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# MOON LANDINGS TO MARS EXPLORATION: THE ROLE OF SMALL BUSINESS INNOVATION IN AMERICA'S SPACE PROGRAM

## FIELD HEARING

BEFORE THE

## COMMITTEE ON SMALL BUSINESS AND ENTREPRENEURSHIP UNITED STATES SENATE

ONE HUNDRED SIXTEENTH CONGRESS

FIRST SESSION

JULY 19, 2019

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COMMITTEE ON SMALL BUSINESS AND ENTREPRENEURSHIP

ONE HUNDRED SIXTEENTH CONGRESS

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ALPHABETICAL LISTING

# MOON LANDINGS TO MARS EXPLORATION: THE ROLE OF SMALL BUSINESS INNOVATION IN AMERICA'S SPACE PROGRAM

**FRIDAY, JULY 19, 2019**

UNITED STATES SENATE,
COMMITTEE ON SMALL BUSINESS
AND ENTREPRENEURSHIP,
*Merritt Island, FL.*

The Committee met, pursuant to notice, at 11:30 a.m., in Room M6–306, Kennedy Space Center Visitors Complex, Hon. Marco Rubio, Chairman of the Committee, presiding.

Present: Senators Rubio and Scott.

Also Present: Mr. Waltz.

## OPENING STATEMENT OF HON. MARCO RUBIO, CHAIRMAN, A U.S. SENATOR FROM FLORIDA

Chairman RUBIO. The Senate committee on Small Business and Entrepreneurship will come to order. I want to thank everyone for being here today. I want to especially begin by thanking our witnesses. I want to thank my colleague from Florida, Senator Scott, and Representative Waltz also from Florida, who are here serving as honorary members of the committee today as well. I also want to recognize a couple of our State officials that are here. State Senator Tom Wright and thank you for being here. My friend Debbie Mayfield, State Senator Debbie Mayfield. We have known each other for a long time. And also State Representative Thad Altman who I have also known for a long time. He is the CEO of the Astronaut Memorial Foundation, which is our host here today, and we want to thank him for that. I am pleased everyone can be here, and of course, a special thanks to the Kennedy Space Center for welcoming us.

So the hearing today is about the role of small business innovation in America's space program, and since the 1960s, this Center has served as the world's leading human space flight launch center. There is frankly no more appropriate or more fitting place to mark the 50th anniversary of humanity's first steps on the moon than in this place, the place from which the Apollo 11 mission launched our brave astronauts. There is also no better place to look forward to what the next 50 years of space exploration will require than here at the Nation's premier spaceport. It is from this place America launched the first human to the lunar surface, solidifying the United States as a dominant world leader in space achievement.

And of course, there is no better place to examine the critical role of small business in America in space exploration than our State of Florida. It is the space capital of the world, and it is America's gateway to the stars. Fifty years ago, Neil Armstrong and Buzz Aldrin left mankind's first steps on the moon. The Apollo lunar landing and returning the astronauts safely back to Earth was the greatest technical achievement the world had ever seen. It was an astonishing testament to the spirit of American ingenuity, exploration, and courage. It was also a testament to the strength of America's commitment to national development. It took a nationwide dedication to our own innovation and advancement, to power and achievement as monumental as the lunar landing. It took partnerships between the government and private businesses working together to build possibilities that did not previously exist.

The shared commitment that took us to the moon is essential if we are to remain the global leader in space exploration, and it is essential that America does remain the leader in space because there is a lot at stake. Our national security depends on American leadership in space and our continued innovation in space-based technology. The success of American space exploration is shared with our local communities. The Kennedy Space Center alone is responsible for approximately 20 to 3,000 jobs here in the State of Florida. It contributes more than $3.9 billion in total economic impact to the State. When we consider aerospace in the context of national defense, the economic impact is even larger. Patrick Air Force Base, Cape Canaveral Air Force Station, and the Naval Ordnance Test Unit together account for over 47,000 jobs and over $5.3 billion in total economic impact in Brevard County alone. Florida is a global leader in the aerospace industry with dozens of innovative companies focused on manufacturing, commercial space flight, and aeronautics.

Finally, I believe that great nations do great and remarkable things. I always tell the story of my grandfather. He was born in 1899 in rural Cuba. So if you think about, if you are born in 1899 in rural Cuba, there aren't even airplanes. You have never seen anything flying in the sky that is man made. And then in 1969, he watched an American step foot on the moon. And I recall him telling me that when he saw that image is when he knew for sure that Americans could do anything, and I think we all know him to have been right in that assumption. We have an obligation to our children to ensure that we are living up to that potential. Getting it right is not inevitable. Leading the advanced industries of the 21st century is a necessity. Innovating our way back to the moon, and to Mars, and beyond, must be prioritized.

Since the last time we visited the moon, research and development spending has fallen meaningfully. Our economic status quo has allowed too many advanced manufacturing jobs to depart our shores to places like China and elsewhere. China has dedicated itself to dominating the critical industries of the 21st century, and one of those is space. We need to commit ourselves to catalyzing the kind of innovation that will maintain our technological edge and our leading role in space exploration. We need to commit to the big ideas that may seem impossible but are worthy investments,

much like the ones made that took us to the moon over 50 years ago.

Small businesses have always been critical to our efforts in space and will continue to be in the future. Numerous small businesses throughout the history of American space exploration have done the research and development to provide critical components that have enabled Americans to safely launch and return to the moon and back. NASA has expressed this commitment to partnership with small- and medium-sized businesses since its early days and it continues to do so now. I applaud NASA's recent decision to invest more than $45 million in innovative small business through its Small Business Investment Research Program. NASA also recently announced that it has awarded $106 million for 142 Phase II proposals covering 28 States. These awards will help develop technologies that, among other things, will help humans live on the moon and Mars. The Small Business Innovation Research and Small Business Technology Transfer Programs are critical tools in strengthening the partnership between the Federal Government and innovative small businesses. These programs have been proven time and again as impressive examples of what investment in research and development by small businesses can accomplish. Because of these programs, firms like Made In Space, who we welcome as a witness today, have been able to pioneer the development of 3D printers to manufacture structures and microgravity.

The Navy found in a study of their SBIR and STTR programs from the Fiscal Years 2000 to 2013 that $2.3 billion in investment into these programs generated an economic output of $44.3 billion—$2.3 billion generated $44.3 billion. That kind of return on investment is astonishing, and it is something that we should be encouraging as policymakers. The committee that I chair, this committee, is currently working hard to reauthorize our Nation's Small Business Act and modernize the programs of the SBA, including the SBIR and STTR programs. And chief among these improvements is making these outstanding programs permanent in law which will provide certainty and will improve their performance.

Using the SBA to promote innovation, including in space-related technologies, is indispensable if we are to return American development to where it needs to be at home and in space. America's future will be the result of ingenuity and investment of real assets, like the materials and components that small businesses have been innovating for the space program since its early days. If an American is to be next to walk on the moon, Mars, or beyond, he or she will do so as a direct result of our investment in small businesses and technologies that they can create.

Now, I want to recognize Senator Scott.

## OPENING STATEMENT OF HON. RICK SCOTT, A U.S. SENATOR FROM FLORIDA

Senator SCOTT. First it is great to be here. I want to thank Senator Rubio for hosting this here. Thank him and Congressman Waltz for their unbelievable commitment to NASA and for space exploration. I want to thank my predecessor Senator Nelson for his commitment to NASA. I want to thank my own State government.

When I became Governor a little over eight years ago, manned flight had stopped here, thousands of jobs have been lost, and with Debbie and others, Thad and others' commitment, we invested over eight years $230 million to get more jobs here. And you can see the names of all of the buildings of these big companies like Blue Origin, and SpaceX, and OneWeb, and what they are doing is they are helping a lot of small businesses prosper. And a lot of—this is unbelievable the growth here and how we do not have enough engineers, which is a good problem.

I want to thank Dr. Cabana for his absolute commitment to bringing in the private sector and making sure that this is a place that could prosper when we found out less expensive ways and more effective ways and faster ways to get to space. And it would not have happened but for Dr. Cabana's absolute commitment, so I want to thank him for that.

I just had the opportunity to come visit the Visitors Center and the best thing out of it was I brought seven-year-old and a five-year-old grandson, and I talked to my seven-year-old—both of them couldn't believe I was not bringing them back today and told me how interesting this would be, and they would love to sit here for a couple of hours and listen to everything. But the seven-year-old told me that his plan is he is going to be the first person on Mars. And so that would be—and as Governor my goal was that every kid in the State believe they could be anything, and so if we can get every child in this country to see the value of becoming the next astronaut to get to wherever, think about we are going to get, what is going to happen.

So it is great to be here. I am on the Commerce committee. Mr. Bridenstine has already testified a couple of times. He was there last week. He is absolutely committed to making sure—as long as I know, everybody I know is absolutely committed to getting the funding to make sure we not only get to the moon, but we get to Mars as quickly as we can in a safe manner. By the way, my grandson said it is completely safe to go to space now. There is no risk.

[Laughter.]

So I am sure that is absolutely true. So it is great to be here, and I look forward to hearing everybody's points.

Chairman RUBIO. Well, I am glad to hear that because apparently, NASA is offering either you or I a chance to go to space because——

Senator SCOTT. I thought that was my spot.

[Laughter.]

**STATEMENT OF MIKE WALTZ, REPRESENTATIVE, 6TH DISTRICT OF FLORIDA**

Mr. WALTZ. Well, thank you. Thank you, Senator Rubio and Senator Scott. I am joined today, I will embarrass her a little bit, by my 15-year-old daughter Anderson here in the audience and taking her through the launch sites this morning. Thank you, Bob, for your time this morning. Was just truly an honor as an American, as a soldier, as a businessman standing here where it all happened, this week, is really special, and thank you for holding us this week.

You know, when I was reading the book Moonshot over the last couple of weeks and just realizing that when President Kennedy made his famous speech, his second State of the Union as it was called at the time, saying that we would go to the moon before the end of the decade, there was no rocket capable of doing it, there was no spaceship, heck, there was not even a computer small enough to power any of these things in the moon. And he ended up garnering—unbelievable now that I am in Congress—garnering the support of the Congress for the equivalent in today's dollars of $280 billion, 4% percent of our national budget to unify the country to be able to achieve such a great feat. It is just, I think, worth remembering, and it has certainly been inspiring to me and should be inspiring to all of us.

That said, I do feel like as a member of both the Armed Services committee where I see the military side of what is going on in space, both on our side and our adversaries', and then also in the Space committee with oversight of NASA, NOAA, and the civilian side of space, I do feel compelled to ring the alarm bells to some degree. We are no longer alone up there, and we cannot take for granted American leadership in space.

The Chinese and Russians have and are continuing to develop the ability to take down our infrastructure through anti-satellite weapons, through killer satellites, through lasers, through different types of cyberattacks, and it is, I think, worth reminding everyone and continuing to educate everyone how the dependencies we have now in our own economy in 2019 that we did not have in 1969, from our banking system to our financial systems, to how things arrive in Walmart from around the world at a cost-effective price, and then of course from a military standpoint, the Russians and Chinese have stated explicitly, publicly that if we ever have any type of conflict, that they are not going to match us tank to tank or plane to plane, it is going to be the infrastructure in space that all of that depends on.

It is also worth remembering that the Chinese do not have a NASA equivalent. Everything that they are doing in space has the Chinese military behind it. Their new space station, their plan to put a manned station on the moon, all will be there for military purposes. And it is not just them. The Indians are going to the moon. The Israelis are going to the moon. The Chinese and the Russians, of course, have done so and planned to do so. So the United States needs to step up.

I think the Congress needs to step up, and we need to compete and lead. Part and parcel, and the tip of the spear for that leadership will be Florida, of course, and I think the engine will be the private sector. I also served as a small business CEO that competed and won and grew our company on government contracts. That was an incredible experience. Could also be a very painful experience. As I am looking a lot of people nodding around the room. I have walked the walk, whether it comes from bid protest to RFPs, to what it takes, I think, to be able to also serve through the private sector. What I love about the civil program at my company—we have participated in it—is everything that has come from it, from anti-icing to virtual reality, to surgical robots. So many amaz-

ing spin-offs have come from this program. And I thank you again for looking at how we can further it.

And then finally I will just leave us with, we can never lose sight of the human capital piece of this. Just in the North of here, in my district, we have Embry-Riddle Aeronautical University, with the premier Aeronautical University in the world, Daytona State, which really focuses on the vocational pieces, but importantly STEM education and that STEM has to start before secondary school and has to start before higher education. It has to start in elementary school.

There is an amazing Elementary School in Oak Hill just to the North of the cape called Burns Science and Tech where you have kindergarteners coding and building robots, and half of every class are girls. And we have to improve the diversity that is in STEM education.

So America must continue to lead the bottom line. It is competitive space and this type of conversation I think is absolutely critical to that leadership and having that public-private partnership be the engine for America's future in space.

Thank you.

Chairman RUBIO. Thank you. Let me bring in the first panel here. Robert Cabana, the Director of the John F. Kennedy Space Center. He is our gracious host. Thank you for having us. He is responsible for all NASA facilities and activities, which as you can imagine is no small task, but he is also a veteran of four spaceflights. Has logged 38 days in space. He is a distinguished member of the Astronaut Hall of Fame and is a recipient of the distinguished Flying Cross. He was commissioned Second Lieutenant in the U.S. Marine Corps and completed Naval flight officer training in Pensacola in 1972. Thank you for being here and for allowing us to have this hearing. We also have Ms. Jenn Gustetic?

Ms. GUSTETIC. Gustetic.

Chairman RUBIO. Gustetic. I practiced last night——

[Laughter.]

Is the Program Executive at SBIR, STTR Program Management Office at NASA headquarters. She served in numerous roles prior to this one, including serving in the White House Office of Science and Technology Policy. She is a graduate of MIT, but most important of all she is a graduate of the University of Florida.

[Laughter.]

Go Gators. Thank you for being here. So, Mr. Cabana, I will recognize you first for opening statements.

## STATEMENT OF ROBERT CABANA, DIRECTOR, JOHN F. KENNEDY SPACE CENTER, MERRITT ISLAND, FL

Mr. CABANA. Chairman Rubio, thank you for the opportunity to appear today to discuss Kennedy Space Center's partnerships with the business community, especially small businesses as we enter a new period of space exploration with the Artemis Program that will take us forward to the moon. I have submitted a written statement for the record, but I would like to make a few brief remarks. NASA's John F. Kennedy Space Center is the Nation's preeminent multi-user spaceport for both government and commercial access to space.

