SIXTY YEARS OF NASA LEADERSHIP IN HUMAN SPACE EXPLORATION: PAST, PRESENT, AND FUTURE

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED FIFTEENTH CONGRESS

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SIXTY YEARS OF NASA LEADERSHIP IN HUMAN SPACE EXPLORATION: PAST, PRESENT, AND FUTURE

WEDNESDAY, SEPTEMBER 26, 2018

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 2:11 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Babin [Chairman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future

Wednesday, September 25, 2018
2:00 p.m.
2318 Rayburn House Office Building

Witnesses

Mr. William Gerstenmaier, Associate Administrator, Human Exploration and Operations Mission Directorate, NASA

Mr. Mark Geyer, Director, Johnson Space Center, NASA

Ms. Jody Singer, Director, Marshall Space Flight Center, NASA

Mr. Robert Cabana, Director, John F. Kennedy Space Center, NASA

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

Charter

TO:	Members, Committee on Science, Space, and Technology
FROM:	Majority Staff, Committee on Science, Space, and Technology
DATE:	September 26, 2018
SUBJECT:	Space Subcommittee Hearing: "60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future"

On Wednesday, September 26 at 2:00 p.m. in Room 2318 of the Rayburn House Office Building, the Subcommittee on Space will hold a hearing titled, "60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future."

Hearing Purpose

To provide NASA and Center Directors with significant Human Spaceflight responsibilities the opportunity to describe how they are positioning their respective centers to enable NASA to execute successfully a sustainable human exploration program that mitigates the negative impacts experienced in the course of prior human spaceflight program transitions.

Witnesses

- **Mr. William Gerstenmaier**, Associate Administrator, Human Exploration and Operations Mission Directorate, NASA
- **Mr. Mark Geyer**, Director, Johnson Space Center, NASA
- **Ms. Jody Singer**, Director, Marshall Space Flight Center, NASA
- **Mr. Robert Cabana**, Director, John F. Kennedy Space Center, NASA

Staff Contact

For questions related to the hearing, please contact Mr. Ryan Faith, Professional Staff Member, Space Subcommittee, or Ms. Sara Ratliff, Professional Staff Member, Space Subcommittee, at 202-225-6371.

Chairman BABIN. Good afternoon. The Subcommittee on Space will now come to order.

Without objection, the Chair is authorized to declare recesses of the Subcommittee at any time.

Welcome to today's hearing titled, "60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future." I'll recognize myself for 5 minutes for an opening statement.

The 36th Congressional District of Texas is home to the Johnson Space Center, a source of pride for all Texans. Representing my constituents and JSC has been one of the proudest and most exciting experiences during my Congressional tenure. I am honored to have the privilege of serving as the Chairman of the Space House Subcommittee as well. This role has shown me just how vital NASA is to our Nation.

Sixty years of outstanding achievements by NASA have served to lay the foundation for even more incredible feats over the next 60 years. Every single one of these remarkable accomplishments would not have occurred had it not been for the amazing individuals who have made up the NASA team over the years. The unique capabilities and experience of the workforce at each of NASA's centers, three of which are represented here today, were very critical in helping NASA accomplish such audacious goals. To accomplish remarkable feats in the future, our NASA centers, workforce, and industry must be healthy and vibrant.

One of the first bills signed into law this Congressional session was the 2017 NASA Transition Authorization Act, which directed NASA to provide a Human Exploration Roadmap. Although that report arrived a little later than originally planned, it is finally here.

The new National Space Exploration Campaign laid out in the report not only charts a bold course for American human space exploration in the years and decades to come, it also provides an opportunity for JSC to continue serving a central role in exploration, as the expertise in Houston is critical to taking our astronauts beyond low-Earth orbit. As I said in my July 25 column in the Houston Chronicle, the next time any American sets foot on the Moon or Mars, I want to again ensure that the first word from the surface is "Houston." To meet these new goals, we need to build upon and cultivate the invaluable and unique capabilities of each center and to utilize their irreplaceable workforce, which is a competitive asset for our Nation.

Following the passage of the 2017 NASA authorization, I introduced H.R. 5503, the 2018 NASA Authorization Act. This bill reaffirms JSC's leadership role in human spaceflight operations and consolidates NASA's systems and integration work on space suits, providing greater efficiencies, preserving the industrial base, and keeping JSC's engineering and space operations capabilities "front and center."

Just this morning, I introduced the Leading Human Spaceflight Act to provide further Congressional direction to NASA. This bill reaffirms JSC's leadership role as the home of American human spaceflight, and this legislation also recognizes that, based on their historical role and extensive expertise and capabilities, Johnson Space Center is the logical center to serve a lead role in program

management, systems engineering, program integration, and operations for NASA's human space exploration program, particularly those outlined in the Human Space Exploration Campaign.

As I've said before, the ISS is the crown jewel of America's human spaceflight program. Leadership in LEO returns tremendous economic benefits of space exploration to Earth. My bill promotes policy that will lead to a permanent and continuous U.S. human presence in LEO and authorizes NASA to operate the ISS until 2030, or until we have demonstrated a sustainable lower-cost alternative. At the same time, NASA is directed to start work with the private sector in developing the commercial capabilities to meet America's future needs in low-Earth orbit.

And while I've talked at length about JSC this afternoon, space exploration is a team effort, and I am very, very proud of the work done at all of our NASA centers. We must ensure that we learn from the past to prevent the detrimental gaps in prior transitions and protect our most important asset—the people—the irreplaceable workforce that have brought us this far and will take us into the next 60 years of space exploration.

[The prepared statement of Chairman Babin follows:]

COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Lamar Smith, Chairman

For Immediate Release
September 26, 2018

Media Contacts: Heather Vaughan, Bridget Dunn
(202) 225-6371

Statement from Chairman Brian Babin (R-Texas)

60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future

Chairman Babin: The 36th Congressional District of Texas is home to Johnson Space Center, a source of pride for all Texans. Representing my constituents and JSC has been one of the proudest and most exciting experiences during my congressional tenure. I am honored to have the privilege of serving as Chairman of the House Subcommittee on Space. This role has shown me how vital NASA is to the nation.

Sixty years of outstanding achievements by NASA have served to lay the foundation for even more incredible feats over the next 60 years.

Every single one of these remarkable accomplishments would not have occurred had it not been for the amazing individuals who have made up the NASA team over the years. The unique capabilities and experience of the workforce at each of NASA's centers, three of which are represented here today, were critical in helping NASA accomplishing such audacious goals. To accomplish remarkable feats in the future, our NASA centers, workforce and industry must be healthy and vibrant.

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I've said it before—the International Space Station (ISS) is the crown jewel of America's human spaceflight program. Leadership in LEO returns tremendous economic benefits of space exploration to Earth. My bill promotes policy that will lead to a permanent and continuous US human presence in LEO and authorizes NASA to operate the ISS until 2030, or until we have demonstrated and sustainable lower cost alternative. At the same time, NASA is directed to start work with the private sector in developing the commercial capabilities to meet America's future needs in low—Earth orbit.

While I have talked at length about JSC this afternoon—space exploration is a team effort and I am very proud of the work done at all of our NASA centers. WE MUST ENSURE that we learn from the past to prevent the detrimental gaps in prior transitions and protect our most important asset—the people—the irreplaceable workforce that have brought us this far and will take us into the next 60 years of space exploration.

I thank the witnesses for joining us here today and look forward to their testimony.

###

Chairman BABIN. And speaking of the invaluable workforce, I understand that NASA's Flight Director class of 2018 is in the audience today. I just shook hands with all of them, I believe. These new Flight Directors have begun their training on flight control and vehicle systems, operational leadership, and training and risk management, and they aim to complete their training in 2019 and join an elite group of less than 100 Flight Directors who will lead America in our future human spaceflight missions. We welcome you today and thank you for your service.

I want to thank the witnesses. I'm sorry I was running late. I didn't get a chance to come in the room in there and get to shake your hands. We had to vote, and I rushed in as quickly as I could, but I want to thank you for—each and every one of you for being here, and I look forward to your testimony.

Let me introduce—what do we have? Oh, I now recognize the Ranking Member. I don't have that page. I'm sorry. Sorry about that——

Mr. BERA. Don't worry.

Chairman BABIN. —Ranking Member. I now recognize the Ranking Member, the gentleman from California, a good friend, for an opening statement.

Mr. BERA. Thank you, Mr. Chairman, and thank you for calling this hearing on 60 years of NASA leadership in human space exploration, past, present, and future. I've said this often in this Committee when I think about the past, having grown up in Downey, California, which was the home of Rockwell International at that time and in the midst of the Apollo program, just the excitement of the late '60s and early '70s. In many ways that led to my interest in science. And while I didn't become a NASA astronaut, I did go to medical school and become a doctor.

And I think for a generation of kids, it led to kids going into engineering, kids going into the sciences and really captured our imagination. So, you know, the past and when we think about NASA, it is one of the iconic brands that has accomplished a lot, but it also in a sense of patriotism, it's one of the things that we're most proud about in the last 50 years.

It's also—when I—we think about the present, it's not that often we get four senior-level NASA Administrators and the folks that are really on the forefront here, so thank you to the witnesses for being here and the work that you do and the pride that you give us as Americans.

When we think about the future and we think about our NASA centers—and I think that's something that the Chairman and I and the full committee have thought about. We really have to start giving NASA and our whole space program a roadmap, a strategic plan. We can't change that strategic plan from Administration to Administration, particularly if we're setting a goal—and my colleague Mr. Perlmutter from Colorado is not here, but he'd say well, the goal is to get to Mars by 2033. Well, if we are setting that goal, again, we've got to give NASA that roadmap and give the men and women and our commercial industries that roadmap so we can move forward with that. That was one of the things that made us very successful in the lunar mission was it didn't matter if it was a Democratic Administration or Republican Administration. We set

a goal, we set our minds to it, we put our ingenuity into it, and we got there. And I think that's certainly my hope is Congress working with the Administration does start to lay out what that roadmap looks like.

With that I'd be interested as we start hearing from the witnesses within our centers, how can the centers be a cornerstone of that sustainability and how we move forward? In addition, what are the challenges that we might face as we look at those future missions, whether those are an aging workforce, if there's a skills gap, et cetera, and what are some things that we should be focusing in on as we look at the question of the future, and where should we focus as Congress?

And then what are some of the barriers in terms of funding and predictability, et cetera, because, again, if the goal is to go to Mars by 2033, we don't know how we're going to get there. We didn't know how we were going to get to the Moon, but let's set that challenge and then let's put our shoulders into it and our ingenuity into it and then let's go meet that challenge.

So, again, thank all of you for your service and, you know, making this country proud. And again, I look forward to the testimony. Thank you.

[The prepared statement of Mr. Bera follows:]

OPENING STATEMENT
Ranking Member Ami Bera (D-CA)
of the Subcommittee on Space

House Committee on Science, Space, and Technology
Subcommittee on Space
"60 Years of NASA Leadership in
Human Space Exploration: Past, Present, and Future"
September 26, 2018

Good afternoon.

Thank you Mr. Chairman for calling this hearing on "*60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future*" and welcome to our witnesses. It is not often that we have the privilege of hearing from a panel composed of only active NASA senior executives.

Mr. Chairman, this Subcommittee and its Members know that NASA has done a lot during its 60 years of operation and their human spaceflight accomplishments continue to have a special place in this country's history. I have often talked in this committee about how Apollo and the Moon landing drove my interest in science and my desire to become a physician. After serving on this committee, I know that I am not alone in having been inspired by NASA. Sadly, the missions planned to follow *Apollo 17* were cancelled and we never were able to explore the Marius Hills volcanic domes on the Moon nor the Copernicus crater. As we all know, many of NASA's missions take years to complete.

