you fly a commercial vehicle off a Federal range, it has both FAA and Air Force involvement. So you're providing the same types of documents—safety analyses, hazard analyses reports—but in different

formats to different agencies, and that is what I referred to earlier as duplicative and we think it's unnecessary.

The CHAIRMAN. One additional question, Mr. Bigelow. If Bigelow Aerospace sought to place a Bigelow habitat either on the surface of the Moon or in orbit around the Moon as a lunar depot, are there any significant regulatory barriers to doing so, and does the U.S. Government have a workable framework in place to enable and support commercial space activities in space and on and around planetary bodies?

Mr. BIGELOW. We don't believe so. We think that it's consistent within the framework of the 1967 Space Treaty. We also think that as a partner in the context of a commercial-government partnership with NASA, we would be mutually aware that we had to follow prescriptions of behavior to invoke safety where it would be necessary. We have considered this type of activity for some years, deploying structures on the surface of the Moon. We have architectures that address that, and is the same with orbiting depots.

The CHAIRMAN. Thank you.

Senator Markey.

Senator MARKEY. Thank you, Mr. Chairman.

Mr. Bigelow, what role do you see public-private partnerships filling in regards to maintaining a national laboratory in space?

Mr. BIGELOW. I don't see it as a zero sum game. I don't see it as a choice of either/or. If I were in a position of decision for NASA, I would say I want both. I would want to harmoniously blend the obtaining of commercial assets under affordable circumstances and reliable circumstances and be accustomed to their operation, acclimate my own astronaut corps to those facilities, those platforms, concurrent with the operation of the ISS.

And then at the time that the ISS is eventually repositioned or reassigned other missions may be involving commercial uses, or not, then I would already have platforms in place in low Earth orbit where at the same time that those are being positioned, I would be able to increase the size of my astronaut corps. I would increase the size of the population of Johnson Space Center, because now there isn't just one platform to monitor and to operate. There could be three or four or five, and the advantage with the commercial sector is that those platforms, the ones that would be added, would be at a small fraction of the cost of the original station.

Senator MARKEY. Thank you.

Mr. Meyerson, Russia, India, China, United Arab Emirate, Saudi Arabia—there can be a lot of traffic up there as each year goes by. How would you suggest that we work together in order to ensure that there are common minimal safety standards that are established and adhered to globally?

Mr. MEYERSON. Well, I think the FAA is currently doing a very good job of developing those standards. What we need as space gets global—we need more launch capacity. So with the long-term vision of millions of people living and working in space, it's going to be not just Americans, but it's going to be people throughout the world that are living and working in space, and we'll need launch capacity to do that. So what I'm suggesting and urging is a very stream-

lined process for doing that so that different companies in different countries can demonstrate their capabilities in that approach.

Senator MARKEY. And what would be, from your perspective, the correct mechanism to use in order to ensure that there is a minimal international safety standard?

Mr. MEYERSON. You know, I'd be happy to provide an answer to that one on the record. I'm not really prepared to answer that question. It's a complex question.

Senator MARKEY. That's fine. We would appreciate it.

Anyone on the panel have any suggestions?

Mr. BIGELOW. Well, I think, initially, the philosophy is less regulation is better while maintaining the context of common sense and safety and organization. So we have—two or three years ago, we were working with George Nield and FAA AST to acquire a policy change within the FAA AST, and that was achieved, where our company was used sort of, more or less, as a guinea pig, where launches would not be sanctioned from U.S. territory to be vectoring a payload to a location on the surface of the Moon where Bigelow Aerospace had some kind of activity ongoing, and that was a policy change.

The next step from that is to—in addition to that would be probably to prescribe a standoff distance, because that was mute, as to—if there were some kind of miscalculation in the delivery of that payload, what is a logical standoff distance of safety? Would it be 300 kilometers, 250 miles, whatever, as a radius so that you have geographic protection.

Senator MARKEY. Thank you. And maybe I'll just throw this out for anyone who wants to take it. What is the role of the Air Force going forward? Do you see that ultimately being phased out, and the private sector will just be in charge of its own responsibilities? Can any of you take that as a question?

Mr. BIGELOW. We would like to see a Space Command have a presence in space. We would like to actually see that those kinds of assets are accessed earlier than later. We think that the Naval Research Laboratory or the Air Force Research Laboratory could use those kinds of locations for unique laboratory purposes.

Mr. MEYERSON. I'd like to add the urging is on FAA regulation of commercial launches. The Air Force, of course, has their own missions that are of a national security nature and would require a different type of oversight, and that is absolutely necessary and essential, and we'd see that continuing.

Senator MARKEY. Thank you.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Senator Nelson.

Senator NELSON. I was fascinated, Mr. Rush, in you telling about using a 3D printer to create a new, more pure fiber optic cable and because of the properties of Zero-G. It would be so pure that it becomes economical to manufacture it in space and take it back to Earth because it can convey so much more information so rapidly. Is that correct?

Mr. RUSH. That is correct, Senator.

Senator NELSON. Well, so how can we improve the ISS as an incubator to help enterprises such as yours, and do you see that it needs to be extended beyond the existing life, which is 2024?

Mr. RUSH. I believe that similarly amazing strides have been taken to let folks like us operate on the ISS, period, and pursue these things. You know, really, having the framework of the ISS National Lab gives us access to that in a way that, you know, I can build a pilot factory that's maybe 50 kilograms and get that up and operate it, where, if absent that facility, I would be buying a ride from some of these fine gentlemen's companies at, you know, orders of magnitude, greater costs, which for a commercial entity might not be possible.