KSC's rich history dates back to 1962 when it was first established as the NASA Launch Operations Center. Our many accomplishments include those first steps on the moon whose 50th anniversary we celebrate tomorrow, 30 years of space shuttle operations, the completion of the International Space Station, and very soon the return of U.S. astronauts to space on U.S. rockets from U.S. soil right here at the Key with our Commercial Crew Program.

We have also played an integral role in NASA science missions, expanding our knowledge of the universe and our home planet. Today, Kennedy is an integral part of the local community, providing nearly 10,000 jobs for civil servants, contractors, tenants, and construction crews. NASA partners with more than 90 companies across private, academic, and public sectors, and small business is well represented in those partnerships. NASA has been charged with landing the first woman and next man on the moon by 2024 with the Artemis Program. Small businesses will play a critical role in our success as we move forward in partnership with our commercial partners, establishing a sustainable human presence on the moon by 2028.

Using what we learned from the moon, we will take the next giant leaps, sending astronauts to Mars as we establish a presence in our solar system beyond our home planet. When I served as Commander of Endeavour on STS–88, the first space station assembly mission, I noted in the first log entry, from small beginnings great things come. Since then, the ISS has served as a world-class microgravity laboratory, a superb engineering testbed, and a model of international partnership for the future. Today NASA is opening the International Space Station for commercial business so U.S. industry, innovation, and ingenuity can accelerate a thriving commercial economy in low Earth orbit.

Since the first log entry of the ISS and during my tenure as Director here at the Kennedy Space Center, I have watched many small beginnings grow into something greater. J.P. Donovan Construction was a small business started in nearby Rockledge, Florida. This general construction firm now specializes in aerospace steel fabrication and marine construction. They worked with the Exploration Ground Systems Program here on the refurbishment of historic Launch Pad 39B to support the upcoming test flight of SLS that will send the Orion spacecraft around the moon on Artemis 1. They also made significant structural modifications on the mobile launcher for the initial Artemis missions as well as installing the systems on it.

J.P. Donovan Construction has been in business for 27 years now, and thanks to their work for NASA and KSC, they are no longer a small business. They have grown and now serve other defense contractors, port authorities, and local governments, including several beach restorations serving our coastal community. Our goal at KSC is to help small businesses navigate the world of government contracting and provide private industry with maximum business opportunities at KSC by increasing contracting competition and strengthening socioeconomic programs.

KSC has exceeded all goals for the past two years, and NASA received an A grade on the most recent SBA small business score-

card. As of July 8th, KSC's total expenditure this year for small business is more than $159 million. The NASA's Small Business Innovation Research and Small Business Technology Transfer Programs fund the research, development, and demonstration of innovative technologies that fulfill NASA's needs and have significant potential for successful commercialization. These programs are vital to NASA and to our Nation's prosperity and security, and KSC is very proud of the role we play in helping these programs succeed.

Mr. Chairman, Senator Scott, Representative Waltz, thank you for your time and attention this afternoon, and more importantly, thank you for support of NASA and America's space program.

[The prepared statement of Mr. Cabana follows:]

**Moon Landing to Mars Exploration:**
**The Role of Small Business in America's Space Program**

**Statement of**

**Robert Cabana**
**Director, Kennedy Space Center**
**National Aeronautics and Space Administration**

**Before the**

**U.S. Senate Committee on Small Business and Entrepreneurship**

Chairman Rubio, Ranking Member Cardin and members of the Committee, thank you for the opportunity to appear today to discuss Kennedy Space Center's partnerships with the business community, especially small businesses, as we enter a new period of space exploration with the Artemis program that will take us forward to the Moon. We are going.

NASA's John F. Kennedy Space Center is the United States' preeminent multi-user spaceport, for government and commercial access to space. KSC's rich history dates back to 1962, when it was first established as the NASA Launch Operations Center. Accomplishments include those first steps on the Moon, 30 years of Space Shuttle operations, the completion of the International Space Station and soon, the return of astronaut launches from U.S. soil through the Commercial Crew Program. We have also played an integral role in NASA's science missions, expanding our knowledge of the universe and our home planet. KSC has led the way in innovative, efficient and cost-effective spacecraft processing, launch, and recovery.

Today, Kennedy is an integral part of the local economy, providing nearly 10,000 jobs for civil servants, contractors, tenants and construction crews. NASA partners with more than 90 companies across private, academic and public sectors. Small business is well-represented in those partnerships. KSC will be proactive to remain the Nation's preeminent multiuser spaceport supporting government and commercial operations.
NASA has been charged with landing American astronauts, including the first woman and the next man, on the Moon by 2024. Small businesses are critical to NASA's mission. Last time we went to the Moon it was a government operation. This time, we won't go alone. Through Artemis, NASA and a growing host of partners will establish a sustainable human presence on the Moon by 2028. We will go together and we will go in a sustainable way – with innovative new technologies and systems to explore the entire lunar surface. We will use what we learn on the Moon to take the next giant leap – sending astronauts to Mars.

By the time NASA sends crew to the lunar surface, many science and technology demonstrations will have been sent to the lunar surface through commercial Moon deliveries by Commercial Lunar Payload Services (CLPS), helping us learn more about the Moon ahead of a human return. The first commercial delivery is targeted for September 2020.

When I served as commander of Endeavour on STS-88, the first Space Station assembly mission, we noted in the first log entry of the International Space Station, "From small beginnings, great things come." The ISS has served as a world class microgravity laboratory, a superb engineering test bed and a model of international partnership for the future. Today, NASA is opening the International Space Station for commercial business so U.S. industry innovation and ingenuity can accelerate a thriving commercial economy in low-Earth orbit. NASA will continue research and testing in low-Earth orbit to inform its

lunar exploration plans, while also working with the private sector to test technologies, train astronauts and strengthen the burgeoning space economy. Providing expanded opportunities at the International Space Station to manufacture, market and promote commercial products and services will help catalyze and expand space exploration markets for many businesses, including small business. Opening the ISS for commercial activity allows small businesses access to space that they would never be able to achieve on their own.

NASA is also supporting the development of new commercial space stations that could be temporarily attached to the ISS or operate independently. By taking advantage of technological advancements since the time ISS was designed, as well as lessons learned from operating the current station, NASA expects that new, more modern stations will have lower operations costs than ISS does today. This will make NASA's operations in low Earth orbit more sustainable, and will also make it easier for innovative small businesses to access and use space.

Since the first log entry of the Space Station and during my tenure as director of Kennedy Space Center, I have watched many small beginnings grow into something greater. JP Donovan Construction was a small business started in nearby Rockledge, Florida. This general construction firm now specializes in aerospace, steel fabrication and marine construction. They worked with Exploration Ground Systems to install segments of the new flame deflector at historic Launch Pad 39B used during the Apollo era and where we will soon launch the Artemis program missions.

J.P. Donovan Construction worked on the mobile launcher, assisting in the refurbishment to handle the Space Launch System rocket, including upgrades to the steel structure, and installation of umbilicals that provide mechanical, electrical and fluid subsystems. JP Donovan Construction has now been in business for 27 years and, thanks to their work for NASA and Kennedy Space Center, they are no longer a "small" business. They have grown their business serving other defense contractors, port authorities and local governments, including work on several beach restoration projects to the benefit of the entire coastal community.

Our goal at KSC is to help small businesses navigate the world of government contracting and provide private industry with maximum KSC business opportunities by increasing contracting competition and strengthening socioeconomic programs. Currently, KSC is exceeding all of its small business goals. As of June, our total spend to small business was more than $159 million ($159,628,035.)

The NASA Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs fund the research, development, and demonstration of innovative technologies that both fulfill NASA needs and have significant potential for successful commercialization. Commercialization encompasses the transition of technologies into products and services for NASA mission programs, other Government agencies, and non-Government markets.

The overall focus of the SBIR and STTR Programs is vital to NASA and to the Nation's prosperity and security. SBIR/STTR seeks to increase opportunities for Small Business Concerns (SBCs) to participate in government R&D, to improve overall U.S. competitiveness, increase national employment, stimulate technological innovation in the private sector, and encourage participation of socially and economically disadvantaged persons and women-owned small businesses.

KSC's excellent engineers and scientists continually develop innovations to benefit the space program. The Technology Transfer Licensing Program helps industry benefit from these inventions by widely disseminating the technologies for scientific, academic, industrial, and commercial use. In order to protect the Government's interests, technologies are patented, marketed, and licensed to industry partners for commercial applications. The Technology Transfer Office has the authority to negotiate and

grant patent licenses and can provide assistance in navigating the licensing process and pinpointing technologies that might be a good fit for a specific business. We are very proud of the accomplishment of our Tech Transfer Office at Kennedy. With their hard work, KSC executed the most patent licenses in the Agency for 2018.

Mr. Chairman and Members of the Committee, thank you for your time and attention this morning, and, thank you for your support of NASA, and America's space program.

Chairman RUBIO. Thank you.
Ms. Gustetic.

**STATEMENT OF JENN GUSTETIC, PROGRAM EXECUTIVE, SBIR/STTR PROGRAM MANAGEMENT OFFICE, NASA HEADQUARTERS, WASHINGTON, DC**

Ms. GUSTETIC. Chairman Rubio, thank you for inviting me here today to discuss the incredible impact that American small businesses are making across the country within the space and aeronautics industries. On behalf of the NASA SBIR and STTR programs, we are honored by the genuine commitment that members of this committee have shown to the American small businesses.

Chairman Rubio, as you noted in your remarks, we are especially pleased to read your June statement applauding not only the $55 million in investment NASA will make this year through our Phase I awards, but more broadly the critical role that SBIR and STTR programs play in helping small businesses across Federal research and development funding. NASA's SBIR and STTR programs are key components of the agency's technology portfolio, which are managed by NASA's Space Technology Mission Directorate.

At NASA, we like to say technology drives exploration. And as we all know, American small businesses and entrepreneurs drive innovation, transformation, and economic prosperity. Our path returning to the moon and forward to Mars will literally go through hundreds of small businesses across this great Nation. As the program executive for the SBIR and STTR programs at NASA, I have the privilege of overseeing programs designed to encourage small businesses and research institutions to develop innovative ideas that make specific research and development needs for the Federal Government and have significant potential for commercialization.

Since the formalization of the SBIR program in 1982, NASA's SBIR programs have made over $3.6 billion in awards to small group businesses across all 50 States and Puerto Rico. With these awards, we fund an exciting frontier of technology interests across NASA, including human exploration, space technology, science, and aeronautics related investments. NASA's SBIR and STTR awardees have played a central role in nearly all of the agency's programs and missions. Currently, the SBIR and STTR programs are working with small businesses on their research and development to contribute to landing the first woman and the next man on the moon by 2024, followed soon thereafter by landing the first Americans on Mars.

For example, Astrobotic, a space robotics company headquartered in Pittsburgh, Pennsylvania, was one of several companies selected by NASA to deliver demonstration payloads to the moon under the agency's Commercial Lunar Payload Services, or CLPS, contracts. Astrobotic is a successful multiple SBIR and STTR awardee that has been expanding operations and growing its team thanks in part to 16 NASA SBIR and STTR contracts it has been awarded since 2010. As our Nation reflects on the 50th anniversary of Apollo 11 and works toward a return to the moon surface, we at NASA recognize that we are in a new era of space exploration, one anchored by an emerging commercial space sector that includes cut-

ting-edge companies growing and innovating at a faster pace than ever before.

NASA's SBIR and STTR programs are critical in seeding the growing, emerging commercial space ecosystem while also bearing a responsibility and providing the patient capital for small businesses to succeed in bringing their innovative technologies to market in a high-cost industry. Our role is particularly important because the space industry can be a hard place for small businesses to work, requiring a significant investment of time, expertise, and resources to scale up.

While many small businesses have achieved great success, it does not happen overnight. For example, Aurora Flight Sciences was selected for its first NASA SBIR award in 1990 and continued to work with the program for 26 years until being acquired by Boeing in 2017. Another 26-year-old NASA SBIR partner and recent notable acquisition, Honeybee Robotics, became a standalone, wholly owned subsidiary of Ensign Bickford Industries in 2017.

For companies such as these, we serve as an important source of R&D funds and a forward-leaning resource available to small businesses looking to launch and scale their innovative products and technologies. These companies have leveraged their SBIR success to develop breakthrough technology and become industry leaders. We are living in an exciting time, a time that will see American astronauts return to the moon's surface and explore farther than they ever have before, but NASA cannot do this alone. Our programs will continue to look to the brightest minds and most innovative ideas in our country's small business community to bring Americans to the moon, to Mars, and safely back home.

We know that we cannot do this also without the support of Congressional members and committees like this one. By including qualified small businesses in the Nation's R&D investments, high-tech innovation is stimulated, and the U.S. economy grows as agencies meet their specific R&Ds.

Thank you to Congressman Waltz, to Chairman Rubio, and Senator Scott for your continued support of NASA.

[The prepared statement of Ms. Gustetic follows:]

**Moon Landing to Mars Exploration:**
**The Role of Small Business in America's Space Program**

**Statement of**

**Jenn Gustetic, Program Executive**
**Small Business Innovation Research and Small Business Technology Transfer**
**National Aeronautics and Space Administration**

**Before the**

**U.S. Senate Committee on Small Business and Entrepreneurship**

Chairman Rubio, Ranking Member Cardin, members of the Committee on Small Business and Entrepreneurship—thank you for inviting me here today to discuss the incredible impact that American small businesses are making across the country within the space and aeronautics industries.

On March 26, 2019, the Vice President announced at a meeting of the National Space Council in Huntsville, Alabama, that, at the direction of the President of the United States, it is the stated policy of the United States of America to return American astronauts to the Moon within five years. When the first American astronauts return to the lunar surface, they will take their first steps on the Moon's South Pole. We will use what we learn on the Moon to take the next giant leap – sending astronauts to Mars.

Tomorrow we celebrate the 50th anniversary of the Apollo 11 mission landing on the Moon. At this point in 1969, astronauts Neil Armstrong and Buzz Aldrin were preparing the lunar-landing module for their historic trip to the surface. Now, we have another historic lunar landing ahead of us, in the form of Artemis 3, which will land the next man and the first woman on the surface of the Moon in 2024. This bold mission will require new, revolutionary technologies and capabilities, and NASA will look to American small businesses to create many of these. At NASA, we like to say: technology drives exploration. And as we all know, American small businesses and entrepreneurs drive innovation, transformation, and economic prosperity. Our path returning to the Moon and forward to Mars will go through literally hundreds of small businesses all across this great nation.