With the goal of sending humans to the surface of Mars, the sequence of activities leading up to that goal will likely occur over several decades or more. Prior starts and stops and unscheduled transitions have taxed NASA's workforce, its supporting contractors, and the communities surrounding NASA centers. That's why it's critical that we find a way to sustain a multi-decadal program over several Congresses and Administrations.

Late last Friday, NASA finally provided the Committee with its National Space Exploration Campaign report. Although I am appreciative of receiving it, I would have hoped it came closer to the December 1, 2017 due date established in law. And while we are certain to have additional opportunities to discuss the details of the plan, today I hope to hear from NASA how this new campaign will enable, as the agency states in the report, an innovative and sustainable program of exploration that "*does not assume or require significant funding increases*".

However, there are fundamental issues related to sustainability that we also need to discuss today. These include:

- *What allows a human space exploration to be sustainable? What can NASA centers do to ensure sustainability?*

- *What negative impacts have centers and their surrounding communities experienced during past human spaceflight program transitions, both scheduled and unscheduled?*

Do existing conditions at the centers and their surrounding communities make the re-occurrence of such negative impacts less likely or more likely, and does it vary by center?

- *Has NASA identified any gaps in the skills, knowledge, experience, or expertise needed to carry out its planned human spaceflight activities? Does NASA require additional authorities to address any workforce-related shortcomings?*

Well Mr. Chairman, as you can see, we have much to discuss today. Thank you and I yield back.

Chairman BABIN. Thank you. I now recognize the Ranking Member of the full Committee for a statement, the gentlewoman from Texas.

Ms. JOHNSON. Thank you very much, Mr. Chairman.

Good afternoon and welcome to all of our NASA witnesses. It's really good to see all of you here from NASA.

In concert with our international, academic, and commercial partners, NASA and the Nation are closer than we have been in decades to launching the world's largest heavy-lift rocket, sending crew beyond the Earth's neighborhood, launching humans to the International Space Station from domestic soil, and developing a shared vision on how to get humans to the surface of Mars. This is an exciting time in our nation's space history, and NASA and its workforce are planning an important role in bringing these dreams to reality.

So I'd like to take a moment to thank all of you from the NASA Centers and the Directors of the workforce that you represent, and the work that you do every day to achieve America's goal.

Last Friday, NASA transmitted the National Space Exploration Campaign report in response to direction in the NASA Transition Authorization Act of 2017. I'm pleased that we have finally received this report, and I look forward, Mr. Chairman, to a vigorous discussion of the report's contents. The report was to provide the necessary plans to enable a human mission to Mars, a national goal enshrined in law.

I also look forward to continuing our discussion of the proposed International Space Station transition. If Congress decides to end direct financial support for the Space Station at some point during the next decade, we will need a well-thought-out transition in place. A repeat of the negative experience that followed the end of the Shuttle program would not be in the best interest, and nor would it be consistent with the goal of a sustainable exploration program.

And, Mr. Chairman, before closing, I want to say that it is important to recognize that today's space program is not the government program that existed 60 years ago. The expanding number of space actors, both government and non-government, provide increased capabilities that NASA can leverage in meeting our space exploration goals. But it is equally important to recognize that, as NASA is doing with the International Space Station, we need NASA to provide the leadership required for a successful long-term collaborative partnership to send humans to Mars.

I thank you, Mr. Chairman, for having this hearing, and I hope that we'll follow a sensible course. Thank you.

[The prepared statement of Ms. Johnson follows:]

OPENING STATEMENT
Ranking Member Eddie Bernice Johnson (D-TX)

House Committee on Science, Space, and Technology
Subcommittee on Space
"60 Years of NASA Leadership in
Human Space Exploration: Past, Present, and Future"
September 26, 2018

Good afternoon and welcome to all of our NASA witnesses. It is good to have you here.

In concert with our international, academic, and commercial partners, NASA and the nation are closer than we have been in decades to launching the world's largest heavy-lift rocket, sending crew beyond the Earth's neighborhood, launching humans to the International Space Station from domestic soil, and developing a shared vision on how to get humans to the surface of Mars.

This is an exciting time in our nation's space history, and NASA and its workforce are playing an important role in bringing these dreams to reality. So, I'd like to take a moment to thank all of the NASA Center Directors and the workforce they represent who work so hard each and every day to help achieve America's goals in space.

Last Friday, NASA transmitted the "National Space Exploration Campaign Report" in response to direction in the NASA Transition Authorization Act of 2017. I'm pleased that we have finally received this report. I look forward, Mr. Chairman, to a vigorous discussion of the report's contents. The report was to provide the necessary plans to enable a human mission to Mars, a national goal enshrined in law.

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Before closing, Mr. Chairman, it is important to recognize that today's space program is not the government program that existed sixty years ago. The expanding number of space actors—both government and non-government—provide increased capabilities that NASA can leverage in meeting our space exploration goals. But it is equally important to recognize that, just as NASA is doing with the International Space Station, we need NASA to provide the leadership required for a successful long-term collaborative partnership to send humans to Mars.

Thank you, Mr. Chairman, and I yield back.

Chairman BABIN. Yes, ma'am. Thank you.

I now recognize the Chairman of the full Committee, the gentleman from Texas, Mr. Smith.

Chairman SMITH. Thank you, Mr. Chairman.

The recently released National Space Exploration Campaign report shows we are truly in an exciting time for our Nation and NASA.

Our witnesses today include the head of NASA's human spaceflight programs and the Directors of three NASA centers who carry out major human spaceflight responsibilities. Together, they are responsible for implementing and carrying out much of this campaign, and we are fortunate to have them with us.

With clear Congressional direction, strong White House leadership, and NASA's tremendous expertise, we have all the resources available to make significant progress in human space exploration. I'm pleased that NASA has delivered a Human Exploration Roadmap, as required by the 2017 NASA Transition Authorization Act. The National Space Exploration Campaign lays out a bold and achievable plan for human exploration that includes low-Earth orbit, the Moon, Mars, and beyond. The report also specifies key critical decision points for future human space exploration. By laying out an open architecture with key decision points, off ramps, and deadlines, the campaign demonstrates resilience, constancy, and sustainability. We cannot always predict which ambitious projects will succeed or what future missions may discover, but this campaign builds in opportunities to capitalize on successes while mitigating misfortunes.

I believe this report also clarifies the Administration's policy on the International Space Station and its future. Clearly, NASA and the Administration do not intend to abandon America's presence in low-Earth orbit. This campaign lays out some of the first details about how the United States can preserve its leadership in low-Earth orbit, while extending its reach outward to the Moon, Mars, and beyond.

At the same time, I note that Subcommittee Chairman Babin has introduced the Leading Human Spaceflight Act, which builds on the ISS Transition Report and the ISS policy laid out in the National Space Exploration Campaign report and provides forward-leaning Congressional leadership as we move into the next phase of low-Earth orbit utilization, and I want to thank the Chairman of the Subcommittee for introducing that legislation.

I am sure that Mr. Gerstenmaier will agree that all of NASA's centers play an important and vital role in our Nation's space program. Each center is an incredible technological asset and engine of economic development. The goals and tasks laid out in the National Space Exploration Campaign will provide many opportunities for each center to bring their unique capabilities to bear. Three of those centers will be represented here today to tell us how they intend to contribute to this campaign and what it means for their workforces and their communities.

As we near the end of this Congress, I cannot tell you how pleased I am with our progress in space over the last six years. We are on the verge of one of the most ambitious eras in space that

this country has ever seen. I hope the testimony we hear today will shed additional light on these exciting times.

Thank you, Mr. Chairman, and I'll yield back.

[The prepared statement of Chairman Smith follows:]

COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Lamar Smith, Chairman

For Immediate Release
September 26, 2018

Media Contacts: Heather Vaughan, Bridget Dunn
(202) 225-6371

Statement from Chairman Lamar Smith (R-Texas)

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###

Chairman BABIN. Thank you. I appreciate you, Mr. Chairman.

Now, I'd like to recognize the gentleman from Florida for an opening statement, Mr. Posey.

Mr. POSEY. Thank you, Mr. Chairman, and thank you for holding this hearing.

This year, we celebrate the 60th anniversary of the National Aeronautics and Space Administration, the world's premier and most respected space exploration agency and the only federal agency tasked with space exploration. We've come a long way since the inspiring words of President Kennedy, who motivated this country to make and keep a promise to put a man on the Moon and return him safely to Earth by the end of the 1960s, not because it was easy but because it was hard.

If I were to say, "Kitty Hawk," everyone would immediately think of the Wright brothers and the first flight of man. If you say, "Cape Canaveral" or "Kennedy Space Center," most people, in my generation certainly, would say in return, "Mercury, Gemini, Apollo, Space Shuttle." Our nation is so very proud of the men and women at our space center who continue the noble work of our space program. They know and we know that space exploration is demanding work and that they will meet any of the challenges, however bold that they may be in the future.

As other members have mentioned earlier today, Members of Congress have been asking NASA for a detailed roadmap to Mars for several years now, and I've advanced a bipartisan legislative proposal to return to the Moon and to go onward to Mars from there. Today, we have bold leadership. The President's directive, NASA, and the National Space Council are all preparing the way. America must not fall behind. I look forward to hearing our witnesses and learning more about the national space exploration strategy.

Thank you, Mr. Chairman.

Chairman BABIN. Yes, sir. Thank you.

And now, I'd like to introduce our witnesses today. Mr. Bill Gerstenmaier, our first witness today, is the Associate Administrator of the Human Exploration and Operations Mission Directorate at NASA. He develops the strategic direction for all aspects of NASA's human exploration of space and provides programmatic direction for the continued operation and the utilization of our International Space Station. Mr. Gerstenmaier began his NASA career in 1977, performing aeronautical research, and he's managed NASA's human spaceflight portfolio since 2011. He received a Bachelor of Science in aeronautical engineering from Purdue University and a Master of Science in mechanical engineering from the University of Toledo. Thank you for being here, Mr. Gerstenmaier.

Our second witness today is Mr. Mark Geyer, Director of NASA's Johnson Space Center in Houston, Texas, located in my district. In his role, Mr. Geyer leads a workforce of about 10,000 civil servants and contractor employees. He began his NASA career in 1990 and later joined the International Space Station program in 1994. He has served in a variety of roles there, including Chair of the Space Station Mission Management Team. Mr. Geyer earned both his Bachelor of Science and Master of Science degrees in aeronautical

and astronautical engineering from Purdue University in Indiana. Thank you for being here.

Ms. Jody Singer, our third witness today, Director of NASA's Marshall Space Flight Center in Huntsville, Alabama. Appointed in September of 2018 as the first woman to ever run Marshall. Ms. Singer manages one of NASA's largest field installations with nearly 6,000 civil service and contractor employees and an annual budget of $2.8 billion. During her 32-year career at NASA, Ms. Singer has held leadership roles in human spaceflight, technology, and science programs and projects. Ms. Singer earned a bachelor's degree in industrial engineering from the University of Alabama. Welcome. Your football team is just doing fantastic this year.

And last but not least is Mr. Bob Cabana, our final witness today, Director of NASA's John F. Kennedy Space Center, or KSC, in Florida. Mr. Cabana manages all NASA facilities and activities at the spaceport, including the team of civil service and contractor employees who operate and support numerous space programs and projects. Mr. Cabana was selected as an astronaut candidate in 1985, and he served in a number of leadership positions at the Lyndon B. Johnson Space Center Astronaut Office. He has logged 38 days in space. Mr. Cabana graduated from the U.S. Naval Academy in 1971 with a bachelor's degree in mathematics. I welcome you as well, Mr. Cabana.