As we move forward, I would recommend that the ISS National Lab and the folks that support that entity more fully embrace commercial pathfinding on the ISS and commercial profitmaking on there, because the ultimate goal is for companies like us to transition to commercial platforms, like Mr. Bigelow's facilities. But we can't jump from, you know, making a little bit of money or no money to paying for a significant portion of his module or anybody's facility because the math just doesn't quite solve. So we need a step-wise transition to laws to expand operations, first on ISS and then perhaps next on a commercial module attached to ISS, and then ultimately to a free flyer.

We would strongly recommend that a transition plan be created that is committed to a continuous presence in low Earth orbit for persistent microgravity platforms, which likely looks like supporting a commercial space station being created and put up in space while the ISS is still there, whether that's by 2024 or beyond.

Senator NELSON. So that fits very nicely with what Mr. Bigelow testified about. Now, you are a small group of folks that started this startup. You got a NASA space grant. So do you want to tell us in 45 seconds, no more, how important it is for NASA to invest in young scientists and engineers in your example?

Mr. RUSH. Absolutely, yes. I got my very first job in the industry via a NASA space grant. A couple of the co-founders of our company have similar experiences, as well as a lot of the guys that we employ, including new interns that are working for us. Just as NASA invests in technology from, you know, a low Technology Readiness Level and eventually brings it into operational capabilities, we need to do that with people as well, and I'm proud to be one of those people and to employ people like that.

Senator NELSON. I want Mr. Whitesides and Mr. Meyerson to be contemplating the need to streamline the regulatory process for the growing commercial launch industry. Already, we had a major step forward that a lot of people don't realize. The destruct system that previously was always done by the Air Force with an Air Force lieutenant sitting there with his finger on the destruct button in case it started going off course and headed to a populated place—has on some of the commercial activities and launches been replaced with an autonomous flight safety system which allows the turnaround for rocket launches to be much greater.

SpaceX, for example, told me in a few years, they expect to be—just SpaceX—launching 40 launches a year just from the Cape, additional ones from Brownsville, and additional ones from Vanden-

berg that need to go into polar orbit. But the biggest bulk of them, 40—that’s quite an activity when you add all the others in. So I want you all to be thinking and give to us how that regulatory process, particularly with the FAA, can be improved?

[The information referred to follows:]

SPACE LAW & POLICY SOLUTIONS
Rochester, NH, April 21, 2017

Senator Ted Cruz (R-TX), Chairman, Senator Edward J. Markey (D-MA), Ranking Member and Members of Space, Science and Competitiveness Subcommittee

Re: Reducing Regulatory Barriers and Expanding American Free Enterprise in Space

Senator Cruz, Senator Markey and Members of the Subcommittee:

My name is Michael J. Listner, and I am an attorney licensed to practice law in and before the state and Federal courts of the State of New Hampshire. I am also the Founder and Principal of the legal and policy consultation firm, Space Law and Policy Solutions and the editor of the space law and policy briefing-letter *The Précis*.

On July 4, 1982, President Reagan steered the United States on a path to permit private actors to perform activities in outer space per his executive order found in National Security Decision Directive Number 42 (NSDD-42). Congress subsequently supplemented the leanings of President Reagan and passed the Commercial Space Launch Act of 1982 (Public Law 98-575), which created a private interest for non-governmental actors to perform outer space activities pursuant to licensing and regulation through the Department of Transportation.

The implementation of both NSDD-42 and Public Law 98-575 has been followed by successive Administrations and Congress who have laid out further directives both through superseding executive orders most recently in PPD-42 and legislation amending Public 98-575 most recently with the Commercial Space Launch Competitiveness Act of 2015 (Public Law 114-90). These directives and legislation have the effect of directing agencies of the United States Government to encourage the development of commercial space activities as opposed to strictly government space activities.

The direct result of these initiatives is the creation of a new economic sector that has vast potential. The realm of commercial space is found most prolifically in new commercial space launch companies who not only provide launch services for commercial satellites but also national security and eventual crewed missions to the International Space Station. There has also been an upsurge of companies offering the promise of a gambit of outer space activities from sub-orbital and orbital tourism and even harvesting of space resources from celestial bodies like the Moon and asteroids. In each of these cases, the Executive Branch and Congress have created or need to create a conducive legal and regulatory environment to facilitate these activities.

The call to reduce regulations from the commercial space industry is a consistent one and the focus of this Subcommittee’s hearing. Indeed, regulatory and licensing requirements are a stepping stone for private actors to bring their commercial activities to fruition but also represent an actual expense and time impediment to these proposed activities. However, the answer to the industry’s call does not lie in completely deregulating the commercial space industry.

The United States has ongoing legal obligations to the international community through treaty commitments, including the Outer Space Treaty, which among other obligations requires the government to “authorize” and “continually supervise” the activities of non-governmental entities. These international legal obligations, while imputed to the United States government, are executed and exercised by the Commercial Space Launch Act of 1984 and successive commercial space laws passed by Congress and signed into law by the Executive Branch. Regulation in some form is necessary for the commercial space industry if not only to meet the United States’ international legal obligations under treaties like the Outer Space Treaty, then to address national security and public safety. That said, regulation need not be prescriptive in nature but could take the form of performance-based regulations or has been proposed to take the form of self-regulation by the industry itself.

Ancillary to the issue of regulation is the extent to which private space activities will begin to move beyond the bounds of what was foreseen under the current body of international space law. Issues like real property rights for private actors in particular is one that is coming to the forefront, yet the current state of international space law does not provide for it. Indeed, issues like real property rights raises the

temptation to make interpretations of international space law that might form a favorable customary interpretation to benefit commercial space activities. Considering the ability of the United States to create customary international law and binding interpretations through its actions as a state, this Committee would be prudent to consider not only the immediate effect of adopting interpretations of the Outer Space Treaty that may be outside the province of current international space law but the long term effects of those interpretations as well.