NASA believes the next economic revolution will happen in space, and the United States must play a leading role if we are to empower future generations and secure our nation's long-term prosperity. An emerging space economy built on scientific research, technology advancements including both low-Earth orbit and lunar commercialization, will empower countless future generations and create new jobs and industries. The investment in NASA's Moon to Mars exploration is already providing direct economic benefits and creating a variety of jobs across the country. In fact, more than 3,000 companies—many of them small businesses—in all 50 states are already doing work to support Artemis missions.

NASA's Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) programs are key components of the Agency's technology portfolio and are managed by NASA's Space Technology Mission Directorate (STMD). STMD's investments target crosscutting technologies that benefit both human and robotic exploration, actively engaging with internal NASA organizations, industry, academia, and other federal government agencies to help define investment content. Through a combination of unique in-house activities, procurements, research announcements, and public-private partnerships, STMD investments develop and test technologies that drive space exploration.

As the Program Executive for SBIR/STTR programs at NASA, I have the privilege of overseeing programs designed to encourage small businesses and research institutions to develop innovative ideas

that meet the specific research and development needs of the federal government—and have significant potential for commercialization. Since the formalization of the SBIR program in 1982, NASA's SBIR/STTR programs have made awards to small businesses in all 50 states and Puerto Rico. And since 2011, when the SBIR/STTR Reauthorization Act increased the required funding allocation, our programs have funded an annual average of $139 million in Phase I and Phase II contracts, making an average of 355 and 145 of these foundational awards, respectively, to deserving small businesses and entrepreneurs every year. With these awards, we fund an exciting frontier of technology interests across NASA including human exploration, space technology, science, and aeronautics related investments.

On behalf of the NASA SBIR/STTR programs, we are honored by the genuine commitment that members of this committee have shown to American small businesses. Chairman Rubio, we were especially pleased to read your June statement, applauding not only the $45 million investment NASA will make this year through our Phase I awards, but more broadly, the critical role that the SBIR/STTR programs play in helping small businesses access federal research and development funding. As I mentioned earlier, technology drives exploration, and we are proud to be working with you and your fellow committee members to help connect the most innovative small businesses in the country with the funding and support needed to shape their technologies into those that can change the trajectory of American space exploration and boost the country's economy.

I have personally been working on innovation-driven growth in America for over a decade, having led efforts both at NASA and the White House Office of Science and Technology Policy to involve more Americans in innovation through a number of cutting-edge business practices including grand challenges, prizes and challenges, citizen science and crowdsourcing, citizen assessments of technology, and now SBIR/STTR. And what is common to all these practices? That innovation can come from anywhere—and it is our job to shine a spotlight on and resource the best ideas so they have a chance to succeed and be the next breakthrough company or product. History has proven that many inventions revolutionary ideas have stemmed from small businesses and entrepreneurs—and our programs have found no exception.

NASA SBIR/STTR awardees have played a central role in nearly all of the agency's programs and missions—including the International Space Station (ISS), the Mars Curiosity Rover, and Juno. For example, one of our awardees has made great use of the ISS facility in developing commercial space capabilities. Made in Space, a 24-person, California-based company that has an office in nearby Jacksonville, Florida—is partnering with NASA to bring 3-D printing to the ISS and establishing itself as the first commercially available manufacturing service in space. These efforts have the potential to help revolutionize in-space servicing, assembly, and manufacturing—and can be leveraged for NASA's future missions. Currently, the SBIR/STTR programs are working with small businesses on their research and development to contribute to landing the first woman and next man on the Moon by 2024, followed soon thereafter by landing the first Americans on Mars. Astrobotic, a space robotics company headquartered in Pittsburgh, Pennsylvania, was one of several companies selected by NASA to deliver demonstration payloads to the Moon under the agency's Commercial Lunar Payload Services (CLPS) contracts. Astrobotic is a successful, multiple SBIR/STTR awardee and has been expanding operations and growing its team thanks, in part, to the 16 NASA SBIR/STTR contracts it has been awarded since 2010.

As our nation reflects on the 50th anniversary of Apollo 11 and works toward a return to the Moon's surface, we at NASA recognize that we are in a new era of space exploration, one anchored by an emerging commercial space sector that includes cutting-edge companies growing and innovating at a faster pace than ever before. This evolution presents opportunities for NASA SBIR/STTR to invest in and support this ecosystem in even more meaningful ways.

**The Unique Impact of NASA's SBIR/STTR Programs**

U.S. small businesses working in the aerospace industry are unique in their needs, and we are constantly striving to innovate our programs to better assist the community of small businesses that we serve. We view our programs as having a dual mandate, focusing not only on advancing research relevant to NASA where NASA is the primary customer, but also acting as early stage seed funding for promising high-growth commercial space ventures where NASA is not the first—or the only—customer.

- The first objective is to further relevant research for NASA, the commercial aerospace industry, and the nation as whole. As I mentioned, SBIR/STTR awards have been key to previous space missions by providing awards to small businesses whose technologies have been used for space exploration. For example, six innovations advanced by the SBIR/STTR programs were used on the Mars Curiosity rover, including gearboxes for the robotic arm, lithium ion batteries, and software for rover operations. In addition, the SBIR/STTR programs provided awards for several technologies used on the ISS, including a universal battery charger, a deployable vegetable production system, a permanent additive manufacturing facility, and a device that can be used to recycle plastic waste and repurpose it via 3-D printing.
- The second objective is to stimulate technological innovation and increase the commercial application of research results. Each year, approximately 27% of the new technologies reported to NASA as new inventions through the technology transfer program are from SBIR/STTR, many of which go on to commercial markets. From life-saving sutures made of materials designed for Mars to spacesuit air filters that eliminate household pet odors, one of the greatest outcomes of the SBIR/STTR programs is the ingenuity that comes from small businesses that not only make it to space and back here to benefit us on Earth.

To fulfill these dual objectives, we encourage diverse participation—including first-time recipients and underrepresented communities like minority and women-owned businesses—and strive for a balanced portfolio of investments. We know the many companies that seek to work with NASA take several forms, such as those that are high-growth oriented and are seeking to capture aerospace markets outside of NASA, those that are looking to be reliable small business suppliers of innovative research and development (R&D) to NASA, and those that are hoping to become subcontractors and eventually prime contractors themselves. We've established our role in the aerospace innovation ecosystem by meaningfully interacting with each of these groups and supporting modern technologies, successful companies, and commercialized products.

This role is particularly important because the space industry can be a hard place for small businesses to work, requiring a significant investment of time, expertise, and resources to scale up. While many small businesses have achieved great success, it does not happen overnight. For example, Aurora Flight Sciences was selected for its first NASA SBIR award in 1990 and continued to work with the program for 26 years, until being acquired by Boeing in 2017. Another 26-year NASA SBIR partner and recent notable acquisition, Honeybee Robotics, became a stand-alone, wholly-owned subsidiary of Ensign-Bickford Industries in 2017. For companies such as these, we serve as an important source of R&D funds and a forward-leaning resource available to small businesses looking to launch and scale their innovative products and technologies. These companies have leveraged their SBIR/STTR success to develop breakthrough technology and become industry leaders.

While we are proud of the strong, consistent partnerships that our programs have established with innovative small business partners across the country, we know that to increase our effectiveness by an order of magnitude, we need to evolve to meet the growing needs of the new space industry, which is seeing more entrepreneurial space firms emerge than ever before. According to the fourth in a series of Bryce reports on the start-up space ecosystem: "Since 2000, more than 220 angel and venture backed space companies have been founded and funded... In the early 2000s, an average of four funded space

companies were started per year; in the last six years, the number of funded new companies have averaged 21 per year." We believe there is a continued need in the industry for a reliable government source of non-dilutive seed funding to support companies in the space industry.

SBIR/STTR funding plays several important roles for many of these emerging space companies: providing funds to help them to get started and reduce the risk of their technologies; helping companies to attract private investment thanks to the credibility signal that NASA funding provides; and enabling small businesses to use their awards to identify customers within the aerospace industry. According to a recent Space Angels report funded by NASA, "SBIR/STTR programs awards are the most common forms of public funding for entrepreneurial space companies that are eight years and younger, accounting for 44% of all awards." NASA's SBIR/STTR programs are critical in seeding the growing, emerging commercial space ecosystem, while also bearing responsibility in providing the patient capital for small businesses to succeed in bringing their innovative technologies to market in a high-cost industry.

**Importance of SBIR Program Flexbility to Establishing a Sustainable Space Economy**

One of the most beneficial features of the Small Business Act and its subsequent reauthorizations is the built-in flexibility for federal agencies to customize the design of their programs to each agency's unique mission. As such, NASA's SBIR/STTR programs have taken on a distinct, effective structure to accommodate the nature of the aerospace industry, while sharing objectives and best practices with other agency's programs as applicable. Within our programs, we are conscientious about the need to strategically consider the markets we are creating to sustain our small business awardees. Given that NASA typically only needs a few units of a commercialized technology, the company often must find customers beyond NASA to survive and grow. As such, we see a benefit in developing technologies with an infusion path not only to our agency but also potential for future spinoffs with agencies or industries such as defense and energy.

Not only have NASA's SBIR/STTR programs been able to put in place a foundational structure that works for the unique needs of small businesses in the aerospace sector, but the programs have been able to continue to evolve over the last several years because of the flexibility afforded to us through the reauthorizations. The administrative pilot program has been particularly enabling for NASA. For example, we have been able to apply needed funding to administrative enhancements, such as modernizing our IT system for the first time in nearly a decade. Through this modernization, we have effectively reduced the level of effort placed on small businesses to submit proposals by making the submission process more intuitive. As the Committee heard in May from the Small Business Administration, reducing this barrier to entry is a shared priority of all SBIR agencies.

Our goal is to not only help U.S. small businesses break into the government sphere, but to provide the individual support and guidance that they need to continue growing and innovating after our standard funding phases have concluded. To this end, for the last three years, we have utilized a portion of the administrative funding authority to offer I-Corps training to a small cohort of Phase I awardees. Participants hold the I-Corps training, offered through partnership with the National Science Foundation, in high regard for its value helping them to identify customers and develop their business strategy. According to one small business lead, "it has helped us successfully raise over $2 million in funding, but more importantly, it helps guide us to clarify our value propositions, and gives us the confidence to keep making progress into an unknown market."

Also, with the funding made available through the administrative pilot program, NASA also collaborates with the SBA to present and participate in its SBIR Road Tour, a national outreach effort to increase program access and awareness. This year, NASA will join SBA and other agencies at all 16 planned road

tour stops, including this November in Miami and Puerto Rico. NASA SBIR/STTR is an active collaborator with NASA's Office of Small Business Programs (OSBP) and Office of STEM Engagement (OSTEM) in presenting the NASA HBCU/MSI Technology Infusion Road Tour, which already visited Tuskegee University earlier this year and travels to New Mexico State University next month. This series of events, now in its fourth year, provides an open platform for representatives of Historically Black Colleges and Universities and Minority Serving Institutions to learn about NASA's Mentor-Protégé Program (MPP), SBIR/STTR opportunities, OSTEM's grant and cooperative agreement opportunities as well as science research opportunities, grants, fellowships and contracts.

Additionally, our annual industry day has been a highly effective use of administrative funding. Our first industry day, piloted in 2016, has evolved over the last two years into a public-private partnership focusing in large part on educating small businesses experienced with SBIR/STTR awards about various transition opportunities post Phase II within and outside the agency to advance technology, and connecting them to customers and other funding programs. The 2018 Innovation and Opportunity Conference provided significant value to participants through two days of interactive programming, including 212 one-on-one meetings between small businesses and NASA SBIR/STTR, other NASA programs, as well as DARPA, US Air Force, DoE, and USDA. Encouraged by feedback that most participants made a connection that may lead to a new business opportunity, we will be returning to Aurora, Colorado this November for a second conference, and intend to continue these events in the foreseeable future.

Finally, leveraging a different pilot program authority, the Civilian Commercialization Readiness Pilot Program (CCRPP), NASA's SBIR/STTR programs also provide additional research and development funding after Phase II to support transitions and commercialization to Phase III. By requiring matching funding for several of these opportunities, NASA's post-Phase II funding catalyzes investments by other investors and customers to commercialize research to Phase III.

**Conclusion**

We are living in exciting time—a time that will see American astronauts return to the Moon's surface and explore farther than they ever have before. But NASA can't do this alone. Our programs will continue to look to the brightest minds and most innovative ideas in our country's small business community to bring Americans to the Moon, to Mars, and safely back home again.

We also know that we cannot do this without the support of Congressional members and committees like this one. By including qualified small businesses in the nation's R&D investments, high-tech innovation is stimulated and the U.S. economy grows as agencies meet their specific research and development needs.

Thank you for your continued support of NASA. Our programs welcome the opportunity to be a resource to the Committee on current and future matters related to the R&D being done by American small businesses in partnership with our agency, and we look forward to additional conversations around the critical role that these small businesses and entrepreneurs are playing in the nation's space exploration.

Chairman RUBIO. Thank you both for being here. I am going to keep my opening questions brief so I can get my colleagues in first, but I want to ask just to make it real for everybody, do you have any doubt that the first person to walk on the surface of Mars will be an American?

Mr. CABANA. We are going to make it happen.

Chairman RUBIO. And is that American alive today? And if so, how old are they more or less?

Mr. CABANA. Absolutely. So we will have to see. I would have to think about that, sir, but you know——

Chairman RUBIO. Are they in their teens?

Mr. CABANA. They could be in their teens or younger.

Chairman RUBIO. The reason I am asking——

Mr. CABANA. They could still be in school. This could happen—in the 2030s we are going to put Americans on Mars.

Chairman RUBIO. The reason why I asked you that there was a—you mentioned earlier from backstage before we started, there was a poll out that said that the number one profession the Chinese kids want to be is astronauts. The number one profession Americans want to be is YouTubers. I do not see the conflict with a YouTuber from Mars, right? But——

[Laughter.]

But I think that is our fault. I do not blame it on young Americans because we have not spent enough time outside of the confines of this debate in Washington talking about this. So it is important to go into our schools and our universities and tell people that the first person to walk on the surface of Mars is alive today in one of our schools and so we need them.

And we need to do everything we can to be in that position. The second question I have is, will it be possible to execute that mission without the assistance of dozens and dozens of small and midsize businesses who find unique solutions to problems or things that we need to solve in order to make that mission possible?