I now recognize Mr. Gerstenmaier for 5 minutes to present his testimony.

TESTIMONY OF MR. WILLIAM GERSTENMAIER, ASSOCIATE ADMINISTRATOR, HUMAN EXPLORATION AND OPERATIONS MISSION DIRECTORATE, NASA

Mr. GERSTENMAIER. Thank you very much. It's an honor to be here with this panel and also to represent the men and women of NASA.

Stopping to reflect on the past, present, and future of human exploration at NASA on this 60th anniversary is important and worthy of serious discussion. As we look back on the past, we must be extremely careful. As we look back, we carry a bias in the way we—as we know the outcome of the events that transpired. We also tend to link decisions and outcomes in ways that may not be correct. We have a natural hindsight bias and have a tendency to remember only the good things or the tragedies, and we miss the subtle things that were critical to success. We miss understanding the difficult decisions that were made with little data and appear perfect—and appear as perfect decisions in hindsight. We also discount the role of luck in some of our outcomes.

I can tell you from my own experience of having written many design requirements and flight rules in the past and now hearing the new generation of engineers and designers discuss the logic for these flight rules and design criteria, their perception today for the requirements and flight rules does not match the logic or the environment in which these requirements were written. We should learn from the past but recognize that our view of the past is flawed and try not to develop a strategy based solely on our perception of the past. There are also new processes and techniques that

did not exist in the past. We need to look for new approaches and develop new ways of designing systems and building hardware.

The capabilities of others outside of NASA is radically different than in the past. Both private industry and countries have the ability to contribute in huge ways that were not possible in the past.

And looking forward to the future, it's difficult to predict the exact plan or capability that we need. Space Policy Directive–1 provides an appropriate solid base for the future. I'll read from the policy. It says, "to lead an innovative and sustainable program of exploration with commercial and international partners, to enable human expansion across the solar system, and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations."

This policy is great in that it does not over-specify the how but describes key considerations, that is, an innovative and sustainable program with commercial and international partners and to enable human expansion across the solar system. The policy even covers the why, to bring back to Earth new knowledge and opportunities. This is a good policy to build off of for the future.

Rather than speculate on the future, let's spend a few moments reflecting on the present. Today, we sit with more hardware in development for human spaceflight than at any time in our past. We have two commercial crew transportation systems nearing completion and ready for—ready to fly crew to the ISS in the next year: Boeing CST–100 and SpaceX Dragon. We have an Orion capsule ready for Exploration Mission 1 and the European Service Module for Orion that has completed assembly in Germany. The service module will shift to the Kennedy Space Center for integration with Orion in late October and will undergo 400 days of integrated testing at KSC in Plum Brook in Ohio prior to flight.

The flight engines and solid rocket motors and liquid engines are ready for flight. The Space Launch System flight hardware is undergoing manufacturing and is planned to ship to Stennis next June for testing. In the next nine months, there will be two uncrewed flight tests to the ISS, a pad abort test for Boeing, a high-altitude abort test for SpaceX, a pad abort test for the Orion vehicle. Further, the Orion capsule pressure shell for the first human crewed mission around the Moon, EM–2, is at KSC beginning integration. This is an amazing time. Outside of NASA, we should also see the private sector suborbital flights with Virgin Galactic and Blue Origin next year.

Lastly, we've had crews in space continuously for 18 years. The research being done by the crews on ISS is amazing, and the technology development will allow divisions of Space Policy Directive–1 to be accomplished. We are likely never to see another space facility as amazing as the International Space Station in our lifetimes. These may be the good old days for the future generation.

We in human spaceflight are often accused of being too optimistic by review teams and inspectors. I like to think that we are appropriately optimistic. We must dream big to lead. The challenge of the lunar landing was huge and required appropriate optimism. We can do these big things, but there will always be risks, risks to the

lives of our astronauts, risks to our careers and legacies, risks to schedules and budgets. We can mitigate some of these obvious risks, but these risks cannot be truly managed or eliminated. We need to openly discuss these risks and make sure that they are understood. These risks are part of enabling human expansion across the solar system. Appropriate optimism is required to be a leader and to create the next 60 years of amazing accomplishments.

I look forward to a good hearing. Thank you.

[The prepared statement of Mr. Gerstenmaier follows:]

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BY WITNESS
September 26, 2018

Statement of

William H. Gerstenmaier
Associate Administrator for Human Exploration and Operations
National Aeronautics and Space Administration

before the

Subcommittee on Space,
Committee on Science, Space, and Technology
U. S. House of Representatives

Mr. Chairman and Members of the Subcommittee, I am very pleased to appear before you today. NASA is proud to be at the forefront of a global effort to advance humanity's future in space, leading the world while expanding on our Nation's great capacity for exploration and innovation. This is a role the Agency has played for 60 years, leveraging the talent and hard work of America's skilled Government and aerospace industry workforce to push the boundaries of science, exploration, and technology development to achieve bold goals in the aviation and space arenas. Now, pursuant to Space Policy Directive-1 (and consistent with the NASA Transition Authorization Act of 2017), NASA is pursuing "an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities." We are working on a sustainable campaign of exploration, transitioning the International Space Station (ISS), returning humans to the surface of the Moon and lunar orbit, where we will build the systems, deep space infrastructure, and operational capabilities to expand human presence beyond the Earth-Moon system, eventually embarking on human missions to Mars and other destinations.

The Past Is Prelude

From its earliest days, NASA has pushed the envelope in human spaceflight, with the 1960s dominated by the Agency's efforts to land a man on the Moon and return him safely to the Earth before the end of the decade. The Apollo program sent nine crews around the Moon, with six of those conducting landings on the lunar surface. The 1970s saw Skylab, America's first space station, the Apollo-Soyuz mission, and the development of the remarkably capable Space Shuttle. From 1981 to 2011, NASA launched 135 Space Shuttle missions, with crews conducting an array of research, repairing and extending the operational life of the Hubble Space Telescope, deploying space probes, delivering satellites, conducting docked missions with the Russian Mir space station, and playing a key role in building and supplying the ISS. In the 1990s, NASA worked with its international partners on the ISS, the first element of which was launched in November 1998. By the advent of the first expedition to ISS in November 2000, a new era of international collaboration in LEO had begun. With the retirement of the Space Shuttle in 2011, NASA relied on U.S. commercial providers for cargo transportation, and soon, Americans will be flying to and from ISS aboard vehicles owned and operated by U.S. industry – a very different paradigm from the framework used previously. ISS represents the current pinnacle of human spaceflight, building on NASA's 60-year history of achievement, yet it is also the starting point for an Exploration Campaign that will carry humanity out into the solar system.

Exploration Campaign

The National Space Exploration Campaign builds on 18 years of Americans and our international partners living and working continuously on the ISS. It leverages the advances made in commercial launch vehicle capabilities, robotics, and other technologies, and accelerates in the next few years with the launch of the Orion capsule and Space Launch System (SLS) rocket which will expand human exploration to cislunar space and the surface of the Moon.

A key component of establishing the first permanent, American presence and infrastructure on and around the Moon is the Gateway, a spacecraft assembled in cislunar space that will be used as a staging point for missions to the lunar surface and to deep space destinations. The Gateway will not be continuously occupied like the ISS. NASA currently envisions crew visits approximately once per year, so a strong focus is placed on robotic activities and infrastructure to foster ongoing investigations and operations that can operate autonomously between crew visits. Gateway in-space assembly starts with the launch of the power and propulsion element (PPE) no later than 2022 aboard a commercial rocket. Gateway ground testing, risk reduction, and development activities are already underway at NASA centers across the United States, including facilities in Ohio, Texas, Florida, Virginia, and Alabama, as well as in facilities of private sector partners in those states as well as in Colorado and Nevada. Following the successful in-space demonstration of the PPE and the delivery of the first pressurized Gateway modules, U.S. astronauts will be visiting before the end of 2024.

As part of the Campaign, we will also begin sending increasingly capable robotic missions to the lunar surface in the next two years. Developed by U.S. commercial companies, these spacecraft will conduct scientific investigations, characterize resources, and provide lunar landing services to customers from America and around the world. Ultimately, these efforts will culminate in the safe landing of U.S. astronauts on the Moon before the end of the 2020s.

We will also continue to execute sophisticated robotic missions to Mars while we work to develop and demonstrate the deep space capabilities required to safely send a human crew to the Red Planet.

Activities across these domains are closely related and mutually supportive; for example, NASA's drive to conduct robotic and human exploration of the Moon informs the research and technology development we will conduct on the ISS and potential future orbital platforms, as well as the development of technologies needed for future Mars missions. Likewise, current and future robotic missions will provide vital science, reconnaissance, and technology demonstrations in support of future human exploration, in addition to their science objectives. NASA is actively working now to support sustainable exploration and development over the coming decades in all three domains.

The Exploration Campaign has five strategic goals:

1. Transition U.S. human spaceflight in LEO to commercial operations that support NASA and the needs of an emerging private sector market.

2. Lead the emplacement of capabilities that support lunar surface operations and facilitate missions beyond cislunar space.

3. Foster scientific discovery and characterization of lunar resources through a series of robotic missions.

4. Return U.S. astronauts to the surface of the Moon for a sustained campaign of exploration and utilization.

5. Demonstrate the capabilities required for human missions to Mars and other destinations.

NASA will act as architect, mission leader, and in several key areas, systems integrator, defining an open architecture that meets National objectives. The Exploration Campaign will draw upon a variety of innovative partnerships with U.S. commercial industry, other Government agencies, academia, and international partners. We have designed the Exploration Campaign to enable early successes, relying on seamless collaboration across the Agency, including Deep Space Exploration Systems, Exploration Technology, LEO and Spaceflight Operations, and elements of Science, and the rapidly advancing capabilities of our commercial partners. I'll now describe our plans in each major domain of the Campaign – Earth Orbit, the Moon, and Mars – in more detail.

Transitioning LEO

The ISS will continue to serve as a core long-duration human spaceflight asset through at least 2024 – which will mark nearly 25 years of continuous human occupancy. Currently, NASA is leveraging the ISS to learn how to keep crews healthy and productive on deep space missions, and as a testbed to develop technologies to support those missions. The ISS is an experiential testing ground that enables discovery and development of advanced robotics, communications, medicine, agriculture, and environmental science. ISS also provides an example of international collaboration on large space projects. ISS can also enable the transition to commercial companies' use of LEO. NASA recently awarded 12 study contracts to industry to investigate the best way to use the ISS to enable commercial industry to take a lead role in LEO. The portfolio of selected studies will include specific industry concepts detailing business plans and the viability of habitable platforms, using Station or separate free-flying structures.

Maintaining the ISS and future orbital platforms requires a fleet of vehicles to sustain a constant supply line of both crew and cargo. Under the original Commercial Resupply Services (CRS) contracts, our two commercial cargo partners, Space Exploration Technologies (SpaceX) and Orbital ATK (now Northrop Grumman), are providing cargo deliveries to the ISS. Under the new CRS-2 contracts, SpaceX, Northrop Grumman, and Sierra Nevada Corporation will deliver critical science, research, and technology demonstrations to the ISS over five years from 2020 through 2024. Working with our commercial crew partners, SpaceX and the Boeing Company, NASA plans to return crew launch capability to American soil in 2019.