That said, the time may come where the Outer Space Treaty itself may become an impediment to developing and exploiting outer space. At this point, it may be necessary to review the United States' participation in this foundational Treaty and take steps to withdraw and refashion outer space law to be more responsive to the needs of commercial space actors. This type of consideration is not to be taken lightly and the consequences must be fully examined if it is decided to do so at some future point.

In conclusion, I respectfully request this Committee consider the gravity of international treaty obligations when it discusses the future regulatory environment of the commercial space industry. Regulation of the commercial industry need not be non-existent or overly burdensome but rather it is plausible to strike a proper balance that encourages the expansion of commercial space activities and satisfies the legal obligations of the United States.

Respectively submitted,

MICHAEL J. LISTNER.

cc: Senator John Thune (R-SD), Chair, Senate Committee on Commerce, Science, and Transportation

Senator NELSON. I would say, in closing, Mr. Chairman, that, shortly, we expect the Vice President to be announced as the head of a re-established Space Council in the White House. I think this is a good step, and I think it will allow us, as Members of Congress, to work much more easily with a group that is dedicated to focus on the space program, and that will, I think, improve the lines of communication considerably.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Nelson.
Senator Udall.

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

Senator UDALL. Thank you, Chairman Cruz, very much.

And thank you to this excellent panel for your insightful testimony here today, and Chairman Cruz for focusing in on this subject.

Last Saturday was Earth Day, and the first March for Science took place across the country—I was in Santa Fe at one of the 600 marches across the globe—to highlight the importance of scientific research at a time when many scientists, and especially climate scientists, believe they are under attack from the Trump administration. American leadership in science put a man on the Moon. This committee has a responsibility to stand up for science, to stand with researchers and innovators who keep America at the cutting edge of science and technology.

The commercial space industry, I think, is a great example here. Suborbital spaceflight from Spaceport America in my home state of New Mexico will soon be a reality. George, you mentioned that in your opening statement. Commercial space companies are aiming for the stars, and this committee has an important role to help them reach this new frontier, as emphasized by the questions before me.

Mr. Whitesides, many New Mexicans hope to see full commercial spaceflight operations begin as soon as possible. Sir Richard Branson said that he would be very disappointed if Virgin Galactic's commercial service is not well underway by the end of next year. Is that a realistic timeline?

Mr. WHITESIDES. It is, Senator, yes. We're well into test flight now, and we're looking forward to moving a fairly big transition of our staff to your state of New Mexico.

Senator UDALL. That's great, and as you know, New Mexico has invested, I think, \$200 million in that Spaceport. So we want to see you be a success there.

Mr. Rush, I was pleased to read in your statement about how Made In Space took advantage of NASA's Flight Opportunities Program to test a 3D printer on a low-cost suborbital flight, and I think Senator Nelson talked about that. This is exactly the kind of low-cost, high-impact success story I envisioned when fighting to authorize the Flight Opportunities Program in the 2009 NASA bill. Flight Opportunities costs less than one-one thousandths of the NASA budget, and I believe it delivers a big bang for the buck.

Mr. Rush and Mr. Whitesides, do you support funding for the NASA Flight Opportunities Program?

Mr. RUSH. Yes, absolutely. The Flight Opportunities Program is an integral portion of our technology development process, that we're able to take low-cost prototypes and expose them to micro-gravity and see if they work before we make more investments in that to put them into orbit.

Mr. WHITESIDES. Senator, I think it fits well with the ecosystem. Testing out space technologies in suborbital or other platforms and then moving those to the International Space Station and beyond is a terrific investment and allows great companies like Made In Space and others to prosper and grow. So we think it's a really exciting area for our American researchers.

Senator UDALL. Good. Thank you.

Mr. MEYERSON. If I may add, Senator—

Senator UDALL. Yes, please, Mr. Meyerson.

Mr. MEYERSON. Our *New Shepard* system which has been flying—we've already flown payloads at our own expense on the *New Shepard* rocket over the last year and are part of the Flight Opportunities Program. We support it. We think it's a great opportunity to get our students from K-12 all the way up to our scientists in national labs using space weightlessness as a science platform and demonstrating new things. So we're very excited about it.

Senator UDALL. Great. Thank you.

Mr. Bigelow, do you have a comment on that?

Mr. BIGELOW. Well, all of these activities are building blocks. They're all part of the entire mosaic that we're all trying to achieve. So I approve and applaud all these kinds of efforts.

Senator UDALL. Great.

Mr. Whitesides, your written testimony notes that Virgin Galactic worked extensively with the FAA's Office of Commercial Space Transportation when getting an operator's license for SpaceShipTwo. Given the growth in the commercial spaceflight industry, do you expect the resource needs for the FAA AST office to

grow as more and more commercial companies develop and launch space vehicles?

Mr. WHITESIDES. I do, Senator. The reality is that the AST is a very small fraction right now of the FAA's budget, and if you look to the horizon, all these exciting increases in volume is going to drive significant resource demands inside AST. I think relatively small increases from the perspective of the Federal budget would drive huge results in terms of enabling companies like ours, like Rob's, and others to quickly get to the operating line and moving out. So we really think—you know, it may be rare for companies to be pushing more funding for their regulators, but we really think that this is a case where it could be a good investment for the country.

Senator UDALL. Great. Thank you so much. We look forward to working with you.

Thank you, Chairman Cruz.

The CHAIRMAN. Thank you, Senator Udall.

Let's shift to a different aspect to focus on, which is, as we discussed earlier in the hearing, the United Nations Outer Space Treaty was enacted 50 years ago in 1967. How relevant is that Treaty today, and how do you see it impacting commercial operations for your company and others in space?

Mr. BIGELOW. I think the Treaty needs to be updated. I think there are aspects of that Treaty that should always be maintained, such as the prevention of nuclear weaponry in low Earth orbit or other remote places on foreign bodies or in deep space, whatever. But I think that that Treaty was cast in a time-frame where the United States and Russia didn't know who was going to be reaching the Moon first. There were concerns about proprietary possession, ownership of different—perhaps of that asset of the Moon. So the philosophy was different than today.