Mr. CABANA. No, I absolutely think that we have to have small businesses as part of this architecture with their innovative thinking, and they are going to be critical to our success. They will be a part of it. They are a part of it right now in these CLPS payloads that are going to the moon in these initial small landers gaining that knowledge in science, and they will continue to grow. So I totally agree with that, sir.

Chairman RUBIO. So I know the mission is still being defined, but can you just give us like an example of the kinds of things that you need to come up—some of you, as you walk through what it would take to put a human being in space on the moon, anywhere, for any extended period of time, the sort of, you may think them small but critical problems that emerge that people realize we have got to have a solution for this, and it may not be the big contracting famous company that goes out and solves it for you.

Mr. CABANA. So, well, robotics was mentioned. We have one of our scientists here at KSC was working with them extensively on developing a drill to be able to drill for water on Mars, to drill down into the regolith to find the ice when they get to the South Pole and they have it work in those conditions.

So that is one. You know, it is a lot easier to send probes than it is humans. As soon as you start sending humans, now you have got to provide a pressurized environment for them, give them oxygen, scrub the $CO_2$, provide for food, take care of their waste, maintain the temperature, and having reliable systems that can do that. Especially if we are going—you are talking a Martian mission right now with current propulsion technology, it is a year and a half to two years. It is like six to eight months to get to Mars, another six to eight months on the lunar surface, for another six- to eight-month trip home.

To have the systems reliable enough to do that, we have got a lot of work to do, and I believe that small businesses are going to be part of helping us innovate and helping these large companies be successful.

Ms. GUSTETIC. Yes, and I will add to that and that if you look the Mars Curiosity Rover that is on the surface of Mars today, a number of SBIR companies that have technologies actually on that rover that are enabling critical science to be done on the surface of Mars, whether it is gearboxes, whether it is drills, whether it is just removal tools. We estimate that we spend roughly $9 million in SBIR awards that were leveraged with about $72 million of other NASA funding to fly six different companies solutions that enabled even more science to be done on the surface of Mars through our SBIR program.

Mr. CABANA. And you know, if I could go, sir, real quick go back to your first question on motivating students. I get out and talk at a lot of schools, especially, you know, even at the elementary level, and I have not been to a school yet where every student was not engaged and excited when we talked about going into space, going to the moon, exploring beyond our home planet. So I agree with you. We have to get the message out and we have to show the art of the possible.

Chairman RUBIO. Yes. And the last question I have is, when you talk about these solutions, the drill, you know, the ability to manufacture in space because you cannot ship a replacement part over there, these things do not stay there. If you can drill on the surface of Mars, I imagine whatever it is you innovated, you are learning things that have applicability here on Earth. How those products transition over into commercialization and they actually lead to technologies that solve problems for us here.

Ms. GUSTETIC. Yes, so SBIR companies at NASA drive a ton of what we call the spin-offs content that we talk about annually. So one of my colleagues that runs the tech transfer program at NASA publishes an annual spin-off publication that tells the stories of how NASA investments are actually transferred into technologies that we see in our everyday life, and in this year's edition of the spin-offs magazine, a third of those came from SBIT investments.

And on average over the last five years, it is around 27 percent of the things that we are seeing pop up and spin-off come out of the SBIR program for other applications.

Chairman RUBIO. All right, thank you.

Senator Scott.

Senator SCOTT. So, what do you need from Congress to be able to get to Mars besides—I know you need money.

Mr. CABANA. Money and support. And primarily, we have to be funded properly if we are going to be able to do this. And you know, Senator Rubio mentioned earlier we were talking to Congressman. Waltz, you know, the Apollo program in today's dollars is $280 billion. Well, we know what we need to do to get back to the moon. We have to use the lunar surface, lunar operations to develop those systems that will allow us to get to Mars and it is going to be costly, but I think it is critical that we continue to expand, you know, the presence in our solar system beyond our home planet to explore and to learn. Every dollar that is—no dollar has been spent in space, they have all been spent here on the Earth enabling our economy, and growing it, and growing our technology to keep us a world leader.

If as Senator Rubio said, great nations do great things, if we are going to remain a world leader, I believe we need to continue to lead in space. And we are looked upon as a world leader now in space and I do not want to lose that. And I think that showing that we can get to Mars, to make that happen, to develop the systems, to get the reliability, we need to keep humans alive and expand us to Mars is crucial and it is going to require proper funding to make it happen in a timely manner.

Senator SCOTT. How do you determine whether it is—I mean, how do you decide what grants you are going to put out and how you are going to spend your money?

Mr. CABANA. I am sorry, how we do what?

Senator SCOTT. How do you decide how you are going to spend your money in these grants, and how do you measure whether you did a good job or not?

Ms. GUSTETIC. So for the SBIR program, we go through an annual process where we develop what we call subtopics that are actually problem statements. And there are just a hundred problem statements of research and development needs that we know that either NASA has a loan or that the broader commercial aerospace industry has, and we pose a challenge to small businesses and we say, how would you solve this particular challenge through a Phase I feasibility study, and then potentially through a Phase I, Phase II prototype? And then a whole bunch of post Phase II investments that help those prototypes transition to increase their commercialization success because oftentimes a one single $125,000 Phase I and one single $750,000 Phase II is, you know, does not necessarily translate to a final product for the aerospace industry where things are quite expensive.

So we do a lot post phase also to try to help companies transition their technologies, but there are a whole host of different problem areas and it is across NASA's whole portfolio. So we have challenge statements for science, for space technology, for aeronautics, and for human exploration ranging on almost any emerging technology area you could imagine, autonomy, UAVs, Eclipse systems. Anything that we do we likely have an SBIR subtopic to get small businesses involved in R&D.

Senator SCOTT. What changes have you made in how you do the grants to make sure you are successful?

Ms. GUSTETIC. Yes, so we certainly are consistently listening not only to our internal community of folks that are trying to solve par-

ticular problems through working with small businesses to ensure that we are able to get the most relevant problems on the street in a timely way to solve those problems in NASA, but also from the small businesses that participate as our solvers. Without the small businesses participating in the problem, we cannot be that matchmaker between the people that have the problems and between the people that have the solutions. So one thing that we started to do annually over the last few years is introduce an annual request for information process to our small businesses, seeking not only input on the problem statements we are asking for, but also on program processes and things that we could improve about the way that we conduct the process of our program.

Senator SCOTT. So what type of grant have you done that you are most proud of?

Ms. GUSTETIC. I think that recently the contracting vehicles that we have offered post Phase II. So we have expanded the vehicles that are available to actually, as I mentioned before, help to transition companies after a Phase II award to more commercial success. I think diversifying those vehicles that are available for companies to compete for, whether that is our Commercialization Civilian Readiness Pilot Program, it is one of the pilot programs, Chairman Rubio, under the SBIR authorization bill, whether that is sequential Phase II or Phase III awards. We offer many paths for companies to customize their path for commercialization, not assuming that it is a one-size-fits-all solution for companies. So I am particularly proud of the fact that we are diversifying the ways that companies can navigate our program, and not assuming that we have it all figured out, one path that companies need to take in order to commercialize.

Senator SCOTT. What changes are going to happen at Kennedy Space Center to make sure we can get to Mars?

Mr. CABANA. Make sure that the Kennedy Space Center what, sir?

Senator SCOTT. That as a country we get people to Mars. What changes are you going to have to make here?

Mr. CABANA. So at the Kennedy Space Center, our infrastructure is in place now. I believe that the modifications we have made to Launch Pad 39B, the new mobile launcher, the modifications in the vehicle assembly building, we will not be the reason that we do not launch SLS and Orion on time. That rocket needs to grow to have more capability with enhanced upper stage to get us to Mars. It is going to be a partnership with our commercial partners this time. It is not going to be a pure government operation. And what we have done to establish this multi-user spaceport, enabling these commercial companies the ability to launch in an environment where we have reduced regulations, we have worked closely with the Air Force and the FAA to make it more commercially friendly to make launches easier.

I think having that environment in place is excellent. I think we need to continue to build on that, but we have the infrastructure in place. We are going to have to improve some of it. But we have what we need to get to Mars. We need the vehicles and the path forward.

Senator SCOTT. Thanks. Thanks, Senator Rubio.

Chairman RUBIO. Thank you.

Congressman Waltz.

Mr. WALTZ. Relatively briefly, Director Cabana, as I engage industry, they often refer to Florida space triangle, you know, between here and the Cape, up to Daytona and Embry-Riddle, over to Orlando. With the increased frequency of launch, the President's goals of a space force, lunar 2024, Mars, we are seeing industry locate to the area, which is fantastic.

We are seeing, of North of here, we are seeing the development projects like Space Square. Can you discuss, or for either of you, why space triangle, this kind of a regional approach, is inevitable given the projected growth of launch, and how important is that to KSC's ability to execute NASA's goals?

Mr. CABANA. So for us to be able to execute as a spaceport, I think, is critical. As we move forward, it seems that we have less and less of a discretionary budget. So enabling commercial operations—and it is not commercial space or government space, it is if we are going to be successful as a Nation, we need both of them integrated together. And I think the infrastructure that we are putting in place here as we draw these companies, and now as the prime companies come, the supply chain is following. And you know, the Space Coast is doing extremely, well a lot of it with partnership of the State of Florida.

And in space, Florida is an economic development tool, and down in Melbourne with the aerospace industry picking up down there. This is the place to be. I mean, we came to the Cape back in 1962 because it was geologically in the right spot. It is close to the equator as far, as the United States goes, to have the orbital velocity help that you need. We are doing about 910 miles an hour right now sitting still. It also has the ability to launch with the ocean out to the East as a place for hazardous cargo to drop not on populated areas.

So from a geographical point of view, it is an excellent place for a launch site. And now, as we have grown and made it more commercially friendly, I think is critical to our future. But again, it is not government or commercial. It is both of them integrated together to make us successful.

Ms. GUSTETIC. Yeah, from a small business perspective, local and regional ecosystems are absolutely critical as I am sure you can appreciate. Small businesses need a village to support them as they grow and they develop and they scale, and money is not the only thing that is a determinant of a small business' success.

So when you look at all the variety of services that are offered that are complementary to awards, many of which are offered by the Small Business Administration, things like their regional small business development centers, the vast programs that actually provide support for underrepresented communities to be able to apply to programs and get the support they needed, but also efforts that we have done in partnership with the Small Business Administration to go to the places that are actually lower applicant rates than other parts of the country.

We participate in their Road Tours where we actually go and visit parts of the country that might have less participation. We have a Road Tour actually coming up this November in Miami and

Puerto Rico, trying to go toward communities to actually bring the agencies to them as opposed to expecting them to figure us out, you know, the Federal Government out. So we also at NASA have prioritized trying to reach out to HBCUs and MSIs to increase their participation as research institutions in the program.

So there are a number of different ecosystem services that are necessary to support a small business, and we see those as being critical to the long-term success of small businesses, not just our funding.

Mr. CABANA. Every year, the Kennedy Space Center hosts a small business expo, and we work really hard on mentor-protégé partnerships to help grow these small businesses but to help them understand how to do contracting here, and not just at the Kennedy Space Center, but with the government, and it is extremely successful every year and it continues to grow bigger. And we are very appreciative that Port Canaveral always offers up a facility to help host this. And it is—I think we do a good job.

Mr. WALTZ. Along those lines, can you just spend a moment talking about the apprenticeship program and how critical it is to pass on some of those technical trade to the Space Coast apprenticeship program?

Mr. CABANA. So, right here in Eastern Florida, ASRC Aerospace research with Lockheed Martin has a program working with the university to intern and grow technicians to take over. For example, the tiles on the Orion spacecraft that is going to take astronauts back to the moon and on to Mars, our technology that was developed during the shuttle era, the tiles are made here at the Kennedy Space Center in our thermal protection facility. And the workforce to do that is aging, and it is as much an art as it is a skill, learning how to do it correctly. And so we are bringing in this apprenticeship program, these younger folks to take over and learn how to do this to be able to continue to build these spacecraft tiles for the future.

Mr. WALTZ. Just, last question. I think from my perspective, our job as a government is to create the infrastructure and the network for all of this to thrive, which I think is a fantastic example of public-private partnership and how that can grow rather than just throwing funding at a government agency. But we do have a responsibility for the infrastructure piece. Can you just talk to the Indian River Bridge and the space way connector and how important that is to keep funding going?

Mr. CABANA. Absolutely. So right now, the Kennedy Space Center and NASA own the Indian River Bridge. Our gate used to be on the West Bank of the Indian River in order to get into the Kennedy Space Center in Merritt Island. Over time, we have drawn that gate back. We drew it back further when we created Exploration Park in partnership with the State of Florida, the research and development park that allows commercial companies to actually come here and be close to Kennedy in close proximity, but outside our secure perimeter.

Over time, that bridge has become more than just access to the Kennedy Space Center. It has become a major thoroughfare for the community on North Merritt Island to and from the mainland, as well as a major hurricane evacuation route. It is also a bridge that

is required for payloads from Titusville from Astrotech to get to both KSC and Cape Canaveral Air Force Station. That bridge is reaching the end of its useful life, and it has always been our plan to replace it. Currently, we are in partnership with Space Florida.

During our furlough, we could not submit an info grant request in time and Space Florida submitted an info grant request to Department of Transportation for funding to replace that bridge. NASA currently is maintaining that bridge. I put about $2.5 million in a year to keep it operable. We paid for the design of the bridge that meets Florida Department of Transportation standards. We are paying for the environmental impact statement for the new bridge, and we are going to work with, if the State wins this grant, it will also require NASA funding in addition to Air Force funding. The State is only going to end up paying 20 percent or $20 million out of what it is going to cost to replace this bridge.

I will get you the exact figure, sir. So we will see how the info grant turns out, but in the end, NASA, it is our responsibility. If we do not get this grant, we are going to have to find another way. In the meantime, we are going to do what is required to continue to maintain the bridge so that it allows access.

It would be a shame to bring in all these commercial companies and create this great vibrant spaceport and not be able to have access to it with payloads and all the commodities that need to come from the outside in. So, yes, the bridge is critical to our future and we are working to have a proper plan to replace it that meets everybody's needs.

Mr. WALTZ. We will continue to work with your staff——

Mr. CABANA. I am sorry?

Mr. WALTZ. We will continue to I think work with your staff to get that done, and then also the Halls River Bridge to the North of here heading up——

Mr. CABANA. That is another one. We spend a lot of money on State Road 3 on the North part of Merritt Island on the refuge that is also going to need to be replaced in the not-too-distant future.

Mr. WALTZ. Thank you. Senator, I yield.