Under the auspices of the ISS National Laboratory, managed by the Center for the Advancement of Science In Space (CASIS), NASA and CASIS continue to expand research on the ISS sponsored by pharmaceutical, technology, consumer product, and other industries, as well as by other Government agencies, such as the National Institutes of Health and the National Science Foundation. Through CASIS' efforts, the ISS National Lab has reached full capacity for allocated crew time and upmass and downmass. NASA also works with commercial companies, such as NanoRacks, to support commercial activity on the ISS.

NASA intends to transition from the current Government-dominated model of human space activities in LEO to a model where Government is only one customer for commercial services. Starting in 2018, the Agency will increase the breadth and depth of commercial and international LEO activities. NASA will expand partnerships in LEO to include new companies and new nations, including working with commercial partners to support new international astronaut visits. Based on inputs from current ISS partners, commercial and other stakeholders, NASA will shape the plan for the transition of LEO activities from direct Government funding to commercial services and partnerships, with new,

independent commercial platforms or a non-NASA operating model for some form or elements of the ISS by 2025. In addition, NASA will expand public-private partnerships to develop and demonstrate technologies and capabilities to enable new commercial space products and services.

Lunar Exploration

NASA is building a launch and crew system – the Orion spacecraft, the heavy-lift SLS launch vehicle, and the supporting Exploration Ground Systems (EGS) – to support the Exploration Campaign. The Orion crew vehicle will carry up to four humans to deep space for up to 21 days. The Orion will also be able to transport and dock co-manifested modules to Gateway, and provide key initial life-support and abort capabilities. The SLS Block 1 cargo variant will be capable of delivering Orion to cislunar space in the early 2020s, and the Block 1B SLS will be capable of delivering 8-10 metric tons co-manifested with Orion in the mid- to late-2020s. The first SLS/Orion mission will be the uncrewed Exploration Mission-1 (EM-1), to be launched to lunar orbit in FY 2020, followed by the first crewed SLS/Orion mission, EM-2, no later than 2023. These SLS/Orion missions will demonstrate the capability to operate safely and productively around the Moon. These are the early steps on a journey that leads American astronauts into deep space, sustainably and permanently.

SLS Core Stage integration and outfitting (including installation of the four RS-25 main engines developed from the Space Shuttle) has continued at Michoud Assembly Facility. EM-1 flight hardware is being delivered to the Kennedy Space Center (KSC). SLS has continued a series of EM-1 Design Certification Reviews, will conduct the Critical Design Review (CDR) for EM-2, and begin fabrication of components for EM-3 and beyond. For EM-1, the Orion European Service Module is scheduled to be delivered soon to the Operations and Checkout Building at KSC for integration with the Crew Module. NASA is accelerating the Ascent Abort-2 test (AA-2) into 2019, ahead of EM-1. Structural work is already underway on Orion EM-2 flight hardware production. Orion has continued qualification testing of systems for EM-2. This year, EGS will complete the system verification and validation phase and begin the operations and integration phase in preparation for multi-element verification and validation for the Mobile Launcher, Pad, and Vehicle Assembly Building.

NASA will also begin to build the in-space infrastructure for long-term exploration and development of the Moon by delivering to lunar orbit a power and propulsion element (PPE), planned to be launched in 2022 on a commercial rocket, as the foundation of the Gateway. NASA released the PPE final Broad Agency Announcement (BAA) in September and proposals are due in November. This BAA is designed to leverage the commercial communication industry's extensive experience in building and operating spacecraft. The Gateway is envisioned to be a spacecraft operating in the vicinity of the Moon that demonstrates crewed and uncrewed operations in deep space. It will be incrementally built in place using SLS, the Orion crew vehicle, and commercial launch vehicles. The Gateway will be assembled in lunar orbit where it can be used as a staging point for missions to the lunar surface and destinations in deep space, providing a flexible human exploration architecture depending on mission needs. Although there are various concepts for its configuration, current analysis suggests the initial functionality will include four main capabilities: PPE; habitation; airlock to enable science and EVA; and logistics for cargo delivery, science utilization, exploration technology demonstrations, and potential commercial utilization. With the initial habitation capabilities delivered to cislunar space, crews of four – launched on Orion – will visit the Gateway on missions initially lasting 30 days and up to 90 days as new modules are added to complete Gateway's full capabilities.

Gateway will enable system and operational demonstrations, scientific exploration, biological and biomedical science, and will serve as an eventual aggregation and departure point for crewed missions to the lunar surface and other deep space destinations. The Gateway will serve as a critical platform to conduct biological and biomedical studies that require a beyond-LEO space environment to study the

response of biology (human and non-human organisms) to this new environment. A key science-enabling feature of this spacecraft is exposure of organisms to the deep space radiation environment for radiation and combined radiation/microgravity studies. The Gateway will also serve as a platform to mature necessary short- and long-duration deep space exploration capabilities in the 2020s, including highly reliable and dormancy-tolerant environmental control and life support systems; logistics reduction capabilities; advanced in-space propulsion; automated rendezvous and docking; radiation monitoring and mitigation capabilities; and integrated human-robotic mission operations, to name a few.

NASA has established the Lunar Discovery and Exploration Program (LDEP) in the Science Mission Directorate and is leveraging the Agency's extensive lunar science experience and data for lunar exploration. We are jump-starting commercial partnerships, innovative approaches for building and launching sophisticated next-generation science instruments, and the development of small rovers that will reach the Moon's surface via commercial landers. The Agency is integrating science and human exploration goals, including the eventual return of humans to the Moon. Just this past year, scientists used data from NASA's Lunar Reconnaissance Orbiter to identify areas in lunar craters that are cold enough to have frost present on the surface – ice that could provide crucial resources for exploration while also containing valuable information about the chemical makeup of the early solar system.

NASA is supporting the development of commercial lunar exploration capabilities leading to a human lunar landing. The Advanced Cislunar and Surface Capabilities (ACSC) program in the Human Exploration and Operations Mission Directorate will focus on engaging U.S. industry partners using innovative approaches to combine lunar robotics, a cislunar presence, and lunar landing capabilities building up to a human-rated lander. In 2019, ACSC and LDEP will support initial risk reduction activities by incorporating results from the following.

- The Lunar Cargo Transportation and Landing by Soft Touchdown (CATALYST) initiative is encouraging the development of U.S. private-sector robotic lunar landers capable of successfully delivering payloads to the lunar surface using U.S. commercial launch capabilities.

- NASA issued a request for proposals (RFP) for Commercial Lunar Payload Services (CLPS) on September 6, 2018, encouraging the U.S. commercial space industry to introduce new technologies to deliver payloads to the Moon. NASA intends to award multiple contracts for these services through the next decade, with contract missions to the lunar surface expected to begin as early as 2019, and with a company's first delivery no later than Dec. 31, 2021.

- NASA is also working on the second phase of the Next Space Technologies for Exploration Partnerships (NextSTEP), an effort to stimulate deep-space capability development across the aerospace industry. Through NextSTEP, the Agency intends to seek proposals from industry in support of design analysis, technology maturation, system development and integration, and spaceflight demonstrations for human-class lunar landers. This will address the development of medium- to large-scale lunar lander capabilities that have extensibility to reusable, human-class landers to a wide range of destinations on the lunar surface.

Ultimately, the Moon will also serve as a stepping-stone, a training ground, and a platform to strengthen commercial and international partnerships and prepare for future human missions to Mars and other destinations.

NASA will advance robotic access to Mars in preparation for human exploration. The Agency will:

- Continue the search for life with a Mars rover in 2020;

- Demonstrate technology to produce oxygen from Mars resources, critical for future human Mars missions;
- Begin planning a first-ever sample-return Mars mission;
- Prioritize and guide investments and partnerships in long-pole technology areas and resource characterization needed for deep-space exploration; and
- Develop standards for human long-duration deep space transportation vehicles.

Exploration Technology

Critical to the Exploration Campaign, NASA will conduct research and promote technology development to address needs for human and robotic space exploration and to foster commercial expansion in LEO, cislunar space, and beyond. NASA's Technology research drives exploration by spanning the Technology Readiness Level spectrum, including investments in early-stage concepts and prototypes. Exploration Research and Technology key areas of focus will include:

- Advanced environmental control and life support systems;
- In-Situ Resource Utilization (ISRU);
- Nuclear and solar power and propulsion technologies for exploration;
- Advanced communications, navigation, and avionics;
- In-space manufacturing and on-orbit assembly;
- Advanced materials;
- Entry, Descent, and Landing;
- Autonomous operations; and
- Research to enable humans to safely and effectively operate in various space environments.

NASA continues to partner with researchers across academia, industry, and within the Agency to explore transformative technologies and approaches. Upcoming early-stage innovation activities will investigate areas such as breakthrough propulsion, challenges in deep space human habitation, space-optimized energy systems, radiation protection, and materials. These areas are part of a comprehensive approach to efficiently support innovative discovery, progress toward important goals, and development of exciting new capabilities.

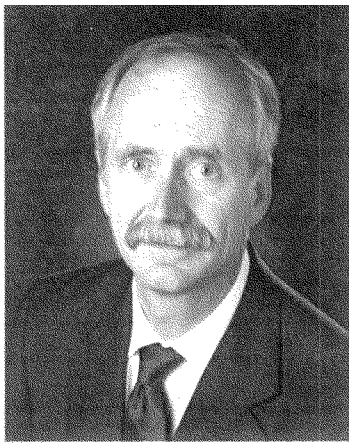
In August, NASA selected 10 proposals from six U.S. companies, with a combined award value of approximately $44 million, to develop commercial space capabilities that benefit future NASA exploration missions in new public-private partnerships, including lunar lander and deep space rocket engine technologies. While these "Tipping Point' partnership selections will enable NASA's future science and human exploration missions, these awards will also grow the economy and strengthen the Nation's economic competitiveness.

This past spring, NASA also selected 10 companies to conduct studies and advance ISRU technologies to collect, process, and use space-based resources for missions to the Moon and Mars. ISRU could increase safety and affordability of future human spaceflight missions by limiting the need to launch supplies such as oxygen and water from Earth. In the area of Flight Opportunities, suborbital flight providers are now on the verge of a significant leap forward, and payloads are beginning to fly from multiple providers. Given this success, NASA will shift our focus to funding more payload flights. To date, Flight Opportunities has enabled 122 flights of 93 payloads. There are an additional 62 payloads awaiting flight. Later this year, we look forward to the launch of the Green Propellant Infusion Mission and the Deep Space Atomic Clock on the U.S. Air Force's Space Technology Mission-2 on a SpaceX Falcon Heavy booster.

Conclusion

As NASA celebrates its 60th anniversary, one of the Agency's key goals is opening the space frontier with the objective of extending human presence deeper into the solar system starting with returning humans to the Moon through a sustainable human and robotic spaceflight program. The Agency has developed a strategic, pioneering approach to expand the distance and duration of human space exploration, building off the research happening today on the International Space Station. NASA is pushing human presence deeper into space while making new discoveries and strengthening the Nation's diplomatic posture. We appreciate the Subcommittee's continued support, and I would be pleased to respond to your questions.

WILLIAM H. GERSTENMAIER
ASSOCIATE ADMINISTRATOR FOR
HUMAN EXPLORATION AND OPERATIONS



William H. Gerstenmaier is the associate administrator for the Human Exploration and Operations Mission Directorate at NASA Headquarters in Washington, DC. In this position, Mr. Gerstenmaier provides strategic direction for all aspects of NASA's human exploration of space and cross-agency space support functions of space communications and space launch vehicles. He provides programmatic direction for the continued operation and utilization of the International Space Station, development of the Space Launch System and Orion spacecraft, and is providing strategic guidance and direction for the commercial crew and cargo programs that will provide logistics and crew transportation for the International Space Station.