It was un-thought of at that time, I'm assuming, that commercial folks would have the wherewithal or the audacity to be thinking about traveling to the Moon and conducting business there. So I think it needs to be updated. I don't think that the updates are inconsistent with most of the language provided in the Treaty today.

The Treaty definitely provides for bases to be positioned by sovereign entities, to allow those sovereign entities to populate those bases with military personnel. The Treaty is mute on any reference to the size of those bases territorially. There are no geographic constrictions. There is no mention of the number of bases that you may have. So it's wide open, as we know. Not to pick on China, but the fact is that the Chinese Red Army controls their space program.

Now, I think that through the FAA AST efforts on sanctioning—or being aware not to sanction launches that could interfere with—payloads that could interfere if they were misdirected into somebody's activity on the surface is a start. I think there needs to be a geographic expansion or definition of what is that isolation stand-off distance. What should that be? It's possible that you could extend that to a patented mining opportunity to define the area in which cadastrals and monuments could be established as they have been for a great length of time here in this country and around the world.

It's very difficult to not want that if you're a company that is promoting mining. You're going to spend large amounts of money, risk people's lives, and you don't have some security of a geographical definition. You're not asking for ownership of the property, but ownership of what you extract in situ from that area.

So I think this is not inconsistent. The 1967 Treaty provides for—that each signatory to that Treaty needs to prepare methods of their own within each country of how they are going to behave to carry out the spirit of that Treaty, which is that all foreign bodies should be used in the interest of the common welfare of mankind. That doesn't exclude free enterprise by any means. Free enterprise hallmark is—free enterprise succeeds the best when it serves the public in the greatest way possible. So free enterprise is definitely consistent with serving mankind.

So I don't see any kind of discontinuity. The Treaty provides for these kinds of things because it leaves it up to sovereign countries to make these decisions, but it also could be updated. The risk of that is trying to get a consensus where you would actually be able to get a large population of countries to agree, I think.

The CHAIRMAN. Are there any specific updates to the Treaty that you think are necessary?

Mr. BIGELOW. I think good fences make good neighbors. I think that there needs to be some language that for the common good of mankind that activities are going to be exercised on the Moon, that there needs to be some specificity to conducting an operation under some geographic definition. And, again, as I said, the location of bases is permitted. There is no language as to how many or the size of those bases. One base could be the size of Texas, because there is nothing in that Treaty that says it couldn't be.

The CHAIRMAN. Now, you mentioned China in your testimony, and earlier this morning, you and I were visiting about a number of issues, including China. Could you share with this committee your concerns about China's lunar ambitions?

Mr. BIGELOW. I have a great respect for any company, any country, any people that achieve great things, and China falls into that category very much. So I respect China a great deal. I also have—I believe I have an understanding that's correct that China is very predisposed to ownership. Whether it's creating the islands in the South China Sea, whether it's properties in massive quantities that they purchased in South America or Africa, other places, whether you open a company and can only own 49 percent of it, they are very ownership minded. I think that that logically is possible to be extended in that philosophy to the Moon.

So I can see a scenario that's not unrealistic to me that China could exercise an effort to start to lay claim to certain lunar territories. They could do it the old fashioned way, by using lasers to mark the points, put down cadastrals and monuments, and, over time, acquire a very large amount of territory that might be in the select areas where there's constant sunlight and those kinds of things, you know, in terms of location, location, location on the Moon.

So I don't think it's a joke. I don't think it's something to be cavalier about. I think such an ownership consequence would have an amazing impact on the image of China, vis-à-vis the United States

and the rest of the world, if they should own large amounts of territory on that body, and we stood back and we weren't prepared. So it's a concept that I think deserves thinking about.

The CHAIRMAN. Do others on the panel share the concerns about China's ambitions? And I want to expand the question also to include the potential military threat of China in space, taking out space assets, potentially.

Mr. RUSH. I would say with respect to Chinese ambitions, you know, more folks launching into space and conducting space activities is generally a good thing. But there are certainly aspects—there are certainly technologies that they have stated, including our own technologies and the ability to manufacture in space, to manufacture large assets and assemble them in space, which we believe have a—provide an asymmetric advantage to the U.S. military, that we should be cognizant of other countries attempting to develop as we move forward.

The CHAIRMAN. Last year, Russia signaled that it might separate the Russian segment of the ISS from the American segment sometime between 2023 and 2024. What would it mean to the United States and to our space program if Russia were to separate from the ISS? And could you foresee Russia operating its own station or partnering with China in doing so?

Mr. BIGELOW. We've had some business relationships with the Russians, and we were treated very well. So what we learned is that they are very accomplished, and they tend to build things that are bullet-proof, you know, as an alternative to other approaches in terms of the way that you have a philosophy in creating space hardware.

I think it would be devastating to the Station, in my understanding, was initially created as a mechanism to do two or three or four different kinds of things, and one of those was to gather together a number of countries in a communal relationship that was unique. I think that the history of the Station ought to be that, when it's written—the cessation of the station ought to be in some kind of a context that emerges into something else that, if not profound, at least was amenable to everybody, and it wasn't a step going backward.

I would see a dislocation of those modules by the Russians as a step backwards, unless there was some kind of alternative agreement that said, "Well, they may do that, but, oh, by the way, we are doing other things here to continue the relationship between the two countries." And I don't see that that necessarily also is not applicable to China in some way. I wouldn't say that—again, it's not a zero sum game. I don't see these as being mutually exclusive.

The CHAIRMAN. Thank you.
Senator Peters.

**STATEMENT OF HON. GARY PETERS,
U.S. SENATOR FROM MICHIGAN**

Senator PETERS. Thank you, Mr. Chairman.