Chairman RUBIO. Thank you. And just to close the loop, a couple of you just mentioned Space Florida. As an editorial statement, but I remember back when the shuttle program ended and there was the real fear, and we got 10,000 jobs sort of vanished overnight, and there was a real fear that this part of our State would kind of be left behind. There was real concern about the future and a lot of people ended up moving too because of it.

And you look at just the figures up to 2017, we do not have the latest here, but almost 9,000 jobs have been created, many more that are ancillary, and there has already been national media coverage of the sort of resurgence of the area. And I can just—an editorial statement, the Governor was there for much of the period of time. In fact, this whole period of time that we are talking about, Space Florida. Without Space Florida, they deserve a tremendous amount of credit as really a model for the country to keep this part of our State and our Space Coast with its head above water while we at the Federal level sort of figured out what was next. And had that work not been done, it is quite possible that this hearing and

all these conversations we are having today would be, may be, occurring somewhere else in the country.

And so I think they deserve a tremendous amount of credit. I know you have a great partnership with them. I wanted to ask you about the Pentagon, the Department of Defense, because NASA and Apollo trace its roots back to military spending. The majority of the astronauts, I think going back to Mercury, Gemini, Apollo, they all served in the military, had also served in the military.

There is also a component of the small business contracting that is tied to the defense industry. And how is their synergy there with hypersonics, their own space ideas? I mean, separate from the NASA program, is there not also spin-off and ancillary and sometimes direct benefit at some of the small business endeavors that are being pursued through that funding stream at the Department of Defense?

Ms. GUSTETIC. From the SBIR perspective, we see a lot of handoffs between NASA awards and Department of Defense awards. Many companies that work with us also work with a particular part of the Department of Defense, and oftentimes the DOD also piggybacks off of our awards and will offer second Phase II awards to companies that we funded the Phase I or the Phase II. So, and we see them do a lot of Phase III on our Phase I and Phase II because there is certainly technology areas that are of mutual interest.

Chairman RUBIO. Sounds like a good argument for why we need the space force to be in Florida.

[Laughter.]

But the—I'm sorry, Ms. Gustetic, let me ask you about, you know, one part of what we are trying to do is with reauthorizing the Small Business Administration, two decades since we have done that, and is that the programs that we are discussing expire in 2022. So a lot of these, and the stuff that people are going to be—a lot of these endeavors that people are undertaking need some patience. They take some time. And the uncertainty about whether—if you get closer to 2022 and we do not reauthorize this program, what is the practical impact it begins to have on folks coming forward and looking to be a part of it?

Ms. GUSTETIC. It has an impact not only on the Federal agencies that pre-plan for those activities but also on regional ecosystems that plan and create positions, for example, to help companies that are local to them prepare for these kinds of funding opportunities. It also certainly affects companies that may not know if this funding resource will actually be as predictable as it has been historically. We hear all the time from our small businesses, and also from other countries, that will come and talk to us to learn about how the small business program in the U.S. works, where they say just how much of a gem this 37-year-old program is. That the United States is a consistent, predictable, repeatable source of funding for small businesses on the innovation side of things. They actually develop new and advanced technologies.

And so the predictability of that funding, even if there might be a little bit more bureaucracy associated with applying and also complying with contract terms, the predictability of that funding is something that diversifies the overall availability of money in the

ecosystem, whether it is also angel investing, venture capital, and other sources of funds, that make it a really critical and important player in the ability for our small businesses in this country to thrive.

So that permanence increases predictability and it can allow a whole ecosystem of other support services to form around that permanent and predictable program in order to better leverage it.

Chairman RUBIO. And the last question I have really has more, not NASA specific, but it is part of our bill. One of the things we want to do is, and right now this is all housed under the Office of Investment and Innovation, and our view in our bill we are trying to do is bifurcate that we are going to sort of leave the Office of Investment, but then create a separate office for innovation and technology, put these programs with its own so that it has its own specialized focus and attention paid on it.

And I do not know if you have any thoughts or views on how that could or could not impact the program. I know the SBA will have its own views about how to staff and how to fund it, but just having an office that is dedicated to that sole mission of innovation and technology, and technology transfer peace. Would that in your view be helpful to helping the program be more successful and do you have any views on that?

Ms. GUSTETIC. I think anything that enables that SBIR program to get direct connections to their leadership to increase the support that they continue to have in their programs is likely a positive thing. The SBA, we work with them on the policy directive that they issue and also the activities that they do on behalf of all the agencies. It does not make sense for all ten of us to do our own individual outreach efforts. That is not the best use of our money.

So we work together to—actually, an SBA coordinates those things. We work together with them in order to get the best use of the money that you are giving us. And so, their ability to operate at a high level and an innovative level just makes all of the other agencies able to execute at a higher level as well.

Chairman RUBIO. Well, thank you both for being here. I appreciate it very much. Thank you for hosting us, and we look forward to working with both of you in the months and years to come. And tomorrow will be a big day. I will be around here as well, so, but again, thank you both for coming here. I am going to start introducing the second panel. Thank you. And so let me introduce the second panel while the staff here transitions the name tags. Our second panel, Mr. Andrew Rush of Jacksonville, Florida, is the President and CEO of Made In Space, Inc., which specializes in manufacturing in space and other extreme environments. He holds a Bachelor of Science and Physics from the University of North Florida, and a Law Degree from Stetson University. I have got to ask you about that. You know, the physics and then philosophy your brain is like, you can stretch in two very different directions there. But thank you for being here.

Dr. Gordon Nelson is a Principal at Gordon Nelson and Associates in Melbourne, Florida. The Gordon Nelson Associates, working with the Florida Institute of Technology, has been a recipient of NASA SBIR, STTR awards, and I want to thank both of you for

being here, but we will start with you, Mr. Rush. Thank you. You are recognized for your opening statement.

**STATEMENT OF ANDREW RUSH, PRESIDENT AND CEO, MADE IN SPACE, INC., MOUNTAIN VIEW, CA**

Mr. RUSH. Chairman Rubio, Senator Scott, and Congressman Waltz thank you for the opportunity to speak with you today. Fifty years ago, American innovation put American boots on the moon for the first time.

Today, American innovation in space, driven by emerging companies like Made In Space, is alive and kicking today. We and our fellow innovators are ready to progress beyond Apollo, not only putting humans back on the moon to stay and on to Mars but revolutionizing the way the spacecraft are built and creating sustainable commercial business operations in low Earth orbit.

As CEO of Made In Space, I have the great honor of leading a talented and passionate team and support international exploration goals. We are an industry leader in developing and deploying space-capable manufacturing technologies, a suite of technologies that will enable more capable, cost-effective in-space operations and make human spaceflight missions safer and more responsive. Made In Space has been able to achieve multiple world's first because of the support of space technology development programs led by NASA, DARPA, and others.

As a young bootstrap company, our approach has been to take small practical steps toward our goal of opening the frontier of space via manufacturing. As we have talked a little bit about today, 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 and others to build and launch a 3D printer to the International Space Station in 2014.

Since manufacturing its very first parts, we have been manufacturing tools, and fixes, and other objects for use by the ISS crew and others. This capability is paradigm-shifting because it reduces the need for costly spares and allows tools and fixes to be manufactured on the spot on demand. Consider the life-threatening calamities that befell Apollo 13 or the fictional tribulations of Mark Watney in the Martian. Now consider that if the crew of Apollo 13 had had a 3D printer onboard, they could have more readily repaired their $CO_2$ scrubbing system, and perhaps had Mark Watney been provided with 3D printers and other manufacturing tools, that book would have been a little bit more boring and his survival might have been, you know, not quite so heroic.

Without infrastructures like the SBIR program and the International Space Station, we could not have developed this capability, a capability which will make future human space flight missions safer and more responsive than ever before. Building on the success, a Made In Space-led team began work for NASA's Space Technology Mission Directorate to develop a large-scale, in-space additive manufacturing, and assembly system. We call the system Archinaut.

Archinaut technology will enable optimization of spacecraft structures for their operational environment rather than primarily de-

signing them simply to survive the ride to space. This technology enables providing large structures at lower costs, including robotic manufacture, and assembly of reflectors, space stations, and other applications for civil defense and commercial space customers. STMD has recently funded the first Archinaut satellite for flight. This satellite will prove out this foundational technology in the operational environment, establishing the flight heritage that will enable mission managers to confidently integrate this technology into operational human spaceflight, national security, and commercial missions in the future. The SBIR program enabled transformational ideas like 3D printing in space to go from the drawing board to demonstration in space.

The vision of NASA's Space Technology Mission Directorate to invest in disruptive technology, like in space robotic manufacturing and assembly, will enable satellites to one day self-assemble and repair and augment. In the future, this technology will transform how we build spacecraft, opening after for human and robotic exploration of the cosmos, and enabling commercial space operations to get more capability per kilo sent to space. Made In Space and its customers have benefited enormously from the virtuous cycles of development enabled by a strong SBIR program, a strong independent STMD, and DARPA, and others. Made In Space strongly encourages NASA to look more to small businesses to serve integral roles in taking the United States back to the moon and on to Mars via their technological innovations.

Hand in hand with that, Made In Space encourages increased investment in space technology development, in particular, increasing support throughout the technology development pipeline of mission-enabling technologies will minimize the risk that at early stages of development these technologies languish. These investments are crucial to achieving America's near-term ambitions in space and avoiding being overtaken militarily or peacefully by China and others in space.

This committee is uniquely positioned to extend the legacy of Apollo and help propel the Nation back to the moon and on to Mars by unleashing the time-tested power of American small business innovation.

Thank you.

[The prepared statement of Mr. Rush follows:]

MADE IN SPACE

Andrew Rush
President & CEO
Made In Space, Inc.

**Testimony of**

**Andrew Rush**

**CEO**

**Made In Space, Inc.**

**Before the**

**U.S. Senate Subcommittee on Small Business & Entrepreneurship**

**Field Hearing on**

**"Moon Landings to Mars Exploration: The Role of Small Business Innovation in America's Space Program"**

July 19, 2019

Astronauts Memorial Foundation Center for Space Education, Building M6-306,

Room 6000/8000

Merritt Island, FL

MADE IN SPACE

Andrew Rush
President & CEO
Made In Space, Inc.

**Introduction**

Fifty years ago, American innovation put American boots on the Moon for the first time. American innovation in space, driven by emerging companies like Made In Space, is alive and kicking today. We and our fellow innovators are ready to progress beyond Apollo, not only putting humans back on the Moon to stay, but revolutionizing the way spacecraft are built and creating sustainable, commercial business operations in Low Earth Orbit. Made In Space, Inc. (Made In Space, MIS) is developing technologies and business models 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 support of NASA via the Small Business Innovation Research Program, public-private partnerships like the In-Space Robotic Manufacturing and Assembly Tipping Point program (IRMA), and access to the International Space Station (ISS).

Made In Space-designed ISS payloads are proving out the potential of producing high-value goods in microgravity for ultimate use on Earth which will one day lead to factories in space. These factories may one day be the anchor tenants of commercial space stations.

Made In Space's activities on the International Space Station (ISS) and in ground test facilities have proven the potential of manufacturing and assembling satellites not on the ground but on orbit. NASA's Space Technology Mission Directorate recently awarded a Made In Space-led team a contract to build and launch Archinaut One, the first satellite that will manufacture and assemble portions of itself on orbit. This mission will definitively demonstrate the transformational potential of in-space manufacturing and assembly of satellites, enabling spacecraft to be designed and optimized for their operational environments, rather than hardened to survive launch. In the near term, via large solar arrays constructed on orbit for the satellite, this will provide a 5x improvement in power for small satellites. In the longer term, in-space manufacturing and assembly could enable large space telescopes and future space stations to be cost effectively constructed in space.

Due to the tremendous support of NASA and others, Made In Space will grow from forty employees at the beginning of 2019 to approximately 90 employees by the end of the year. Much of this growth will occur in the great state of Florida, fueled in part by support from Space Florida.

Made In Space strongly encourages continued and expanded support of programs which enable the step-by-step development of new commercial space capabilities, including the SBIR program, NASA's Space Technology Mission Directorate, and the International

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Space Station National Lab. American space technology development generally, and small business innovation in particular, will be integral to Americans returning to the Moon to stay and going forward to Mars in the near future.

Technological innovation, especially small business driven innovation, is the engine which will keep us ahead of China and other nations. Space is acknowledged as integral to our national economy. It is also increasingly becoming a warfighting domain.. For these reasons, the US must redouble its efforts to develop new technologies and business models that utilize space for commerce, science, and defense.

In order to maintain and grow America's space-based edge over China and others, Made In Space strongly encourages continued support of programs that enable the step-by-step development of new commercial space capabilities, including the SBIR program, NASA's IRMA program, DARPA's support of in-space manufacturing and assembly development, and the commercial use of the International Space Station.

**Made In Space, Inc. and the Emerging Cislunar Economy**

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

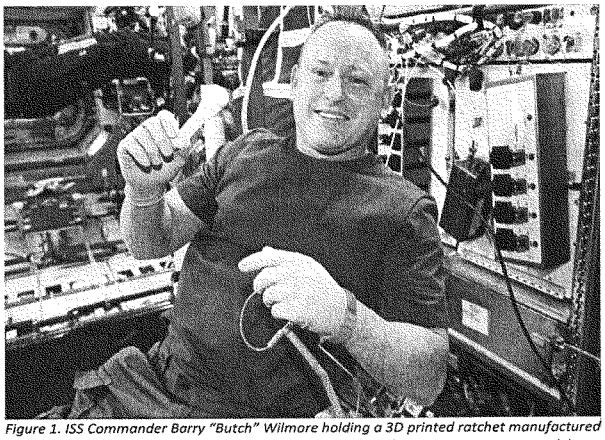

*Figure 1. ISS Commander Barry "Butch" Wilmore holding a 3D printed ratchet manufactured in space. The ratchet was designed on the ground and manufactured in space one week later, making it potentially the fastest delivery to space ever. Image credit: NASA*

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

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.

We focus on two types of space-based manufacturing: manufacturing technologies that enable new missions in space; and manufacturing technologies that leverage the space environment to create high value goods for use on Earth. We believe these areas will drive significant growth of American industry over the next decade. Furthermore, these

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Andrew Rush
President & CEO
Made In Space, Inc.

areas will enable the American human spaceflight program to build on the success of Apollo and return to the Moon and go on to Mars.