Mr. Gerstenmaier began his NASA career in 1977 at the then Lewis Research Center in Cleveland, Ohio, performing aeronautical research. He was involved with the wind tunnel tests that were used to develop the calibration curves for the air data probes used during entry on the Space Shuttle.

Beginning in 1988, Mr. Gerstenmaier headed the Orbital Maneuvering Vehicle (OMV) Operations Office, Systems Division at the Johnson Space Center. He was responsible for all aspects of OMV operations at Johnson, including development of a ground control center and training facility for OMV, operations support to vehicle development, and personnel and procedures development to support OMV operations. Subsequently he headed the Space Shuttle/Space Station Freedom Assembly Operations Office, Operations Division. He was responsible for resolving technical assembly issues and developing assembly strategies.

Mr. Gerstenmaier also served as Shuttle/Mir Program operations manager. In this role, he was the primary interface to the Russian Space Agency for operational issues, negotiating all protocols used in support of operations during the Shuttle/Mir missions. In addition, he supported NASA 2 operations in Russia, from January through September 1996 including responsibility for daily activities, as well as the health and safety of the NASA crewmember on space station Mir. He scheduled science activities, public affairs activities, monitored Mir systems, and communicated with the NASA astronaut on Mir.

In 1998, Mr. Gerstenmaier was named manager, Space Shuttle Program Integration, responsible for the overall management, integration, and operations of the Space Shuttle Program. This included development and operations of all Space Shuttle elements, including the orbiter, external tank, solid rocket boosters, and Space Shuttle main engines, as well as the facilities required to support ground processing and flight operations.

In December 2000, Mr. Gerstenmaier was named deputy manager, International Space Station Program and two years later became manager. He was responsible for the day-to-day management, development, integration, and operation of the International Space Station. This included the design, manufacture, testing, and delivery of complex space flight hardware and software, and for its integration with the elements from the International Partners into a fully functional and operating International Space Station.

Named associate administrator for the Space Operations Mission Directorate in 2005, Mr. Gerstenmaier directed the safe completion of the last 21 Space Shuttle missions that witnessed assembly complete of the International Space Station. During this time, he provided programmatic direction for the integration and operation of the International Space Station, space communications, and space launch vehicles.

In 2011, Mr. Gerstenmaier was named to his current position as associate administrator for the Human Exploration and Operations Mission Directorate.

Mr. Gerstenmaier received a bachelor of science in aeronautical engineering from Purdue University in 1977 and a master of science degree in mechanical engineering from the University of Toledo in 1981. In 1992 and 1993, he completed course work for a doctorate in dynamics and control with emphasis in propulsion at Purdue University.

Mr. Gerstenmaier is the recipient of numerous awards, including three NASA Certificates of Commendation, two NASA Exceptional Service Medals, a Senior NASA Outstanding Leadership Medal, the Meritorious Executive Presidential Rank Award, and Distinguished Executive Presidential Rank Award. He also was honored with an Outstanding Aerospace Engineer Award from Purdue University. Additionally, he was twice honored by Aviation Week and Space Technology for outstanding achievement in the field of space. His other awards include: the AIAA International Cooperation Award; the National Space Club Astronautics Engineer Award; National Space Club Von Braun Award; the Federation of Galaxy Explorers Space Leadership Award; AIAA International Award; the AIAA Fellow; Purdue University Distinguished Alumni Award; and honored at Purdue as an Old Master in the Old Masters Program; recipient of the Rotary National Award for Space Achievement's National Space Trophy; Space Transportation Leadership Award; the AIAA von Braun Award for Excellence in Space Program Management; and the AIAA von Karman Lectureship in Astronautics.

He is married to the former Marsha Ann Johnson. They have two children.

October 2015

Chairman BABIN. Thank you very much for that testimony.

Now, I recognize Mr. Geyer for 5 minutes to present his testimony.

TESTIMONY OF MR. MARK GEYER,
DIRECTOR, JOHNSON SPACE CENTER, NASA

Mr. GEYER. Chairman Babin, Ranking Member Bera, thank you, and Members of the Subcommittee, thank you for the opportunity to be here today to discuss the ISS and human exploration.

So NASA has an exciting and challenging future, and the Johnson Space Center stands ready to support the Human Exploration and Operations Mission Directorate and work in partnerships with our other NASA human spaceflight centers to enable that future.

NASA's JSC was established in 1961, and from the Gemini, Apollo, and Space Shuttle missions to today's International Space Station and Orion programs, the center has led the development and operation of historic human spaceflight programs. JSC's famed mission control center or MCC has been the operational hub of every American human space mission since Gemini IV. The MCC manages all activity on board the space station and will play a pivotal role in commercial crew vehicle flights flying astronauts to and from the ISS in the near future. The MCC will direct the flights of Orion when it launches on top of the Space Launch System that takes humans beyond low-Earth orbit for the first time since 1972.

JSC is also home to the NASA's Astronaut Corps and is responsible for training space explorers from the United States and our space station partner nations. As such, it is the principal training site for the ISS expedition crews.

JSC also leads NASA's flight-related scientific and medical research efforts and strives to make revolutionary discoveries and advances to benefit not only our ability to live and work in space but all of humankind.

Technologies developed originally for spaceflight have already found a wide range of applications in medicine, energy, transportation, agriculture, communications, and electronics. JSC leads the development of the Orion spacecraft and provides space craft expertise in support of KSC's Commercial Crew Program. JSC will lead a high-altitude test flight of Orion abort system in April of 2019, which will showcase the power and complexity of this critical system used to enhance crew safety during ascent. These efforts continue JSC's legacy as human spacecraft development experts.

The Johnson Space Center also has unique expertise in extravehicular activity, suit development, and operations. At JSC we manage EVA execution training integration, as well as development for the suits, systems, and support equipment. The United States has performed a total of 252 EVAs, totaling over 1,500 hours, including over 1,000 hours of EVAs during the assembly and operation of the ISS program.

The Johnson Space Center is a world leader in complex programmatic and system integration. For example, for more than 20 years we have—JSC has managed the integration, assembly, and operation of the ISS. The space station is a multinational microgravity laboratory, continuously occupied since November of 2000. The ISS has hosted 232 individuals from 18 countries. An inter-

national crew of six people live and work while traveling at a speed of five miles per second orbiting the Earth every 90 minutes. Microgravity, along with many other beneficial environmental conditions, provide a unique research environment to support bioscience, physical science, remote-sensing, and technology development projects. Over 2,400 investigations by over 100 countries have been performed in space station history, and this number increases every week.

JSC has also developed and implemented cutting-edge partnering strategies. The Commercial Orbital Transportation Services program, COTS, and the cargo resupply contract strategy enabled two companies to develop launch vehicles and spacecraft through public-private partnerships, which now resupply critical cargo to the ISS. This initiative has shown the power and the challenges of the strategy which will be important—an important part of any future sustainable exploration plan.

Looking forward, the White House Space Policy Directive–1 calls for the NASA Administrator to lead and innovative and sustainable program of exploration and commercial with—with commercial and international partners to enable human expansion across the solar system and bring back to Earth new knowledge and opportunities. JSC has demonstrated the capability to unite commercial and international partners to complete bold missions.

By continuing the use of the ISS as a low-Earth orbit laboratory to buy down human risk factors presented by space travel and to develop the technologies that will enable humans to journey to the Moon and beyond, NASA has already established the foundation necessary to expand the frontier of human space exploration. Partnerships with commercial international partners have already been established to build, operate, and maintain the ISS and have established a template to follow for human expansion across the solar system. Knowledge gained on the space station has already benefited humans on Earth and points to the future promise of new knowledge and opportunities from human space exploration.

NASA and JSC look forward to the future of human space exploration. Commercial companies are currently launching cargo to the space station from Virginia and Florida. In the very near future, the tempo of Americans spaceflight will increase exponentially as commercial companies prepare to launch American astronauts to the ISS from the United States.

On August 3, 2018, at a ceremony at JSC we named the astronaut crew of brave men and women who will fly on our first commercial missions. This milestone was another reminder of JSC's central role in human space exploration.

As I mentioned before, the Orion and SLS will soon be flying humans beyond low-Earth orbit. These systems enable access to the lunar region and will be used in the near term to assemble and utilize elements of a human outpost around the Moon.

JSC stands ready to apply its unique capabilities and complex program management, partnerships, system integration, operations, spacecraft design, and human health and performance in partnership with our fellow NASA centers, commercial partners, international partners as NASA fulfills the initiatives set forward

by the National Space Council and the White House. Thank you very much.

[The prepared statement of Mr. Geyer follows:]

Mark S. Geyer
Director, NASA Johnson Space Center

Mark S. Geyer is the 12th director of NASA's Johnson Space Center, a position he assumed on May 25, 2018. In this role, Geyer leads a workforce of approximately 10,000 civil servant and contractor employees at one of NASA's largest installations in Houston and the White Sands Test Facility in Las Cruces, New Mexico.

Geyer began his NASA career in 1990 at NASA Johnson in the new business directorate. He joined the International Space Station Program in 1994, where he served a variety of roles until 2005, including chair of the space station Mission Management Team, manager of the ISS Program Integration Office and NASA lead negotiator with Russia on space station requirements, plans and strategies.

From 2005 to 2007, Geyer served as deputy program manager of the Constellation Program, before transitioning to manager of the Orion Program, a position he held until 2015. Under Geyer's direction, Orion was successfully tested in space in 2014 for the first time, bringing NASA another step closer to sending astronauts to deep space destinations.

After supporting Orion, Geyer served as deputy center director at NASA Johnson until September 2017. In this role, he helped the center director manage a broad range of human spaceflight activities, including the center's annual budget of approximately $5.1 billion.

From October 2017 to May 2018, Geyer served as the acting deputy associate administrator for technical for the Human Explorations and Operations Mission Directorate at NASA Headquarters in Washington. In this position, he was responsible for assisting the associate administrator in providing strategic direction for all aspects of NASA's human spaceflight exploration mission.

Born in Indianapolis, Geyer earned both his Bachelor of Science and Master of Science degrees in Aeronautical and Astronautical Engineering from Purdue University in Indiana.

Geyer is the recipient of the NASA Distinguished Service Medal, Meritorious Executive Rank Award and the Distinguished Executive Rank Award.

He is married to Jacqueline Geyer, and they have three children.

Chairman BABIN. Yes, sir. Thank you for your testimony.

I now recognize Ms. Singer for 5 minutes to present her testimony.

TESTIMONY OF MS. JODY SINGER,
DIRECTOR, MARSHALL SPACE FLIGHT CENTER, NASA

Ms. SINGER. Thank you, Chairman Babin and Members of the Subcommittee. Thank you for this opportunity to address this Committee and represent Marshall Space Flight Center where I began my 32-year NASA career.

I was recently honored to be named Center Director by the Administrator Jim Bridenstine. It is a privilege to testify before you with my colleagues here today.

At Marshall we make human deep space exploration possible. As you know, one of our flagship programs is the Space Launch System. The Space Launch System is unmatched in its capabilities and will deliver human-rated spacecraft, habitats, along with unprecedented science missions to the Moon, to Mars, and beyond. Our work on SLS builds on nearly 60 years of leadership in human space exploration.

At Marshall, we have a storied history of expertise in developing and integrating large, complex, human-rated systems on behalf of the agency and our country. It started with Apollo, then expanded to include Skylab, Hubble, Spacelab, Shuttle, Chandra, and eventually the International Space Station, or ISS.

Marshall has been essential to the creation and utilization of the International Space Station, beginning with the integration of the modules. Node 1 was built in Huntsville with Marshall supporting the build and delivery of nodes 2 and 3. The U.S. laboratory was built in the Saturn V test facility in Huntsville, Alabama. The Marshall team designed and developed the Environmental Control and Life-Support System called the ECLSS, which provides water and oxygen for the crew. We're using what we know about these essential and complex systems so that we can better enable long-term human exploration into deep space.