This first question is for Mr. Whitesides, but I certainly would love to have a response from all the panel. As we all know, certain countries have and continue to unfairly subsidize their commercial activity, and this undermines competitiveness of many U.S. compa-

nies in many different industries. But in many sectors, a clear line can be drawn between appropriate government support of industry versus anti-competitive business practices. For example, there's a difference between providing infrastructure and then awarding contracts with that underlying infrastructure versus state-owned enterprises that really undercut free market enterprise.

So my question is as the commercial space industry continues to mature, are you concerned that certain governments are going to undermine companies like yours?

Mr. WHITESIDES. We are, Senator, and I think it's something that Congress should maintain an awareness of and potentially to consider as it thinks about future actions. I think that the principles that we would think about are reciprocity—are American companies able to sell into that market? That's an important question. Often, that is not the case—and the creation of corporate entities whose sole purpose is to sell into the commercial marketplace, which often does not allow fair commercial competition.

So, you know, what we've done is invested hundreds of millions of dollars to create new commercial space platforms that we hope to compete successfully. We're asking for a fair shot, both in the U.S. markets and abroad. And because these markets are intrinsically global, if certain players are competing in different terms, then that's something that I think the Congress should be aware of.

Senator PETERS. It's global, but there are also a small number of players and it seems like because there are a small number of players that you're also more susceptible to potential anti-competitive behavior by other countries and their programs. Is that accurate?

Mr. WHITESIDES. Yes. There are certainly a limited number of operators around the world, and, you know, it's a very price sensitive market. So these are important issues, I think, for Congress to be thinking about.

Senator PETERS. Do others have concerns?

Mr. MEYERSON. I'd like to add—I mean, these space programs are a matter of national pride. They're national programs. So it is—you know, having a space program is something that any large government takes great pride in. I think we can take great pride in the innovation that's coming out of the United States aerospace industry with companies that are on this panel and others, and, certainly from my standpoint, demonstrating reusability, which has the greatest potential for lowering cost of access to space and increasing space access for all, not just Americans but people and payloads throughout the world.

So, yes, I agree with Mr. Whitesides that we want to make sure that we have a fair shot at access to these foreign markets. But we should take a lot of pride that that innovation is continuing in the United States, and if we can combine that with some of the regulatory streamlining I talked about earlier, I think it can help the U.S. broaden markets.

Senator PETERS. Thinking of the commercial space industry, is there a line that we draw between appropriate government support and anti-competitive behavior that we may see from other countries?

Mr. BIGELOW. It's tough to compete against operations that are government-supported financially, which is not uncommon.

Senator PETERS. Right.

Mr. BIGELOW. And so that's a significant challenge, because now you're competing against something with a very powerful money-printing partner capability. So that's certainly a significant challenge. How you regulate that or prohibit that, I don't know.

Senator PETERS. Right. Thank you very much. I appreciate it.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Peters.

I want to thank each of the witnesses for coming this morning. I think this has been a productive and informative hearing, and I thank you for the time and energy you have invested in being here and for the leadership you provide in commercial space. It is important, not just to your companies, but to the United States as a whole, to the national interest, and to the future.

The hearing record for this hearing will remain open for 2 weeks. During this 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, this hearing is now adjourned.

[Whereupon, at 11:30 a.m., the hearing was adjourned.]

A P P E N D I X

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MAGGIE HASSAN TO
ROBERT T. BIGELOW

Question 1. Space exploration creates vast opportunities for scientific discovery, advancing our knowledge here on Earth, and creating new and unique places for businesses to thrive. For decades, we as a nation have prioritized sound science in our academic institutions, and in our government. I recently called upon the President to continue this age-old tradition and act swiftly in appointing well-qualified experts to the Office of Science and Technology Policy so that our government can remain informed on areas where science affects our national security, economy, U.S. competitiveness, and innovation. Do you agree that we need leaders in our government who will focus on science and fact-based decision making for space exploration to thrive? Can you speak to how our Federal efforts in science and technology at NASA and in other areas of our government bolster or complement the work of the private sector?

Answer. I believe that we need leaders who understand that people with business acumen provide the necessary and valuable experience to enable free enterprise in space. The costs and risks associated with space exploration and utilization require more than just a fundamental understanding of science, but also economics and budgetary constraints to successfully move humans and spacecraft beyond Earth orbit. In order to effectuate good science and fact-based decision making, I believe that we need bold leadership to further the American ideals of life, liberty, and the pursuit of happiness in space. Bold leaders understand that to achieve success, one must accept the risk of failure and responsibly balance risks and rewards. I believe that continuing adaptive contracting vehicles such as Space Act Agreements and Other Transaction Authorities will bolster Federal efforts in science and technology because these vehicles enable the commercial sector to contribute as a partner in the technological development of space capabilities, sharing resources and risks across the public and private sectors.

Question 2. According to NASA, there are over 500,000 pieces of debris orbiting the Earth. This debris ranges in size from non-functional satellites, to fragmented debris as small as nickles and dimes, or even specks of paint. This debris travels around the Earth at speeds of up to 17,500 miles per hour, roughly ten times faster than a bullet. At these speeds even the tiniest bits of debris can cause damage, and windows on the Space Shuttle were replaced because of damage from tiny debris. In 2007, China blew up one of its satellites with a ballistic missile, creating over 3,000 new pieces of space debris. In 2013 Russian engineers confirmed that pieces of this debris collided with one of their satellites. In 2009 an active American satellite collided with an inoperative Russian satellite still in orbit. When this type of debris comes near the ISS the crew climbs into their escape pod and simply hopes nothing happens. With the increasing launches of micro-satellites and decreasing launch costs it is now easier than ever to launch craft into low Earth orbit, and the problem is likely to increase many times over. Do you believe that current processes and regulations in the United States are sufficient to mitigate the increase in space debris? Do you think that there are opportunities where we can improve our mitigation efforts without hindering commercial development of space?