**NASA and Other Government Agency Support Enables Manufacturing In Space For Use In Space and the Future of American Industry and Exploration In Space**

In-space manufacturing and assembly dramatically reduces spacecraft cost, reduces the limitations rocket launch places on spacecraft design, and removes astronauts from harm's way. Traditionally, satellite design has been constrained by launch-shroud size and launch load/environment survivability requirements. Similarly, due to lift capacity limits and the high risk and low availability of astronaut EVA for assembly, creating large space-based structures such as space stations has been a once-in-a-generation endeavor. Archinaut, our in-space manufacturing and assembly technology for self-assembly of satellites on orbit, minimizes or removes these and other design limitations.

In-space manufacturing and assembly enables a wide variety of desirable missions. These include large-scale telescopes for astrophysics missions, increased power production for small satellites, and future space station backbones. In-space manufacturing and assembly is also transformational for Lunar and Mars applications. Archinaut enables small form factor satellites to provide high resolution mapping and high throughput communications services necessary for sustained human and robotic operations on the Lunar surface. Previously providing these services has been accomplished by large and significantly more expensive assets. Additionally, these technologies enable satellites to be modified, repaired, or reconfigured on orbit, thereby enabling these assets to be more resilient and durable in a manner that does not exist in the current approach to satellite design, manufacture, and deployment.

Working closely with NASA, DARPA, and others and utilizing multiple pieces of the space infrastructure described above, Made In Space has made significant progress in developing and demonstrating in-space manufacturing technologies for both satellite applications and human spaceflight missions. MIS engineers initially internally developed 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.

Based on this success, 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 (see Figure 1).

Thereafter, 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. Made In Space owns and operates the AMF, routinely sending print jobs to the ISS

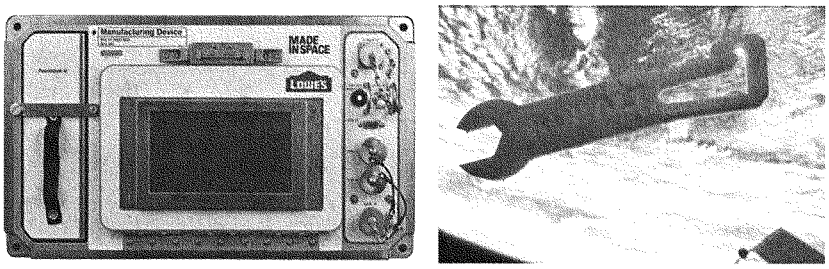


*Figure 2. The Additive Manufacturing Facility (left) is the first ever commercial manufacturing facility deployed to space. The first commercially manufactured part in space was a space optimized hand tool (right). Image credits: NASA/Made In Space.*

and manufacturing them on orbit. 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. This commercial service is one of several pioneering commercial uses of low Earth orbit. These uses represent pathfinders for future commercial space station-based businesses, a future cornerstone of American industry's utilization of 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. One can imagine that the Apollo 13 mission would have faced less adversity if an on board 3D printer had been present. Rather than jury rigging together a wide variety of items to create an adapter for CO2 filters, for example, an on board 3D printer could have quickly and efficiently created the needed fix. Borrowing from fiction, when Mark Watney, the main character of Andy Weir's *The Martian,* was stranded on Mars, he could have been aided in surviving his trials and tribulations had he had access to local manufacturing equipment.

Further building on this success and internal research and development into manufacturing very large, space-optimized structures in space, Made In Space was selected to participate in the two-phase NASA Space Technology Mission Directorate In-Space Robotic Manufacturing and Assembly (IRMA) Tipping Point program . The IRMA program seeks "to transform the way we manufacture, assemble and repair large structures in space, leading us closer to a robust space infrastructure freed from launch

window scheduling, launch vehicle mass limitations and astronaut safety concerns. Ultimately, [IRMA] will enable more frequent science and discovery missions in Earth orbit, across the solar system and beyond."[1] Furthermore, IRMA operates via "public-private partnerships to deliver technologies and capabilities needed for future NASA, other government agency, and commercial missions."[2] Tipping point technologies were sought. That is, technologies and capabilities which, if investment was made in a flight demonstration, there would be "significant advancement of the technology's maturation, a high likelihood for utilization of the technology in a commercially fielded space application, and a significant improvement in the offerors' ability to successfully bring the space technology to market" thereby enabling the capability to be available to NASA and OGA's but sustained by the commercial market, resulting in more cost effective and better technological outcomes for the government.[3]

Phase I of the IRMA program focused on ground demonstrations of in-space manufacturing and assembly technologies, maturing these technologies for flight demonstrations in Phase II where properly planned definitive demonstrations in space will push these technologies past the tipping point and raise their technology readiness level to the point that civil, defense, and commercial customers will utilize the technologies for operational missions. This programmatic structure and focus is enabling American industry to develop and implement technologies which will improve satellite design, operation in the future, providing significant advantages over the U.S.'s competitors.

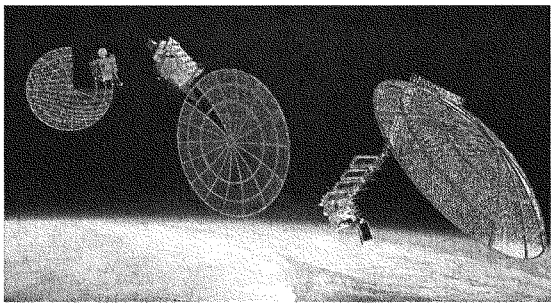

*Figure 3. This artist's rendering depicts the Archinaut payload during its deployment in space. Via additive manufacturing and assembly, a large reflector is manufactured and integrated over time. Image credit: Made In Space*

Under a Phase I contract begun in late 2016, Made In Space led a team including Northrop Grumman to develop its Archinaut in-space manufacturing and assembly technology (see Figure 3). During rocket launch, spacecraft are subjected to high g forces and large vibrational forces, which requires wasting mass to over-engineer components to survive launch. Further, the entire spacecraft must fit within the limited volume of the launch fairing, which requires engineering deployables that unfurl once the satellite reaches orbit, creating points of failure. Archinaut technology will enable optimization of spacecraft

[1] See: https://www.nasa.gov/mission_pages/tdm/irma/index.html
[2] See NASA Solicitation UTILIZING PUBLIC - PRIVATE PARTNERSHIPS TO ADVANCE TIPPING POINT TECHNOLOGIES appendix number NNH15ZOA001N-15STMD-001 to NASA Research Announcement (NRA): Space Technology - Research, Development, Demonstration, and Infusion – 2015 (SpaceTech–REDDI–2015), NNH15ZOA001N released May 21, 2015.
[3] *Id.*

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structures for their operational environment, rather than launch. Additionally, Archinaut will enable repair and reconfiguration of assets once they are on orbit. Further, Archinaut will be able to build large structures at lower cost, including 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 was demonstrated in NASA environmental testing facilities and aboard ISS via AMF, including manufacturing space-optimized structures 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% 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.

On July 12, 2019, MIS was awarded a flight mission to definitively demonstrate Archinaut. Made In Space will construct two ten meter solar arrays, on orbit, to power an ESPA-class satellite. Once on orbit, Archinaut One will employ its extended structure additive manufacturing capabilities and advanced robotics to manufacture and assemble the satellite's power system. The Archinaut-created solar arrays will yield nearly 5x the power currently available to ESPA-class satellites. NASA is providing $73.7 million in funding for this mission, with the MIS led team contributing an additional 25%.

**Manufacturing Space Enabled Products**

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

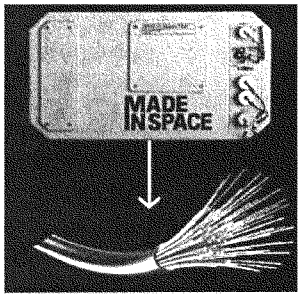


*Figure 4. Made In Space will deploy a payload to ISS this year to manufacture high value optical fiber in space. Image credit: Made In Space*

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 has flown to the ISS four times, produced optical fiber there, and then was returned to Earth where the fiber has been analyzed. Based on the initial promising results, 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 the company's own funds 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**

As described previously, as many other small companies have, MIS has contributed in impactful ways to America's space program and looks to have greater impact in the future. The SBIR program enabled transformational ideas like 3D printing in space to go from the drawing board to demonstration in space. The vision of NASA's Space Technology Mission Directorate to invest in disruptive technology like in-space robotic manufacturing and assembly will enable satellites to demonstrate self-assembly abilities. In the future, this technology will transform how we build spacecraft, opening the aperture for human and robotic exploration of the cosmos and enabling commercial space operations to get more capability per kilo sent to space. Made In Space and its customers have benefited enormously from the virtuous cycles of technology development enabled by SBIR, STMD, DARPA, and others. Made In Space strongly encourages NASA to look to small businesses to serve integral roles in taking the United States back to the Moon and on to Mars via their technological innovations. Hand in hand with that, Made In Space encourages increased investment in space technology development. In particular, increasing support throughout the technology development pipeline mission-enabling technologies will minimize the risk that, at early stages of development, will languish. These investments are crucial to achieving America's near term ambitions in space and avoiding being overtaken, militarily or peacefully, by China or others in space. The subcommittee is uniquely positioned to extend the legacy of Apollo and help propel the nation back to the Moon and on to Mars by unleashing the time-tested power of American small business innovation.

Chairman RUBIO. Thank you.
Dr. Nelson.

**STATEMENT OF GORDON L. NELSON, Ph.D., PRINCIPAL, GORDON NELSON AND ASSOCIATES, MELBOURNE, FL**

Dr. NELSON. I appreciate this opportunity to provide comments on the role of Small Business Innovation in America's Space Program. My comments are based upon my experience on a NASA STTR, which began in 2012, focusing on new, flexible, flame-retardant polyurethane foams for energy absorption applications. That STTR has progressed through Phase I, Phase II, Phase II E, and now in Phase III. Polyurethane foams can be items such as seat cushions, mattresses, all of which you are very familiar. However, significant flame retardancy is required in high hazard seating, Navy mattresses, and many other applications.

This STTR project represents the development of a unique family of highly flame retardant, environmentally friendly, flexible polyurethane foams. The flame retardant package is nonhalogen, chemically bound-in, meaning it is non-migrating, with low volatiles, resolving key concerns for environmental stakeholders. The goal was to exceed the flame retardancy of BX265, NASA SOFI spray-on foam insulation for the shuttle that had a peak rate of heat release of 354. Project foams perform down to 148 peak rate of heat release, less than half that of SOFI, and over 90 percent reduction versus the base foam. Foams meet Cal 133, British Standard 5852, standards for high-hazardous seating, the Federal standard for mattresses, Cal 129 and NFPA 267 for high hazardous mattresses, and the FAA oil burner test for commercial aviation seating, without additional fire barriers.

All foams, of course, meet NASA's 6001 test method. Some foams meet the U.S. Air Force dynamic cushioning test for packaging. Foams can be made to any needed static stress performance, useful for energy absorption foams in automotive or aerospace applications. Some members of the family show enhanced cryogenic insulating performance versus SOFI at soft vacuum. Thus there is a broad family of potential performance. Part of the NASA vision was flexible insulating foam which could be used for cryo line repair yet serve a variety of other applications during a mission. Indeed, project foams provide cost-effective, flexible polyurethane foams for cryogenic insulation, packaging, energy absorption materials, and flame resistant materials, including high-hazardous seating and mattresses, energy-absorbing foams, packaging foam, and anechoic chamber materials.

NASA likes applications beyond NASA mission materials. During Phase III, working with several leading companies, we have focused on foams for prison mattresses, rail car seating, automotive headliners, and anechoic chamber materials. Using the automotive headliner materials as an example, current headliner composite, now think of your automobile, is a fabric of foam behind it and polyethylene film barrier behind that. It must meet the flammability requirement of the motor vehicle safety standard, MVSS302, utilizing a flame retardant fabric. As one, however, goes to an autonomous vehicle, a more pleasing environment will be needed versus the few colors currently available for headliners. Flame retardancy

will no longer be met by the fabric, but MVSS302 performance will need to be provided by the 3 to 4 mm of foam.

So our project materials, in fact, can do that. The project has been very productive. I do have the following comments based upon my seven-year STTR experience. The project had a commercialization panel using three internationally recognized consultants with polyurethane formulation, application, and standards of regulation experience. Several times at NASA briefings the question was raised, well, why commercialization panels were not required. Well, maybe they should be.

I served as the Small Business Concern, the SBC, for the project. Florida Institute of Technology served as the Research Institute, the RI, for the project. STTR requirements allowed the RI 40 percent of project funds and the SBC 60 percent. It is up to half for consultants and at least half spent as 30 percent directly by the SBC. This allowed me, as a sole proprietorship, to function effectively.

However, some STTRs and SBIRs require the SBC to have at least 50 percent of project direct expenditure which effectively excludes sole proprietorships. We had that issue with an Army SBIR. That is my first concern. STTRs many times involve universities. The RI, in this case, Florida Institute of Technology, involved 14 students, 6 M.S., and 8 undergraduate students, in the project. Five of the six M.S. students were women, and three of those were Hispanic. Students have commented that they appreciated the exposure to real industrial applications as part of their project work, having the responsibility to meet real project goals and timelines.

One should not forget that STTRs offer a great opportunity for student experience and exposure. Indeed, the lead M.S. student, Caitlin McKinnon, has had great exposure in managing a project research group. During Phase I, under $125,000, the SBC needed to front $60,000 to $70,000 since expenses are billed after the fact by quarter. That is difficult for sole-proprietorships and would be particularly so for younger entrepreneurs. A Phase I upfront initial payment would be useful and encourage new innovation. So that is a recommendation.

I was approached on several occasions by individuals at other institutions about being the SBC on their projects. Their issue was the time necessary to complete the System for Award Management Registration Project, SAM. Hearing about a potential award topic and being able to respond with the required documentation limits some people with clear specific expertise to respond.

In my case, I have been doing work at Kennedy Space Center for a good number of years. But, someone starting fresh would find it difficult to accomplish registration in the time and context of a specific project submittal deadline. That clearly limits fresh innovations. So, I hope these comments have been helpful. The STTR project over the last seven years has been a whole lot of fun.

Thank you for your attention.

[The prepared statement of Dr. Nelson follows:]

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Small Business Innovation in America's Space Program – From a NASA STTR Experience

I appreciate this opportunity to provide comments on "The Role of Small Business Innovation in America's Space Program." My comments are based upon my experience on a NASA STTR which began in 2012 focusing on "New Flexible FR Polyurethane Foams for Energy Absorption Applications." That STTR has progressed through Phase I (one year), Phase II (two years) and Phase IIE (one year), and is now in Phase III (in its third year). Polyurethane foams can be items such as seat cushions, mattresses, of which you are very familiar. However, significant flame retardancy is required in high hazard seating, Navy mattresses and many other applications.