For more than 17 years we have supported the ISS with our 24/7 operations, 365-days-a-year management of science operations. We have hosted more than 2,300 research investigations from researchers in 103 countries to date.

We also support the Commercial Crew Program, which will allow us to launch American astronauts from American soil to the ISS for the first time since the Shuttle program ended in 2011. In addition to SLS, ISS, and other technology development activities, we are excited to be working with commercial partners and other NASA centers on a number of robotic and human lander development programs, which will return our nation to the Moon.

We have a long and storied role in our Nation's human spaceflight program, and we couldn't do it alone. At NASA, we are driven by partnerships and constantly reminded of the old saying, if you want to go fast, go alone. If you want to go far, we go together. Our partnerships with industry, with academia, and with other government entities are instrumental to our success. As we look ahead to what it will take to expand human presence in our solar system, we look forward to continue to provide our expertise

in large integrated human exploration systems as we partner to develop landers, habitats, transit systems, and integrated exploration systems as we partner to develop as we go forward. All of these will be essential elements for deep space human exploration.

We are preparing for our return to the Moon and to travel on to Mars as we continue to help the United States lead the world in exploration and discovery of the unknown. I am excited to be a part of our Nation's space program, and I'm honored to be part of a team of experienced and passionate professionals who are ready to take on any and all challenges that arise as we aim to push human presence deeper into space than we ever have before.

Thank you, and I look forward to answering your questions.

[The prepared statement of Ms. Singer follows:]

Jody Singer
Director
Marshall Space Flight Center

Jody Singer is the director of NASA's Marshall Space Flight Center in Huntsville, Alabama. Appointed in September 2018, Singer manages one of NASA's largest field installations, with nearly 6,000 on- and near-site civil service and contractor employees and an annual budget of approximately $2.8 billion. Prior to being named to the position, Singer had served as Marshall acting director since July 2018 and was deputy director from February 2016 to July 2018, assisting the director with the daily management of the center's workforce and operations.

During her 32-year NASA career, Singer has held leadership roles of increasing responsibility in human spaceflight, technology and science flight missions programs and projects and was appointed in 2002 to the Senior Executive Service, the personnel system covering top managerial positions in federal agencies. She began her NASA engineering career in 1985 through the professional intern program in the mission planning and development office.

In 1986, she joined the Space Shuttle Program office, where she was an engineer in the Space Shuttle Main Engine office and involved with Return to Flight activities after the Challenger accident. From 1990 to 2002, she was the business manager, technical assistant and deputy manager in the External Tank project office. From 2002 to 2007, she served as the first female project manager for the Reusable Solid Rocket Booster Project and led the team during the Columbia Return to Flight activities. In 2008 until the shuttle's successful retirement in 2011, she served as the deputy manager in the Space Shuttle Propulsion Office.

From 2010 through 2012, she held deputy positions for three concurrent major programs: the Space Shuttle, Ares, and the start-up of the Space Launch System (SLS). As deputy for the Shuttle Propulsion Office, she guided successful fly-out and retirement of the space shuttle in 2011. As the deputy of the Ares Project Office, Singer was responsible for the transition of the workforce and assets after project cancellation. Singer was also integral to the start-up of the Space Launch System (SLS) program. As the deputy program manager of the SLS at Marshall, she helped oversee nearly 3,000 civil servants and contractors involved in the developing and testing of the vehicle, which is the most powerful rocket ever built, able to carry astronauts in NASA's Orion spacecraft on deep space missions to the Moon and ultimately to Mars.

From 2013 until In 2016, Singer served as the manager of the Flight Programs and Partnerships Office at Marshall, where she held primary responsibility for the center's work with human advanced exploration projects, science flight mission programs, technology demonstration missions, commercial crew, and International Space Station life support systems, research facilities, and payload operations. Singer also was responsible for identifying opportunities to develop and maintain partnerships with other government agencies, academia, and international and commercial partners that will help achieve NASA's vision.

Singer, a native of Hartselle, Alabama, earned a bachelor's degree in industrial engineering from the University of Alabama in 1983. She has completed two NASA Fellowships, one at

Pennsylvania State University in State College and another at the Simmons College Graduate School of Management in Boston.

She has been recognized with numerous awards during her NASA career, including NASA Outstanding Leadership Medals and two Presidential Rank of Meritorious Executive Awards, the highest honor for career federal employees. She received the Space Flight Awareness Leadership Award in 2005 for inspiring the Shuttle Propulsion Office to strive for excellence and continuous improvement; and the NASA Exceptional Service Medal in 1993 while managing the External Tank project's business office. For her dedication and commitment to excellence and achievement in support of the human space program, she was awarded the Silver Snoopy Award by the NASA astronaut corps, and was named a Space Flight Awareness Launch Honoree.

Singer and her husband, Chris, live in Huntsville. They have three children and two grandchildren.

Sept. 13, 2018

Chairman BABIN. Thank you, Ms. Singer.

I now recognize Mr. Cabana for his 5 minutes of testimony.

TESTIMONY OF MR. ROBERT CABANA, DIRECTOR, JOHN F. KENNEDY SPACE CENTER, NASA

Mr. CABANA. Thank you for the opportunity to appear today to discuss KSC's contributions to 60 years of NASA leadership in human space exploration, past, present, and future.

NASA's John F. Kennedy Space Center is the United States' preeminent multiuser spaceport for government and commercial access to space. KSC's rich history dates back to 1962 when it was first established as a NASA launch operations center, and from those first steps on the Moon through 30 years of the Space Shuttle, culminating in the completion of the International Space Station to the myriad of NASA science missions, expanding our knowledge of the universe and home planet, KSC has led the way in innovative, efficient, and cost-effective spacecraft processing, launch, and recovery.

Today, we continue to lead. Since the last Shuttle mission in July of 2011, the center has transformed to enable commercial operations, better utilizing our assets and strengthening America's space program. By early next year it is our goal to once again be flying U.S. astronauts to space on an American rocket from U.S. soil, a direct result of establishing KSC as a multiuser spaceport.

In 2017, the United States led the world in launches for the first time since 2003. Of the 29 U.S. launches last year, 12 were from the Kennedy Space Center. I'd like to recognize the great partnership we have with the 45th Space Wing and the FAA that helped to enable that.

In addition to the many ground operations going on at KSC, commercial operations going on at KSC, the Exploration Ground Systems program is preparing the center to once again enable us to explore beyond low-Earth orbit with NASA's Space Launch System and the Orion spacecraft. Recently, the mobile launcher rolled from the park site out to pad 39B for a fit check and is now in high bay 3 of the vehicle assembly building, undergoing verification and validation testing. With this move, we are essentially complete with the construction of all the facilities necessary to process and launch the vehicle for Exploration Mission 1. To support future exploration missions, we're in the process of procuring a second mobile launcher that accommodates the exploration upper stage Block 1B version of the SLS and eliminates a three-year gap between missions.

As we prepare for the launch of SLS and Orion and a return to the Moon, NASA will soon begin work on the Gateway, a flexible outpost in cislunar space that will provide access to anywhere on the Moon and enable sustained exploration of the lunar surface, expanding our knowledge and proving technologies needed for eventual trips to Mars and beyond.

The Gateway, a logistics effort, will involve procuring commercial services via fixed-price contracts for the delivery of cargo to support science and exploration missions staged from the Gateway, including human exploration. KSC is positioned to provide its core area of expertise: commercial acquisition, contract management, payload

processing, ground processing, and launch integration to support Gateway and ensure its success.

Five years ago, the KSC team set out to restore our prominence as the place where astronauts launch to space. With NASA's desire to stimulate commercial markets, coupled with the availability of historic space processing and launch assets, we set an ambitious goal to be the home of five human spaceflight providers. Today, through commercial crew, exploration ground systems, and our commercial partners, we're supporting the development of four human spaceflight providers, and we haven't given up on the fifth.

We're also launching the agency's science missions through the Launch Services Program. With five of six planned missions already successfully completed this year, our multiuser spaceport is prospering like never before. Truly, the sky is not the limit at KSC.

Finally, I'd like to recognize the upcoming 20th anniversary of the first assembly mission of the ISS. On December 4, 1998, I had the privilege of commanding Endeavour on that first mission and activating the space station for the first time and entering it. As we noted in the first log entry of the ISS, "From small beginnings, great things come," and the ISS has more than exceeded its expectation as a world-class microgravity lab, a superb engineering testbed, as a partnership—international partnership model for the future and as a destination that made commercial crew and cargo programs a reality.

Mr. Chairman and members of the committee, I'd like to thank you for your time and attention this afternoon, but more importantly, I'd like to thank you for your support of America's space program, and I look forward to your questions. Thank you.

[The prepared statement of Mr. Cabana follows:]

Robert D. Cabana
Director
John F. Kennedy Space Center

Robert D. Cabana is a former NASA astronaut, currently serving as director of NASA's John F. Kennedy Space Center in Florida. In his current role, Cabana manages all NASA facilities and activities at the spaceport, including the team of civil service and contractor employees who operate and support numerous space programs and projects.

Born in Minneapolis, Minnesota, Cabana graduated from the U. S. Naval Academy in 1971 with a bachelor's degree in mathematics. He was commissioned a second lieutenant in the U.S. Marine Corps and completed Naval Flight Officer training in Pensacola in 1972. Cabana then served as an A-6 bombardier/navigator with Marine Air Wings in Cherry Point, North Carolina, and Iwakuni, Japan.

Returning to Pensacola in 1975, Cabana began pilot training and was designated a naval aviator in September of 1976, earning the Daughters of the American Revolution award as the top Marine to complete flight training that year. He graduated with distinction from the U.S. Naval Test Pilot School in 1981 and served in the Flight Systems Branch at the Naval Air Test Center until 1984. During his career, Cabana has logged over 7,000 hours in 50 different kinds of aircraft.

Cabana was selected as an astronaut candidate in June 1985 and completed his initial astronaut training in July 1986. He was assigned to the Lyndon B. Johnson Space Center Astronaut Office, serving in a number of leadership positions, including lead astronaut in the Shuttle Avionics Integration Laboratory; Mission Control Spacecraft Communicator, famously known as CAPCOM; and chief of NASA's Astronaut Office.

A veteran of four spaceflights, Cabana has logged 38 days in space, serving as the pilot on STS-41 and STS-53 and mission commander on STS-65 and STS-88. His fourth flight was the first assembly mission of the International Space Station in December of 1998. Following his retirement as a colonel from the Marine Corps in September 2000, Cabana was appointed a member of the Federal Senior Executive Service. He served in numerous, challenging senior management positions at Johnson Space Center in Houston, ultimately becoming deputy director.

In October 2007, Cabana was appointed director of NASA's John C. Stennis Space Center in Mississippi. A year later he was reassigned as the tenth director of the John F. Kennedy Space Center.

Cabana's many achievements have been recognized with induction into the Astronaut Hall of Fame and being named an Associate Fellow in the American Institute of Aeronautics and Astronautics and a Fellow in the Society of Experimental Test Pilots. He has received numerous personal awards and decorations, including the Distinguished Flying Cross, the Presidential Distinguished Rank Award, and the National Space Club Florida Committee's Dr. Kurt H. Debus Award. He also is a recipient of the Rotary National Award for Space Achievement's National Space Trophy.

May 2015

Chairman BABIN. Thank you very much, Mr. Cabana.

Now, the Chair recognizes himself for 5 minutes for questions.