Answer. I do not believe that commercial space activities will be the predominant source of future debris because commerce does not thrive in congested and contested environments. Commercial space actors are strongly incentivized to responsibly avoid generation of debris as fundamental to the success of their business operations. Rather, it is foreign and Federal governmental activities, particularly military, that have and may continue to create debris hazards. The focus of effort should be on establishing international standards among national space actors rather than domestic regulation of commercial actors already demonstrating responsible debris practices.

Question 3. I have a number of suppliers working on the Orion crew exploration program in my home state of New Hampshire. As many of you know, Orion is the next generation space vehicle that will be launched on the Space Launch System rocket in a few years, and will carry humans further into space than ever before.

The question I would like to ask is, How can the U.S. maintain a robust and functional industrial base that supports both government and commercial space activities?

Answer. The U.S. can maintain a robust and functional industrial base through the maximization and integration of the best business leaders and entrepreneurs into planning space activities that enable robust and innovative technologies for space exploration and utilization. The commercialization of traditional space activities enhances the American industrial base by incentivizing and enabling sustainable employment in technological and non-technological sectors while preserving limited Federal funding, through servicing both governmental and private customers. In particular, a company like Bigelow Aerospace can provide market certainty that there will be a destination to test technologies and other capabilities when we bring online two flight ready B330s at the end of 2020. In doing so, we will be able to provide an accessible, affordable pathway for inventors and creators to realize their efforts in commercializing their ideas, from terrestrial development to deployment in space. Providing regulatory certainty to commercial entities will enable the economies to grow and maintain a robust industrial base that can support both government and commercial space activities.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO
ROBERT MEYERSON

Question 1. What do you see as the biggest needs for enabling a dramatic increase in launch cadence at the Cape in terms of shared infrastructure, the licensing and approval process, scheduling and de-conflicting launches or other areas where we may be of help?

Answer. An increase in launch cadence at the Cape would be enabled by streamlining the regulatory process for reusable rocket launches from Federal Ranges. Currently Air Force safety requirements for launching reusable vehicles from a Federal Range are completely different from the Office of Commercial Space Transportation (AST) reusable launch vehicle license requirements, yet they claim to address the same goal: public safety. The presence of duplicative authorities creates an onerous approval process for the launch operators trying to make the biggest strides in this industry—those pursuing reusability. Efforts focused on aligning requirements and removing these duplicative authorities will ease the burden on commercial launch providers. Similarly, scheduling and de-conflicting launches from aviation users in the national airspace is a critical long-term need. FAA should address and prioritize with both AST and the FAA's Air Traffic Organization efforts to fully integrate commercial space activities as equal users of the national airspace system.

Additionally, supporting NASA Enhanced Use Lease In-Kind Consideration will also help the Cape by allowing NASA to cultivate public-private partnerships to transform underutilized real property, including launch and test infrastructure remaining from the Apollo and Space Shuttle eras.

Question 2. A number of emerging commercial space activities are not covered by existing regulatory authorities. We will need to provide the appropriate level of supervision for activities in space and we need to provide regulatory certainty for industry. The previous administration proposed expanding the Department of Transportation's jurisdiction to approve and authorize activities in space that aren't covered already by the FCC, Department of Commerce, or Department of Transportation. Do you think it makes sense to expand the purview of the Department of Transportation to approve new activities in space that are not covered under existing authorities? If not, what would you suggest as an alternative?

Answer. Blue Origin is open to the expansion of authorities at the Department of Transportation to meet U.S. obligations under the Outer Space Treaty for "authorization and continuing supervision" for activities carried on in outer space. This effort would require only a narrow expansion of DOT's authority and could be accomplished with minimal additional demand on existing resources. However, it is important to note that the FAA Office of Commercial Space Transportation is currently under-resourced to fulfill its existing mandates for launch, reentry, and spaceport needs. We would advocate for an increase in AST's resources, with a near-term prioritization of its current authorities prior to adding any additional responsibilities.

Question 3. What more does the FAA need to put in place to facilitate human spaceflight and how comfortable are you that the FAA will be ready when the time comes for you to start launching space flight participants?

Answer. The current human spaceflight learning period regime is appropriate and allows companies to create rigorous internal safety standards and robust test programs for unique systems as they are developed. Recently, AST has supported industry consensus standards efforts, and by continuing to do so, AST can ensure that industry focuses on the standards development AST considers most important for human spaceflight safety. When the time comes for AST to further regulate space vehicles for passenger safety, AST can build off the work the industry has already performed by requiring an operator's compliance with industry standards for FAA-licensed activities.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MAGGIE HASSAN TO
ROBERT MEYERSON

Question 1. Space exploration creates vast opportunities for scientific discovery, advancing our knowledge here on Earth, and creating new and unique places for businesses to thrive. For decades, we as a nation have prioritized sound science in our academic institutions, and in our government. I recently called upon the President to continue this age-old tradition and act swiftly in appointing well-qualified experts to the Office of Science and Technology Policy so that our government can remain informed on areas where science affects our national security, economy, U.S. competitiveness, and innovation. Do you agree that we need leaders in our government who will focus on science and fact-based decision making for space exploration to thrive? Can you speak to how our Federal efforts in science and technology at NASA and in other areas of our government bolster or complement the work of the private sector?

Answer. Blue Origin agrees that the country needs government leaders who focus on science and fact-based decision making for this industry to thrive. The work done by NASA and other government agencies has undeniably facilitated the growth of the private space sector. As the private space sector has developed, NASA has played a significant role as a partner and customer, and the two have become inextricably linked. Programs such as Commercial Crew and Cargo, DARPA's XS-1 spaceplane program, and even the Department of Defense national security space launch programs are all examples of how the private sector and government complement each other to achieve shared interests. Emerging NASA programs like Flight Opportunities and NextSTEP continue to further this legacy by encouraging competition, utilizing innovative cost share approaches, and supporting industry-agency knowledge exchange.