This STTR project represents the development of a unique family of highly flame retardant, environmentally friendly, flexible polyurethane foams. The flame retardant package is non-halogen and chemically bound-in, meaning it is non-migrating, with low VOC (volatile organic carbons), resolving key concerns for environmental stakeholders. The goal was to exceed the flame retardancy of BX265 NASA SOFI (Spray on Foam Insulation) (354 Peak Rate of Heat Release by one Calorimetry at 50 kW/m2 external flux, 1-inch thickness). Project foams perform down to 148 PHRR(less than one-half that of SOFI) (over 90% reduction versus 1670 for base foam). Foams meet Cal 133, BS5852 standards for seating, 16CFR1633, Cal 129 and NFPA 267 (Navy Modification) for mattresses, and the FAA oil burner test for commercial aviation seating, without additional fire barriers. All foams of course meet NASA 6001 Method 1. Some foams meet the US Air Force dynamic cushioning test for packaging. Foams can be made to any needed static stress performance, useful for energy absorption foams in automotive or aerospace applications. Some members of the family show enhanced cryogenic insulating performance versus SOFI at soft vacuum. Foams down to 1.8 pcf density are available. Thus there is a broad family of potential performance.

Part of the NASA vision was flexible insulating foam which could be used for cryo line repair, yet serve a variety of other applications during a mission. Indeed, project foams provide cost effective flexible polyurethane foams for cryogenic insulation, packaging, energy absorption materials, and flame resistant materials. Also, some 15 priority applications were identified by the project Commercialization Panel, including high hazard seating and mattresses, energy absorbing foams (automotive, aerospace), packaging foam (US Air Force), and anechoic chamber materials (electronic industry/airports).

NASA likes applications beyond NASA mission materials. During Phase III working with several leading companies we have focused on foams for prison mattresses, rail car seating, automotive headliners, and anechoic chamber materials. Using the automotive headliner materials as an example, currently the headliner composite (fabric, foam, and polyethylene film barrier) must meet the flammability requirement (MVSS302) utilizing a flame retardant fabric. As one goes to autonomous vehicles, a more pleasing environment will be needed versus the few

colors currently available for headliners. Flame retardancy will no longer be met by the fabric, but MVSS302 performance will need to be provided by the 3 to 4 mm of foam. Project foams at the required 1.8 pcf density can provide that performance.

The project has been very productive. I have the following comments based on my 7 year STTR experience:

The project had a Commercialization Panel using three internationally recognized consultants with polyurethane formulation, application, and standards/regulation experience. Several times at NASA briefings the question was raised why Commercialization Panels were not required. Perhaps they should be.

I served as the Small Business Concern (SBC) for the project. Florida Institute of Technology served as the Research Institute (RI) for the project. STTR requirements allowed the RI 40% of project funds and the SBC 60% (up to half for consultants and at least half spent directly by the SBC or 30%). This allowed me as a sole-proprietorship to function effectively. However, some STTRs and SBIRs require the SBC to have at least 50% of project direct expenditure which effective excludes sole-proprietorships. We had that issue on an Army SBIR project. That is my first concern.

STTRs many times involve universities. The RI, in this case Florida Institute of Technology, involved 14 students (6 MS and 8 undergraduate students) in the project. Five of the 6 MS students were women and three of those were Hispanic. All but one of the 14 were from Chemical Engineering. Students have commented that they appreciated the exposure to real industrial applications as part of their project work, having the responsibility to meet real project goals and timelines. One should not forget that STTRs offer a great opportunity for student experience and exposure. Indeed, the lead MS student, Caitlin McKinnon, has had great exposure in managing a project group.

During Phase I ($125k) the SBC needed to front $60-70k since expenses are billed after the fact by quarter. That is difficult for sole-proprietorships, and would be particularly so for younger entrepreneurs. A Phase I up front initial payment would be useful and encourage new innovation. That is a recommendation.

I was approached on several occasions by individuals at other institutions about being the SBC on their projects. Their issue was the time necessary to complete the System for Award Management (SAM) registration process. Hearing about a potential award topic and being able to respond with the required documentation limits some people with clear specific expertise to respond. In my case I had been doing work at Kennedy Space Center for a good number of years. Projects were normally available only to small businesses, thus over the years I had built up experience in maintaining the necessary registrations, accounts, billing practices, etc. But, someone starting fresh would find it difficult to accomplish registration in the time and context of a specific project submittal deadline. That clearly limits fresh innovations.

I hope these comments are helpful. The STTR project over the last 7 years has been fun to work on. Thank you for your attention.

Chairman RUBIO. Thank you. I guess, Mr. Rush, let me ask you, in May Made In Space was selected for two SBIR of Phase II awards that could be worth about $1.5 million each. If you could just describe to people that are not as aware of the program how support from the SBA, and this program, in particular, has helped you grow to this point as a company.

Mr. RUSH. Yeah, absolutely. So we have been very fortunate to win, I think, over a dozen Phase I and Phase IIs throughout the eight- or nine-year period that we have grown as a company. We really started with SBIR, with just an idea, and you know received our first Phase I, and from there received Phase II and Phase III actually simultaneously to put printers on the ISS. And from there, you know, have been able to expand out that technology space into multiple different areas.

So like those two SBIR Phase II we won recently, one of those is focused on a structurally interconnected interferometer in the small satellite that is going to be manufactured using our space-capable 3D printing technology, which was the subject of our first SBIR, to make an interferometer that can spot near-Earth objects if it was put up in space in a really small form factor.

The other SBIR that we won there is in what we call the space-enabled materials area that, you know, is going to manufacture a process class in orbit that because it was made microgravity, it has these really interesting and economically viable properties.

So, and we think that is the key to multiple businesses manufacturing in space that are making, you know, that are profitably manufacturing things in space that we are using back here on Earth, which ultimately we think will be the anchor tenants for commercial space stations and modules in low Earth orbit, which is, you know, which is the low Earth orbit goal of the post ISS future.

And all of that has been enabled, you know, by a really great relationship with NASA and with the SBIR program. Without SBIR, we probably would not have accomplished the things that we have accomplished. We certainly would look really, really different.

Chairman RUBIO. Well, Dr. Nelson, and for you Mr. Rush, both, how would you make SBIR better, easier for other companies like yourselves to get into this to do what you have done? What could we do to make it even easier and better than it is now?

Mr. RUSH. Two things come to mind, and both have to do with speed. As a small business, you know, speed and cash are king. So the time period between submittal of a proposal and notice of award, and then, you know, getting on contract, the more effort that can be spent to compress those timelines the better. And then——

Chairman RUBIO. What are they typically now?

Mr. RUSH. Six months, you know, six months to get onto a six-month contract, and then similarly between Phase I and Phase II. So phase I's are typically six months and Phase II is typically two years. There is a gap of three to six months. You know, you put a proposal into the end of the Phase I and then you wait three to six months to find out if you won, and then to get on contract.

And you know, that is a challenge from a cash flow perspective of you are sort of speculating and saying, okay do we think this is

going to win, do we keep these folks available for this project, or do we put them on something else? And if that time period was compressed or if there was no gap, I think that would enable the program to be that much more effective.

Chairman RUBIO. Dr. Nelson, do you have any suggestions on how to make SBIR even better?

Dr. NELSON. I would certainly agree with Andrew in the issue between the transition between phases. That is, you know when you have a team and you have no money for some months, that is clearly a problem.

Chairman RUBIO. But, why do they tell you it takes longer than you hoped it would? What is your sense of why it takes so long or longer?

Mr. RUSH. I think across multiple agencies, that is the structure. It is between Phase I and Phase II, you submit your proposal for Phase II at the end, and then there is, you know, an evaluation period, and then there is a negotiation period, and then you get on contract for the Phase II. So that is I think just kind of the cadences of the program as it is currently structured.

Chairman RUBIO. Meaning this is the way they have always done it. You know, it is just kind of built into the way it is handled. That is the culture of the program.

Mr. RUSH. Right, right. And you know, and so we as a small business, you know, we adapt to those rhythms, and, you know, with via close relationships with the technical folks that we work with try to get a feel for if that is the direction we are going to be able to continue to go. But that is certainly a challenge from a forecasting perspective.

Chairman RUBIO. Senator Scott.

Senator SCOTT. So, what is the benefit of Kennedy Space Center, NASA's contract with a small company versus a large. Why should they do business with small companies?

Mr. RUSH. Historically, as I have kind of mentioned earlier, small businesses are the epicenter of innovation in America, right. Small businesses are, you know, are extremely capable and sustainable innovation, and where large companies are good at are very capable, it is the same sustainable innovation.

And going forward to the moon to stay and on to Mars, we have to have new ways of doing things, new mission architectures, new technologies to be able to go and stay. The way that we have traditionally done, you know, human space exploration has been some camping trips. And what we need to do is more like pioneering. We need to go and have manufacturing technologies to allow us to adapt to the circumstances that exist, you know, and eventually be able to sort of live off the land.

You know, the ISRU and other technologies. And you see that creativity in small business, you know, not to deride our friends at larger companies, but that is where you see a lot of innovation, and I think we work really well with larger companies, where they can say, hey, this is the well-trodden path that we have gone down and small business can say, hey, have you thought about doing it this way, and then work very, very well together.

Dr. NELSON. And I think the other cases, and certainly, we were one of those, where we have expertise test facilities, so forth, that really very few other people have.

Senator SCOTT. Have you—when you got these grants from Kennedy Space Center, has it allowed you to raise private money?

Mr. RUSH. So as a company, we have never taken diluted outside capital. We have been fortunate to grow by our customers. The SBIR program has enabled us to diversify our client mix. Actually, when we put our first 3D printer on the space station, the second one we put up was a commercial printer, and at the time we launched that, we had over a year of commercial customers including like Fortune 500 companies and large aerospace companies who were signed up to utilize that device. So we have been able to, you know, commercialize that very, very quickly because of SBIR.

Senator SCOTT. So, how about you, Dr. Nelson?

Dr. NELSON. In our case, we are looking to transition our technology to in fact large companies for the applications that I talked about. And so that is really our focus. Simultaneously with that is looking at our technology and how can that technology meet other critical needs.

Senator SCOTT. So how have each of you been able to move outside of just the government contracting into the private sector? Have you both been able to do that?

Mr. RUSH. So one of the ways that we have been able to move out, you know, into the private sector, is building on our expertise in developing manufacturing technologies that work in a zero-gravity environment. We have developed one and now we have multiple payloads in development with our own money or with other private money to make these kinds of space-enabled materials.

So we have actually launched four times a payload that makes an exotic optical fiber called Z Bland on the International Space Station, and this is actually the first kind of commercial industrial utilization of the space environment to make a product that because it was manufactured in space, it has got really, really valuable properties. And we have both follow-up projects to make bigger and more capable payloads to make more of that material, as well as just explore other potential space-enabled materials going forward.

Dr. NELSON. For us, the vision of the project was, in fact, broad utilization of the technology and thus the importance, from really day one, the commercialization panel, international experts who really have the understanding of the use of these kinds of materials in a broad industry application. And so we have done that from the beginning, and we have in Phase III—Phase III, in fact, is commercial industry-funded, not government-funded, and looking for some very specific high-tech applications that will utilize our technology.

Senator SCOTT. So the money you have received from NASA, do you think NASA has gotten a good return?

Mr. RUSH. I would hope so. You know, we have been able to, you know, just in very practical terms demonstrate technologies that have accelerated technology road maps with manufacturing, you know, in space and that kind of local real-time manufacturing, and how many catalogs that, hey, if this breaks we can just print this

part rather than in bringing more and more spares and taxing our mass budgets that much more.

That has really been a, you know, really been a kind of align shift that we hope our friends at NASA have benefited from. And similarly, with our Archinaut technology, that is a truly transformational technology for how we are going to approach manufacturing and assembling satellites. You know, and going forward, you know, one day we think that maybe the sort of successors to James Webb, you know, will be manufactured and assembled in orbit in a much more, you know, efficient fashion and a much more reliable fashion than maybe we can currently accomplish.

Dr. NELSON. Materials are enablers and thus what NASA in fact wanted was materials that could have multiple applications. And so yes, you have a flexible polyurethane foam that can be used to repair cryo lines rather than the hazard of using a spray insulation in space, but simultaneously with that, you have a material that can be used for a whole variety of other applications.

For example, I mentioned packaging and meeting the Air Force packaging standard. So yes, I think they have not only got their money's worth but beyond that given its commercial utilization, one has it at a price of a couple of dollars a pound. In fact, it is very affordable.

Senator SCOTT. What would you think if NASA said the next time, they said, I am going to give you a grant, but I am going to take out royalties if you use anything you have learned from this if you use it for the private sector. What would you think about that?

Dr. NELSON. But in fact, we are doing that under confidentiality agreements with a number of key potential users. So we are actually doing that.

Senator SCOTT. So NASA has a royalty interest?

Dr. NELSON. NASA would not have a royalty interest. That is the NASA royalty is based upon any NASA application is royalty-free. But the small business may, in fact, get royalties on the basis of private sector use.

Senator SCOTT. If you were spending—if you were given the money out of your NASA, do you think they should ask for a royalty?

Dr. NELSON. No, I think that increases the complexity, which is already complex enough, and I think the key for NASA is in fact that they are able to use those materials for their applications in a very cost-effective way. And I think what it does is decrease the cost for them when we can get it out into the commercial sector.

Mr. RUSH. So we have been very fortunate to grow, you know, in double several times in the last, you know, last four or five years, and we have taken the long view and said, hey, we have this great technology and we are really fortunate we have some really smart folks on our team that are able to invent these great things, but we want to get to product. We want to get to the capability. We want to change the way, you know, broad-based satellites are manufactured for government and for commercial. We want to make human spaceflight missions safer and more reliable through in-space manufacturing.

And as such, we take basically every dollar that we have we plow it back into the business, to grow the business more aggressively and to do internal research and development to help move the needle on this technology. And our partners at NASA generally, and the SBIR program specifically, have been great allies in that endeavor. I would view—I think that taking a royalty in that technology would serve as a drag on that, you know, on a scaling-up because rather than us being able to take that money and put it back in the business to grow bigger and faster, you know, that money would be diverted somewhere else.

Senator SCOTT. Thank you. Thanks, Senator Rubio.

Chairman RUBIO. Congressman Waltz.