This is going to be for everyone. Considering the current discussion about ISS transition, what is NASA doing to prevent another detrimental capability gap as we have experienced in the past, most recently with the retirement of the Space Shuttle? And I'll start with you, Mr. Gerstenmaier.

Mr. GERSTENMAIER. You've seen our transition plan for ISS, and we treat that very seriously. And we're not just doing a plan, but we issued some study contracts to 12 companies, and those companies are going to give us business plans and market analysis for how they could potentially use the space station or they could use low-Earth orbit to provide some capability for us in the future. So we're going to see what industry is interested in, what they can provide, and therefore, we'll build a smooth transition so we don't have an abrupt end of one program and then start another program. We need to make sure there's a continuity of human spaceflight where there—we continue this human presence in low-Earth orbit, and NASA becomes one of many users of low-Earth orbit.

Chairman BABIN. Thank you very much. Mr. Geyer?

Mr. GEYER. Yes, I think if we described the incredible things the space station is providing today and I think a great conversation about we really don't want the gap in low-Earth orbit, so as Bill described where we're putting together a plan that looks logically at how we might build other capabilities so NASA is one of many users and put together a well-thought-through plan.

I think also the key is, as we go into exploration further into the solar system, how do we take the lessons from ISS into those other endeavors like the Gateway and so forth and keep those partnerships strong. All those are very important parts to consider.

Chairman BABIN. All right. Thank you. And, Ms. Singer?

Ms. SINGER. Yes, sir. I looked as far as the exploration program and how we're going, that that is setting out a roadmap that will help us. I went through the Shuttle, and I went through the—after flying out the Shuttle in 2011 and saw the gap. I think one of the things that we are looking forward to is learning off of lessons learned, and also going forward, one of the things that we're doing is there's a lot on our plate. The future is very bright. We have to deliver on our missions today and make sure that we invest in our people and making sure that we form partnerships that will make us a sustainable program. So I think all of that focus will keep us strong and going.

Chairman BABIN. Excellent. Mr. Cabana?

Mr. CABANA. Thank you. Mr. Gerstenmaier laid out the plan well, and I think it's critical that we have a follow-on for the International Space Station, that we do have a plan for low-Earth orbit. Even as we explore beyond our home planet, I believe that there is a place for operations in Earth orbit, and it's critical that we have a destination for our commercial partners, both crew and cargo, to have a viable commercial base there, so we're working hard to ensure through our partnerships that we can commercialize the ISS and that we have a future beyond it in low-Earth orbit.

Chairman BABIN. Thank you very much. And then for Mr. Gerstenmaier, during the early development phases of a program, program management from headquarters is understandable. However, once acquisitions begin, do you believe that program management should be done from the centers where the workforce and expertise exist to perform these roles for NASA?

Mr. GERSTENMAIER. Yes, definitely. And we're in the process of laying that out and figuring out the right time to transition activities from kind of putting together the strategy at headquarters and then passing it down to the centers for actual implementation and doing the day-to-day management of the project.

Chairman BABIN. Right.

Mr. GERSTENMAIER. But I think it's important in the beginning headquarters kind of sets those bigger-picture goals of where the partnerships ought to be, new ways of doing business, et cetera. Then we could hand that off, and the execution is much better done at the centers.

Chairman BABIN. Absolutely. Thank you. And then for Mr. Geyer, in your new role as JSC Center Director, how are you leveraging the decades of experience your team has serving as the lead center for human spaceflight program management, systems engineering, program integration, and operations?

Mr. GEYER. So what we do, first of all, is we participate with the studies that are done on the future and the exploration campaign is a good example of that. We provide inputs and expertise as the strategy is being put together, again, bringing what we've seen and what we've learned in the past, and then we support the conversations of—as we decide to roll those programs out, making sure that JSC is poised and has the folks ready to do those jobs.

Chairman BABIN. Thank you. And what is JSC doing to encourage commercial partnerships with the center?

Mr. GEYER. So a couple things, of course, we have the big contracts that are obvious, the commercial cargo is a great example of a technique we've used to buy services, and we've seen what that's done to actually create the capability. We participate with Kennedy on the Commercial Crew Program, which now has taken the next step in actually flying our crews, so it's a bigger, more challenging task. And then we also have—even within the center on tasks that are infrastructure things like training crews, we put into our contracts the capability for those contractors to actually bring in other customers to reduce our fixed cost and help us do our job for less money.

Chairman BABIN. I know I'm out of time, but I just want to get something in. What is the current workforce level, both civil servant and contractor, directly supporting ISS at your center?

Mr. GEYER. I'll—we'll get back to you on that exact number.

Chairman BABIN. Okay. And then do you have a rough estimate on the numbers at the other centers supporting ISS, or maybe I should ask the other two real quick, Ms. Singer and Mr. Cabana?

Ms. SINGER. I don't have the exact number in front of me. I'll have to take that for the record——

Chairman BABIN. Okay.

Ms. SINGER. —and get back to you.

Chairman BABIN. Okay.

Mr. CABANA. I'll take it for the record also, Mr. Chairman——

Chairman BABIN. All right, great.

Mr. CABANA. —and get you the exact number.

Chairman BABIN. Okay. Well, I'll yield back. Thank you very much.

Now, the gentlewoman from Texas, Ms. Johnson.

Ms. JOHNSON. Thank you very much, Mr. Chairman.

Well, Ms. Singer and Mr. Cabana and Mr. Geyer, the Space Exploration Campaign is anticipated to involve partnerships with industry, academia, and international entities. What is the most important role of NASA and the centers in a multi-partner Space Exploration Campaign?

Mr. GEYER. Well, I think, first of all, it's NASA's job to provide the vision and the strategy and then to set the acquisition plan, exactly how are we going to accomplish these goals and how do we decide how to partner, who's going to do what jobs. That's a big part that NASA provides.

Mr. CABANA. Yes, I think I'd say it even more simply than that. NASA leads. We provide the direction, we coordinate, we ensure that we work together as one team, and we set the course with our requirements and how we go about doing it.

Ms. SINGER. And I would add to both of their statements and say a critical part of it is NASA working together. We work together, centers to centers, working with the agency, as well as with our partners, to make sure we deliver on what the Nation needs, and that includes delivering on our commitments, executing our missions, making sure that we have the right infrastructure and people in place with the right training, as well as forward thinking to make sure we have a readiness. We're ready to be able to execute the missions put in front of us. And then obviously cultivating partnerships, having partners, and the ability to be more flexible, agile, and having the ability to execute is critical.

Ms. JOHNSON. Thank you very much, Mr. Chairman. I yield back.

Chairman BABIN. Yes, ma'am. Thank you very much.

I now recognize the gentleman from Oklahoma, Mr. Lucas.

Mr. LUCAS. Thank you, Mr. Chairman.

And, Mr. Gerstenmaier, my colleagues have commented on the early space program, the Apollo program, that went on in my youth of course that instilled in a whole generation of Americans a different perspective for looking at the stars and drove people into the field of math and science. And of course we have a renewed interest now with all the spectacular things going on in space exploration in this country.

Could you expand for a moment on how the National Space Exploration Campaign could potentially have a similar effect on our culture as a society regarding an interest in and fascination with space and science in general?

Mr. GERSTENMAIER. I think what's interesting is there's a couple pieces. First of all, we shouldn't discount the space station and what it can do today to inspire the next generation. I'm often amazed when I go talk to college students how much they're impressed by Station, and they relate to me things that I would think would only be attributable back to Apollo in the other days. So I think we need to celebrate what's going on with Station and what

our crews are doing there every day. You know, continually operating a station is not easy and moving forward.

As we talk about things like the Gateway around the Moon, what's intriguing about that is we're building a piece of infrastructure in space that can be used as a reusable piece by multiple folks, so what's exciting about the new vision is it's not a single mission. It's not a single "achieve this." It has actually put in place an open architecture that can be used by the private sector, used by international partners. It can enable reusable spacecraft.

So on the—in the Apollo program, we had a service module, a command module that was used once and thrown away. The Gateway can be that reusable service command module that's sits in space to be a destination for any spacecraft going to space with open standards. They can dock there. The lunar landing module will be reusable. And the neat thing is all this orbital mechanics, electric propulsion are all new technologies, new analysis, and we need the students today to start looking at new, creative ways to utilize space. So I think if we can put the challenge out there in a way every person in the United States, every person in the world can figure out a way that they can contribute to this space program that is now open, and it's the right role for government to put that piece of first infrastructure in place that just enables the world to innovate and be creative in utilizing space.

Mr. LUCAS. Oh, absolutely. And speaking of Gateway, could you visit with us for just a moment in whatever regard you can about the—and I know it's early in the process—the conversations that are going on with the potential commercial partners? I assume there is interest out there. I assume they are warming up and cranking up the designs to utilize the opportunities. You're getting that kind of feedback, correct?

Mr. GERSTENMAIER. Yes, definitely. With domestic providers we have several companies working on next-step broad-agency-announcement activities where there's actually modules available at some of the centers that you can go see where we're starting to look at what the U.S. habitation module will look like on Gateway. So that activity is moving forward. We're soliciting input from many of the companies, and we're also receiving a lot of interest from the science community. We've done one workshop in Colorado. The interest in doing science around the Moon and using the unique orbit of the Gateway was really amazing. We've also—there was a European activity also looking at science on Gateway, so, so far, there's been very strong support from industry. We're involving them in many ways to see how they can contribute in ways that help build this piece of infrastructure that is multiuse and multi-decades that can be used.

Mr. LUCAS. Absolutely. And speaking of that, I think I'd like to turn now to all three of the Center Directors. Can you visit for just a moment about the unique capacities that each of your particular centers have in regards to NASA's future and for that matter the National Space Exploration Campaign, the unique qualities that each center brings, just a little bit if you wouldn't mind? That's not a trick question, I promise.

Mr. CABANA. So, absolutely, sir. I think, you know, you look at the Kennedy Space Center, this is where we process the vehicles.

This is where we do the launch integration. This is where we launch to space. And there's no other place like it in the United States or in the world in my opinion. I think we do it right, and I look forward to processing and launching the vehicles that are going to be supporting Gateway.

Mr. LUCAS. Thank you.

Ms. SINGER. From a Marshall Space Flight Center standpoint, I look at Marshall's heritage and expertise that we have. We have development and integration experience in large and complex human systems, have been demonstrated in Apollo, Shuttle, and SLS. We have—deep space transportation systems will be critical for ascent and descent. We look to advanced manufacturing and additive manufacturing not only to be able to build our components but to build in space. Also the lifesupport systems that we see, we partner with other centers to make sure that we have the life-support system for survival, and also when I look about large science instruments, being able to understand the science and the world around us.

So I see as our participation from a center perspective and as a group we all have a lot to offer in robotic and human exploration, and I think spaceflight in our future is very bright. And I think we'll be looking as to whether we'll be traveling to and through or living and working in space or understanding our world. I think we all can be significant contributors.

Mr. GEYER. Yes, great. And so, yes, we're excited about the exploration campaign, and I think there's parts of that that we've mentioned. Certainly the astronauts are at JSC. We do operations, flight operations. We do human health and performance, learning how the body behaves in space, spacecraft design, and then really integrating complex not just engineering but also programmatic relationships like space station has both commercial—and ISS will be a big part I think about the sustainability of the new plan. So we're excited to work with our partners and get started on this new endeavor.

Mr. LUCAS. Thank you, Mr. Chairman. And I just note to our panelists that those of us on this side of the table are constantly reminded we have to deliver our message, what, 17 times to get it to stick, so repetitiveness is the nature of bringing the general population along with us.

I yield back, Mr. Chairman.