Question 2. According to NASA, there are over 500,000 pieces of debris orbiting the Earth. This debris ranges in size from non-functional satellites, to fragmented debris as small as nickles and dimes, or even specks of paint. This debris travels around the Earth at speeds of up to 17,500 miles per hour, roughly ten times faster than a bullet. At these speeds even the tiniest bits of debris can cause damage, and windows on the Space Shuttle were replaced because of damage from tiny debris. In 2007, China blew up one of its satellites with a ballistic missile, creating over 3,000 new pieces of space debris. In 2013, Russian engineers confirmed that pieces of this debris collided with one of their satellites. In 2009, an active American satellite collided with an inoperative Russian satellite still in orbit. When this type of debris comes near the ISS the crew climbs into their escape pod and simply hopes nothing happens. With the increasing launches of micro-satellites and decreasing launch costs it is now easier than ever to launch craft into low Earth orbit, and the problem is likely to increase many times over. Do you believe that current processes and regulations in the United States are sufficient to mitigate the increase in space debris? Do you think that there are opportunities where we can improve our mitigation efforts without hindering commercial development of space?

Answer. We believe current processes and regulations are sufficient, but we also understand the increasing burden on the Department of Defense in tracking space debris and facilitating collision avoidance among commercial entities. Currently, internationally recognized debris mitigation guidelines must be met by industry prior to receiving any FCC, NOAA, or FAA licenses for space operations. We support and encourage advancements in technologies with the objective of removing space debris and enhancing collision avoidance. Furthermore, commercial entities have access to data and tools for conducting conjunction analyses and maintaining space situational awareness, and have expressed willingness to partner with the government on this crucial task. While we appreciate DOD's desire to transfer this func-

tion to a civil agency, we strongly encourage the fullest possible utilization of commercial capabilities as a near-term solution.

Question 3. I have a number of suppliers working on the Orion crew exploration program in my home state of New Hampshire. As many of you know, Orion is the next generation space vehicle that will be launched on the Space Launch System rocket in a few years, and will carry humans further into space than ever before.

The question I would like to ask is, How can the U.S. maintain a robust and functional industrial base that supports both government and commercial space activities?

Answer. A robust industrial base is enabled by setting clear U.S. Government civil and national security space goals. The government plays a critical role by being a reliable customer and a promoter of innovation while reducing regulatory barriers and burdens. We believe it is better for the U.S. Government to be one among many customers for the commercial space industry, as opposed to shouldering the entire industrial base.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO
GEORGE WHITESIDES

Question 1. What do you see as the biggest needs for enabling a dramatic increase in launch cadence at the Cape in terms of shared infrastructure, the licensing and approval process, scheduling and de-conflicting launches or other areas where we may be of help?

Answer. Support and encouragement for autonomous flight termination systems, and how those systems interface smoothly with the national airspace system.

Support for standardized launch licenses that permit multiple standard launches on a given flight path, similar to suborbital reusable flights.

Continued government support for physical infrastructure—roads, bridges, rail, seaport, etc.

Assistance on delivery of critical utilities and commodities such as power, water, communications, propellants and hazardous material handling.

Continue support for infrastructure of safety, security, and response.

Support for “lifestyle infrastructure” so that the Cape can attract the best and brightest new talent.

Question 2. What more does the FAA need to put in place to facilitate human spaceflight and how comfortable are you that the FAA will be ready when the time comes for you to start launching space flight participants?

Answer. Currently the Office of Commercial Space (AST) within the FAA has been great to work with for the licensing of our human spaceflight vehicle. They have been doing great work in preparation of human spaceflight, like recently releasing guidelines for informed consent. However, as we move from test flight to commercial operations for the launch of space flight participants, AST needs increased resources to accommodate the increased launch cadence. In addition, as we gain more flight data and continuously improve our systems, AST should also maintain up to date regulations that take into account the latest commercial technology in use. This takes resources that AST does not currently have.

Question 3. A number of emerging commercial space activities are not covered by existing regulatory authorities. We will need to provide the appropriate level of supervision for activities in space and we need to provide regulatory certainty for industry. The previous administration proposed expanding the Department of Transportation’s jurisdiction to approve and authorize activities in space that aren’t covered already by the FCC, Department of Commerce, or Department of Transportation. Do you think it makes sense to expand the purview of the Department of Transportation to approve new activities in space that are not covered under existing authorities? If not, what would you suggest as an alternative?

Answer. Much like the current launch environment, we need a stable, predictable, and permissive regulatory environment that promotes innovation. This can take many forms, but the regulatory environment should be one that allows for sustainable and efficient processes for commercial companies to do business.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MAGGIE HASSAN TO
GEORGE WHITESIDES

Question 1. Space exploration creates vast opportunities for scientific discovery, advancing our knowledge here on Earth, and creating new and unique places for businesses to thrive. For decades, we as a nation have prioritized sound science in

our academic institutions, and in our government. I recently called upon the President to continue this age-old tradition and act swiftly in appointing well-qualified experts to the Office of Science and Technology Policy so that our government can remain informed on areas where science affects our national security, economy, U.S. competitiveness, and innovation. Do you agree that we need leaders in our government who will focus on science and fact-based decision making for space exploration to thrive? Can you speak to how our Federal efforts in science and technology at NASA and in other areas of our government bolster or complement the work of the private sector?