Mr. WALTZ. Thank you, Senator. I want to commend you both for, you know, as an entrepreneur as well for just sliding everything that you ever thought you owned, planned to own, aspire to own, and you know across the table for a product, for an idea, for a service, that you believe in. Mr. Rush. I do not see how we get the quantities of stuff that we need back and forth from Earth. We have to manufacture it in space in terms of getting to the moon, getting to Mars, and really getting the infrastructure that we need up there.

I want to take a step back for a moment and go back to human capital and, you know, on the one hand, I have five great universities in my district producing a lot of STEM talent and other talent, vocational as well, but I also hear from a lot of manufacturers, a lot of industry that they cannot find the skills that they need. We would love for you to share your experiences in terms of your human recruiting and what you are seeing out there in the workplace.

Mr. RUSH. The very first job I had in the space industry was working for this really small rocket company called Masten Space Systems in Mojave, California, which Mojave is in the middle of the desert in Southern California, and some of the other space companies out there kind of joke that one of the things that folks do is when they hire people out there and they bring their spouses, they see how much their spouses cry at, you know, being in this little like you know one truck stop town. But people go and work in Mojave and they come and work in this industry, in this economy, more generally because of the incredible transformational capability and potential that we have.

We believe that what we are working on and the space economy, you know, has the potential to be as disruptive to our daily lives in America both from a military perspective and from a fiscal perspective as, you know, sort of the e-commerce revolution. And because of that, as a small company we have been able to find and, you know, attract talent and retaining talent as we have grown. It is absolutely essential that, you know, programs, you know, from kindergarten through post-secondary education encourage people to understand STEM and view it as something that is accessible.

You know, in my hometown of Jacksonville we have a really prolific FIRST Robotics team that, you know, from elementary on getting folks really involved in that. And I think those things are really, really important. The other thing that I think is important from a workforce development perspective is focusing not just on the en-

gineering jobs, but on, you know, on all the disciplines it takes to run a successful business and to grow a successful business. It is just as important for us to have really talented finance folks as it is to have really talented engineers.

Mr. WALTZ. I am from Jacksonville as well, Mr. Rush. Just great to see such talented entrepreneurs coming out of there. Dr. Gordon, anything?

Dr. NELSON. Yes, and I think that is where perhaps STTRs are a little more special particularly with a university as the SBIR. As I said, in our program, we have had fourteen students. All but one of those, in fact, has become an engineer. And as I said, of the six Masters students involved, five of those have been women so that one, STTRs I think are special. And that in fact, the students have commented that they appreciated the exposure to real industrial applications with the responsibility of real project goals and real timelines.

So they are getting a chance to see all of that. And one student, the lead Master student, in fact, has done a fantastic job in managing a project group and learning how to do that. And so I think that STTRs really have a great opportunity to extend STEM into the real world and get students excited about it.

Mr. WALTZ. Well, thank you. One other questions, Mr. Chairman.

Chairman RUBIO. Yes, of course.

Mr. WALTZ. If time allows. I want to follow up with what Senator Scott was kind of pressing on in terms of put yourself in NASA shoes, put yourself in the government's shoes, there are a lot of reasons we have these types of hearings and our oversight role. You know, in hearing from industry, what would you do different? I have so far cash flow. Cash is king and I know it is brutal when one we don't have it, and two when you cannot predict when you are going to have it.

So if I hear you correctly, Dr. Nelson, providing those, at least those very initial small grants upfront. If I heard you correctly also, getting away from SAM registration in terms of speeding. I don't know how we would get around that. Maybe some regulatory exemptions. I am not sure if I hear you properly there.

Dr. NELSON. Correct. I think it may well be a regulatory exemption but certainly looking at the process and how can one ensure that those who are not already in the grant business can, in fact, bring their special technology to bear on the key agency needs.

Mr. WALTZ. But that is exactly what I—that is kind of what I wanted to get into my last question. So there are a number of companies out there that have the expertise and have products that NASA and the military need in spaces.

Is there anything else that you can think of and how to pull them kind of into the ecosystem, that would make it more attractive, easier? I know in my own experience, I recall a study from Ernst & Young that anyone seeking to do business with the government had to add anywhere from 20 to 30 percent in overhead to handle all of the regulatory requirements. While we all have each other here, is there anything else that you recommend?

Dr. NELSON. I think focusing heavily on the sort of post Phase II directions of things is important. As we heard earlier, you know, there is Phase II E, there is sequential Phase II. There is, you

know, lots of other tools available. But there existed, you know, sort of technology wasteland, right. You know, these really great transformational technologies that you know, bought for and, you know, paid for, a few million dollars more or a few hundred thousand dollars more, and from a space technology perspective, that is a huge opportunity for improvement. That if we can smooth the path and provide multiple paths up that TRL ladder to get to not only to higher, you know, prototype technologies, but to get to flight heritage technologies. I think that that would be an area to really, you know, an area worth exploring and improving.

Mr. RUSH. I think my concern is on the start side. And that is, how do you help young entrepreneurs, how do you help young academics, get into the process in a speed that they can do and without the initial cash investment, which they can't do? So, you know, whether that is a special program or not, perhaps, but I think there is—you know, I have been in academia for a long, long time, and I know there are a lot of ideas that are really beyond the cutting edge. And I think a question is, how can you tap those? How can you get those more quickly into the NASA and other government agency utilization? And that is really my concern.

Mr. WALTZ. Thank you. Thank you both. Senator, I yield my time.

Chairman RUBIO. You know, just to close the loop, I think people would be shocked at how much of the things that we deal with every single day began as a government research project to solve a space, national security, or scientific need. So, you know all the press clippings about Uber and Lyft and all that, they would not exist without GPS technology that was first innovated, I think it was a DARPA project. Same thing with the internet. The internet started as a government project. There are others. I wrote a list here. The first programmable computer was not made by Apple or by Microsoft and some you guys, it was the result of a government need for optical scanners. Apparently low-fat mozzarella cheese. I do not know——

[Laughter.]

So, maybe I should have left that one out. But the point being that these are all, and it strikes me that some of the things you are both talking about doing have extraordinary commercial application, but they also have DOD applications as well.

I want to use as an example. I would imagine if you were deployed halfway around the world, it is going to be a lot easier for troops in the field or major craft carrier to solve a problem it has by being able to carry enough raw material to manufacture on board and spare a part that they need or solution they need than it would be to have it shipped there. The logistical challenges of getting things there. Likewise with the materials that you were talking about, Dr. Nelson.

So I want to talk a little bit about the DOD part of it. Now, we are in the NASA facility that we have already outlined how they interplay with one another. I think that DOD is about half—my notes say about half of SBIR awards, but it continues to experience sort of a shrinking industrial base where we are seeing more and more of the procurements are going to, a larger piece is going to less and less contractors, large contractors. I wanted to ask you

both, have you had experience and what has your experience been doing the SBIR program with the DOD, the Department of Defense?

Mr. RUSH. So to your point about, you know, having local manufacturing being something that could be really helpful to a warfighter, one of the interesting things that we found when we developed the 3D printer for the space station is that making a printer that can survive a rocket and then operate in space means that you also have made a printer that you can put on like a submarine or in a small draft vessel at sea and have it successfully operate——

Chairman RUBIO. Or an oil rig?

Mr. RUSH. Yeah, or an oil rig. Exactly. So those are areas that we have explored some and, you know, done some initial testing on, but I think to another one of your points that we do see on the DOD side, you know, perhaps a larger percentage of the pie being driven by very large contractors. So the transition sometimes from, you know, from NASA SBIR and development over to DOD or from, you know, tech to operational can be a significant hill to climb.

And, you know, the fact that we are, you know, making that hill easier to climb would be really great. Likewise, we have also done some good work on SBIRs for Air Force and for DARPA, and their cycles are a little bit different than NASA. You know, they have maybe more frequent cycles, but generally, you know, during, those processes have been very good and kind of system-focused rather than component-focused

Chairman RUBIO. Dr. Nelson.

Dr. NELSON. Yes, I mentioned an army SBIR, and basically what that was all about was a small inner line. And so if you have a vehicle and you have a shell coming into it, it is the metal that hits the spall liner and that is to stop shell fragments from going on around the vehicle. The whole idea is to have an inner liner. So whatever happens to that vehicle, the vehicle tumble, so forth, you now have a flexible inner liner which will be an energy-absorbing material. So you will have less injury of those people inside the vehicle.

So our material could have played, in fact, a role. Or as I mentioned, since it was an SBIR in DOD, you had the company needed to spend 50 percent of project direct expense. Well, that immediately excludes the sole proprietorship. So we then had to go out, get a company that would be the SBC, very interesting company but did not have the direct spall liner relationship that we in fact had. So I think there is an example were setting something up that does not allow certain kinds of companies to participate simply limits innovation.

Chairman RUBIO. In the Phase III part of the program, where you can there is some opportunity for sole source, which is a huge back-end carrot that draws people into the program and no longer involves the direct funding, it is a contract if by chance you got it, but we have heard, at least that on the DOD side, many of the small businesses say they have mixed results with the contracting officers. Some of them know about it. Some of them don't or they are not as fully informed about all the attributes of the program.

Have you had that experience with DOD or anyone for that matter in your work? Either one?

Mr. RUSH. Yeah, we certainly experienced varying levels of education at the contractor level about——

Chairman RUBIO. Just to let people know, this is the person at the agency or the branch or whatever that is your liaison, your inner interface.

Mr. RUSH. Absolutely. So we have had very varying experiences there because it is a powerful tool not just for us as a small business, but for, you know, for folks within a given agency trying to accomplish things, right, to say, hey, we can avoid the competition process, we can just sole source.

You know, not only that but we have also had some times we run into issues where, you know, with the SBIR law says that if you have a technology that extends, derives, or completes work that was done on an initial Phase I, you should go back to that first SBIR awardee and have them do that work unless you can, you know, tell your SBIR, here is a reason why not. Those two things. We have seen varying levels of education, and sometimes folks really educated about that and other times, you know, other times there are some opportunities for improvement there that could lead to things maybe not being accomplished in the ways that they might otherwise be accomplished or going slower than we would otherwise like.

You know, from a NASA perspective and from a DOD perspective, like going fast is really crucial right now. We are—China is out publicly saying, hey, we are going to in-space manufacture and assemble giant solar ray farms and, you know, we want to get back to the moon and stay, you know, and by 2024. Both of those are things where we cannot, you know, we do not have the luxury of missing some quarters as it were.

Chairman RUBIO. Dr. Nelson.

Dr. NELSON. I really don't have a comment.

Chairman RUBIO. So, let me ask you about my last question for both of you, and this touches on the large, but I think small businesses and mid-sized businesses have a special problem with this potentially.

We are all aware you invent something unique and there are companies and countries out there that specialize in finding out what it is you are doing and reverse engineering, and all of a sudden you wake up one day and realize even if you have never done business in that country, that either someone stole it from you through a cyber intrusion, or you had an employee that gave it to them for money. It happens all the time. So it would be interesting if the American taxpayer is helping you an American company build this capacity that is in our national interest, and we have done all this work and taking all the risk, and all of a sudden we wake up one day and we find that, for example, China is doing what we do, except their company is funded and backed by the government and so they are now competing with you in the commercial space with the advantage of not having to initial make a profit so they can drive the price down and force you out.

Do you feel you are properly postured, and do you have the defenses that you need against whether it is a cyber intrusion on the

intellectual property—I know what the law is about. You know, patents and protecting things legally. We know how well that works in parts like China and other places. Do you both feel like you have what you need to protect yourself whether it is a cyber intrusion or insider transfer, and how real risk is that moving forward? And how much do you think about that?

Mr. RUSH. So I think what you have just described as a CEO of a small company, it is something that I think about, but it is also something that we almost view is as unchangeable as the weather, right. That is the environment that we operate in, that we play in.

And there are folks within the government that, you know, on a sort of an ad hoc basis have reached out to us and said, hey, you are in this emerging technology field, here are best practices, and I think that is really, really great. Perhaps like systematizing that and focusing that on SBIR would be prudent one day, but really our approach to that is our approach to any competitor, to any competitive, you know, outside force, which is to just go as fast as we can, and trust our team, and trust the innovations that we have, and ultimately do our best to be successful that way.

Chairman RUBIO. Any comments, Dr. Nelson.

Dr. NELSON. In our case, and with chemicals materials, is that we are not doing patents, we are doing trade secrets. The reason we don't do patents is the purpose of patents is to give away the technology.

Now, these polyurethane foams are very complex technology, which is very difficult. In fact, to do analysis to find out really how they are made is just what the constituents are, but how you do it. And so from a technology protection standpoint, it has been trade secret and working with companies only after a nondisclosure agreement. And so certainly that has been working very well for us.

Chairman RUBIO. And one of the areas, to close the loop on it, that we have been concerned about is small and midsize businesses are facing nation-state level cyber threat, but do not have nation-state, much less large corporate cyber defensive posture capability because of the cost associated with is real costs. I mean, we have some of the largest companies in America having massive data breaches. So just imagine how difficult it is for someone who is busy innovating and spending all their time, energy, and resources on making something.

And so we have seen numerous cities and municipal entities in Florida be held hostage, had to pay ransom, to someone probably from North Korea in order to get their records back.

So it is an area that we filed some legislation on that we do want to sort of incorporate as part of what we are doing because it is a 21st century threat. You don't even have to have somebody here. You can get into the network because it could be as simple as somebody clicking on an attachment that they shouldn't, and obviously we want to make sure that we can figure out the best way as part of these programs to also protect it, because these technologies are also in our competitive advantage and some cases are not just trade secrets, they are in our national interest, potentially our national security interests to become a significant strategic advantage. Anyone have anything else?

[No response.]

I want to thank you both for being here. I think it has been insightful and helpful. Congratulations on your success, and we look forward to seeing you both again. Thank you.

Again, I want to thank Congressman Waltz, my colleague Senator Scott for being here today as part of this hearing. As I said, we are moving over next week to hopefully reauthorizing all of this. So a lot of these comments that we have gotten here today are going to be very helpful in that regard. And I want to, of course, thank all of our witnesses and our two panels for being a part of this.

The hearing record will stay open for two weeks. You may get some questions from my colleagues around the country that are not here today. We only ask if you could answer them just because they become part of our record and we point to this when we do legislation, we point to testimony and things that are said to justify why we are for something or why we are against something, so it is helpful. That record is going to stay open for two weeks so any statements or questions for the record are going to be submitted by the 2nd of August at 5:00 p.m.

Thank you again. With that, the hearing is adjourned.

[Whereupon, at 1:15 p.m., the hearing was adjourned.]

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