Answer. Many of the current efforts in science and technology development use commercial services in one way or another, but there is room for increased partnership with industry. For example, NASA's Flight Opportunities Program provides commercial suborbital flights for technology development payloads to raise the TRLs of technology critical to the mission of the agency. Another program within NASA, called Venture Class Launch Services, uses commercial small launch providers to launch small satellites from the Science Mission Directorate to perform low-cost, high-value science. Programs such as these, and others that use commercial services to provide an opportunity to do cost-effective and frequent research and technology development will further the agency's work in a fiscally-responsible yet innovative way.

Question 2. According to NASA, there are over 500,000 pieces of debris orbiting the Earth. This debris ranges in size from non-functional satellites, to fragmented debris as small as nickles and dimes, or even specks of paint. This debris travels around the Earth at speeds of up to 17,500 miles per hour, roughly ten times faster than a bullet. At these speeds even the tiniest bits of debris can cause damage, and windows on the Space Shuttle were replaced because of damage from tiny debris. In 2007, China blew up one of its satellites with a ballistic missile, creating over 3,000 new pieces of space debris. In 2013 Russian engineers confirmed that pieces of this debris collided with one of their satellites. In 2009 an active American satellite collided with an inoperative Russian satellite still in orbit. When this type of debris comes near the ISS the crew climbs into their escape pod and simply hopes nothing happens. With the increasing launches of micro-satellites and decreasing launch costs it is now easier than ever to launch craft into low Earth orbit, and the problem is likely to increase many times over. Do you believe that current processes and regulations in the United States are sufficient to mitigate the increase in space debris? Do you think that there are opportunities where we can improve our mitigation efforts without hindering commercial development of space?

Answer. Virgin is committed to running a long-term sustainable space business, and this includes preserving access to space by preventing and managing debris. With the success of small satellite technology and business cases, we will indeed begin to see increased activity on orbit. One opportunity to improve mitigation efforts without hindering commercial development of space would be to begin efforts, with industry, to review and revise existing IADC space debris mitigation efforts that were put into place over 25 years ago. Such a review would likely reveal that there are a number of ways in which the U.S. could lead a collaborative global effort to minimize future space debris.

Question 3. I have a number of suppliers working on the Orion crew exploration program in my home state of New Hampshire. As many of you know, Orion is the next generation space vehicle that will be launched on the Space Launch System rocket in a few years, and will carry humans further into space than ever before.

The question I would like to ask is, "How can the U.S. maintain a robust and functional industrial base that supports both government and commercial space activities?"

Answer. The exploration of space will always include both government and commercial space activities. To maintain a robust industrial base:

First and foremost, the United States should seek to implement policies that encourage private sector innovation and minimize regulatory burdens. The industrial base is rarely a problem in vibrant and growing industries.

As the U.S. Government seeks to develop new and innovative space capabilities, it should encourage partnership with the commercial space sector. This will allow Government programs more capability to achieve agency goals in a cost-effective manner, and create a healthy industrial base in the U.S. for both civil and defense purposes.

The Government should refrain from using taxpayer dollars to fund programs that directly compete with commercial available or emerging services. There are many missions and objectives within NASA that only the U.S. Government has the ability to fulfill—however, by using commercially available services where available,

the Government can make greater use of its unique in-house capabilities to explore further and achieve once inaccessible destinations.

When partnering with the commercial industry, government should strive to use firm-fixed price contracts and efficient acquisition strategies. Overly burdensome and costly contracting methods will stifle private sector innovation and shrink the commercial space industrial base in which government could benefit from.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MAGGIE HASSAN TO
ANDREW RUSH

Question 1. Space exploration creates vast opportunities for scientific discovery, advancing our knowledge here on Earth, and creating new and unique places for businesses to thrive. For decades, we as a nation have prioritized sound science in our academic institutions, and in our government. I recently called upon the President to continue this age-old tradition and act swiftly in appointing well-qualified experts to the Office of Science and Technology Policy so that our government can remain informed on areas where science affects our national security, economy, U.S. competitiveness, and innovation. Do you agree that we need leaders in our government who will focus on science and fact-based decision making for space exploration to thrive? Can you speak to how our Federal efforts in science and technology at NASA and in other areas of our government bolster or complement the work of the private sector?

Answer. Reasoning based on sound scientific and technical analysis is crucial to a sustainable, thriving space exploration program. It is also critical for space-based industry to profitably grow. Technology development by NASA and other government agencies are a critical engine of economic development. Via the SBIR program, initial technology development is done which is often too risky or speculative for private investment. Once developed, products, services, and sometimes entire sectors flourish, based on the government funded work. For example, NASA SBIR funded research into 3D printing in space. Now, Made In Space is operated a commercial 3D printing facility on the ISS and manufacturing parts for customers in space on a routine basis. While SBIR excels at transitioning technologies on the lower end of the Technology Readiness Level (TRL) spectrum, programs like the Tipping Point Program from NASA's Space Technology Mission Directorate, facilitate further development and commercialization of new technology. This ensures that returns are realized on initial investments and that technology is available at a cost effective rate for NASA and other government agency use.

Question 2. I have a number of suppliers working on the Orion crew exploration program in my home state of New Hampshire. As many of you know, Orion is the next generation space vehicle that will be launched on the Space Launch System rocket in a few years, and will carry humans further into space than ever before.

The question I would like to ask is, "How can the U.S. maintain a robust and functional industrial base that supports both government and commercial space activities?"

Answer. The U.S. can maintain a robust and functional industrial base that supports both government and commercial space activities by: (1) clearly defining intellectual property rights for commercial companies operating in space, including aboard U.S. assets and the International Space Station (ISS); (2) providing for a transition plan in Low Earth Orbit from the ISS to commercial space stations; and (3) making continued investment in space technology development via NASA's Space Technology Mission Directorate, the Advanced Explorations Systems division of the Human Exploration and Operations Mission Directorate, the ISS Program Office, and others.

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