Chairman BABIN. Well said.

Mr. PERLMUTTER. It takes us 21.

Chairman BABIN. Thank you, Mr. Perlmutter.

I now recognize the gentleman from Pennsylvania, Mr. Lamb.

Mr. LAMB. Thank you, Mr. Chairman.

Mr. Gerstenmaier, what is the basis for the statement in the report that this strategy does not require significant funding increases or does not assume them? Could you talk a little bit about that?

Mr. GERSTENMAIER. Sure. What we're doing is we're trying to leverage the capability that already exists in the commercial industry. So, for example, the first element of Gateway is the power propulsion element. It will provide communications and electric propulsion for the Gateway spacecraft around the Moon.

We noticed that the commercial satellite buses that are in existence today flying around with commercial satellites are very similar to what we need for this application, so we're going to leverage off of what's available in the commercial satellite industry, offer them the chance to add high-powered solar rays and high-powered electric propulsion to their spacecraft, and we think they'll be very interested in that activity. So therefore, we don't need to do a complete new redesign from the beginning. We can take advantage of the spacecraft that's flying on orbit today with 15 years of reliability and demonstrated performance, and that allows us to keep the cost fairly low, at least for that first acquisition.

We're looking at the same thing for all the elements. We're looking to see what's available from the private sector, what we can do ourselves, where we can contribute to—and we spread the development out across several years such that we don't need a huge influx of funding on an annual basis to make this activity happen.

Mr. LAMB. Okay. And are these mostly American commercial partners that you're talking about?

Mr. GERSTENMAIER. Yes.

Mr. LAMB. Okay.

Mr. GERSTENMAIER. And again, you can see—I think in the report it talks about conceptually what we think it's international as well. If we want to be a leader, we're bringing in some international partners into the Gateway as well, and we've distributed some of the components. We chose areas that we think are uniquely important to us that we want to have in the United States where we want to continue to keep U.S. leadership, so that was kind of strategically defined how we picked our partners and put our partnerships together.

Mr. LAMB. And does the lack of a need for significant funding increases, does that hold true only up to the landing of humans on the Moon or would it include, you know, further missions like the mission to Mars or do you know?

Mr. GERSTENMAIER. Again, I think we've kind of laid out the first framework to that point. We also assume reusability, so, for example, the—like I described earlier, the lunar landing module, we see that the—there's an ascent module that would be reusable and would not have to be replaced. The Gateway, as I described earlier, is a reusable piece. We think that helps keep costs down. It depends how many unique pieces we need going forward. It also depends how much interest there is in low-Earth orbit. We think we need to keep some presence in low-Earth orbit and will the commercial sector be able to generate revenues so NASA is one of many customers. So there's lots of what-ifs as we go out there.

I think we do need more than a flatline budget. We need some increase each year at least consistent with inflation, maybe slightly above, but it's that moderate increase, and that's what that statement tries to capture in the report.

Mr. LAMB. Thank you. Can we talk a little bit about the use of private lunar landers specifically? And this could be for Mr. Gerstenmaier or anyone on the panel who's familiar with it. But there's a company, for example, in Pittsburgh near where I'm from called Astrobotic that's planning on launching its first mission in 2020. This to me seems like a success story along the lines of what

you're talking about where we are having private commercial companies do Moon missions for the first time really in history. Is that—on that specific point of having them do lunar landers, is that a place where you've seen a lot of success, and what opportunities does that create I guess is my question.

Mr. GERSTENMAIER. It—I think as the other Center Directors talked a little bit about, one of the unique roles of NASA is we have a lot of internal expertise, so we supported a lot of these smaller companies transferring some of our knowledge to them, so we helped many of the providers that you've described and talked about. And we're going to do a services contract through the Science Mission Directorate that's a sister directorate to mine that will look at commercial landed services on the Moon, and these will be small landers, less than 100 kilograms or so kind of landed mass, and the company that you described is one of the participants potentially in that activity.

So we're off doing that solicitation now. That will let us see what the commercial sector can provide. Then once we understand that, when we do the more highly reliable, more complex human class landers which are, you know, up to 1,000 kilograms landed or 2,000, 3,000 kilograms landed on the Moon, we can learn from those early activities to see where we need to do extra analysis, extra research to move forward. So we have kind of a phased program of small-class landers, mid-class landers, and then human-class landers, so those are three integrated programs that allow us to explore and see what commercial industry can provide, what their skills are, and then we only dial-in what we uniquely need to add to what the commercial sector can do to give us a highly reliable human transportation landing capability in the future.

Mr. LAMB. Thank you very much, sir. Mr. Chairman, I yield back.

Chairman BABIN. Yes, sir, thank you.

I now recognize the gentleman from Louisiana, Mr. Abraham.

Mr. ABRAHAM. Thank you, Mr. Chairman.

Before I get to my questions, I certainly want to recognize the role that Louisiana plays in our space missions. New Orleans is home to the Michoud Assembly Facility where NASA is building the Space Launch System that Ms. Singer referenced and the Orion spacecraft. And I know everyone here realizes how critical this facility and the entire federal campus, including the NASA Business Development Center and the USDA National Finance Center, are to the federal government and to our mission to explore space.

And for us in Louisiana it's a source of pride. It's a major job provider, so we certainly just appreciate Michoud being there. And I want to acknowledge the fine work being done there to our country and to our space exploration.

I was looking at the bios of you on the panel. It amazes me on the Space Committee, either the full committee or the subcommittee, the intellect and the knowledge base. And you guys and ladies on that panel, you give us mere mortals a bad rep. I mean, it's like, you know, it doesn't take a rocket scientist—well you guys are the rocket scientists that we are compared to. So, you know,

I do have a little bit of chip on my shoulder when my wife says, "it doesn't take a rocket scientist to change a lightbulb."

Mr. Cabana, is there anything you haven't done, sir? I mean, I'm looking at your resume and I'm just blown away at the accomplishments, as anyone on the table. So just thanks for being here and, you know, thanks for taking care of us on the space and exploration frontier. We certainly want to continue to lead as a country, as a nation, globally. We want to certainly command space in every form and fashion.

And the only question I have—and I guess it'll be to all of you and if you can just go down the line—I want to kind of pony on my good friend Mr. Lucas where we left off. What Congressional action do we need to mitigate the feast or famine that we've had in the past, better leverage the resources that you have available, the workforces? What do we need to do as a Congress to make those centers even better than you guys are? Mr. Gerstenmaier, I'll start with you and just go down the line.

Mr. GERSTENMAIER. Sure. I think it's important that we have consistency of purpose, right, where we kind of keep our goals and objectives at a higher level, and then that allows us to continue to keep moving progress and move forward. It's hard when we start a program and then we have to stop a program and then start another program. So if we get too specific a direction, it's difficult for us to implement under that. But I think good steady guidance, good financial support, other pieces are there——

Mr. ABRAHAM. So no C.R.'s if we can help it.

Mr. GERSTENMAIER. Yes, that would be nice if that happens. But we are prepared for those. But we can—but again, I think just consistency would be very important.

I think we also see this as really the ultimate team sport. You know, all of us can contribute in our own way, and each one of us has our own unique strengths. And by pulling all of us together with our diverse backgrounds, we can do amazing things. And I think we need Congressional support, we need Administration support as well, and—but we call you part of the spaceflight team.

Mr. ABRAHAM. Well, we appreciate that.

Mr. Geyer?

Mr. GEYER. Yes, thank you. And—so I think it's great and appropriate to be held accountable for the work that we do, and I appreciate the opportunity to respond to that and talk about the work that we are doing and on the transition report especially about putting together a well-thought-out and logical plan, giving—having the opportunity to do that and show the rationale for the future I would say is really, really important.

And as Bill said, it's working together to make these come together. I would say I just want to echo what you said about Orion. You know, we found that the welding expertise in that location was world-class, and they did a terrific job on Orion and will continue to do so.

Mr. ABRAHAM. Right.

Mr. GEYER. Thanks.

Mr. ABRAHAM. Ms. Singer, any comments on that?

Ms. SINGER. Yes, I would second that from—Michoud Assembly Facility is very near and dear to my heart. I've worked external tank for over ten years, and it is the——

Mr. ABRAHAM. You're welcome to come over to the LSU side—you understand that—from the Alabama side.

Ms. SINGER. And I would tell you, too, thank you so much for you all's bipartisan support. It makes a difference. When we have continuity of funding and continuous pressure, as Mark said, it's great for us to be held accountable, but it does make a difference in how we recruit and be able to get the next generation of folks that want to work on space and space program and exploration. Having that inspiration makes a big difference, too.

Mr. ABRAHAM. Mr. Cabana?

Mr. CABANA. I think, as Mr. Gerstenmaier said, consistency in our direction, and we have that consistency in our funding. One of the things that—the program that we played out, it's sustainable and it's evolvable. It's something that doesn't need to be started over. It is the right path forward to allow us to get back in cislunar space, to get to the Moon and eventually on to Mars as we evolve, and having that continuity is going to be really important.

I think continuing with the authorities that we have, especially looking at the Kennedy Space Center, what we've been able to do to commercialize the assets that we have through the Space Act Agreements, enhanced use lease, and so on is extremely important. And I know that our human resources folks are also looking at human resources initiatives that can help us better recruit and retain the workforce that we have, items such as direct hiring authority, so there are a number of things that can help us and we're looking at that.

And I would also say, sir, that Senator Glenn was 77 when he flew his last flight, and I'm still holding out hope.

Mr. ABRAHAM. I think you could qualify for the physical right now. Thank you, Mr. Chairman.

Chairman BABIN. You're welcome. Thank you.

I now recognize the gentleman from Colorado, Mr. Perlmutter.

Mr. PERLMUTTER. Thank you.

I know I'm a broken record. I know you've seen this before, but I will put it up there one more time because this is a goal I think we all want to achieve, which is to get our astronauts to Mars at a time when it's relatively safer for them because of a shorter trip, less radiation, those kinds of things.

And so, Mr. Gerstenmaier, you and I have had this conversation on occasion, and so I'd just like to kind of talk about where we are because I think in one of the bills that we passed last year we asked for report about a roadmap to Mars, and we have yet to see that. So I know you're not surprised by my question, and I'd just like to see where you think we are and when we're going to see the report.

And I guess there's a third piece based on what I've just read. Have you all decided to make it a backseat to the Moon?

Mr. GERSTENMAIER. Okay. So I think, again, the report's coming. The first report we needed to get done was the Exploration Campaign, which we were late on but you got it last Friday. And I—and Mars is not a backseat to the Moon. What we see is we need

to do the activities around the Moon to really prepare us to go to Mars. So this Gateway spacecraft we talk about around the Moon, it can be moved in different orbits around the Moon. It also could be the basis for a Mars spacecraft. The ascent vehicle that we will use for the lunar activity, we're going to try to size that ascent vehicle that comes off the Moon that takes the crews from the surface of the Moon to Gateway. That vehicle will be sized towards a Mars-class lander. So we're using the region around the Moon to build the skills to build the understanding, the technology that allows us to go to Mars.

I don't think we're ready to go to Mars directly today. We need someplace—we need to use the space station first to build long-duration life-support systems. Those will start flying as early as this fall. There are some scheduled to fly in November, and that'll be really good on Station to see those systems come online. Then we go to the Moon, press the skills a little bit harder, and then we're ready to go to Mars. So I see the Moon——

Mr. PERLMUTTER. So——

Mr. GERSTENMAIER. —as an enabler for Mars.

Mr. PERLMUTTER. Good. And that—I—really was what I wanted to hear. I guess what I'd like to see in the report on the roadmap to Mars is more of a connection between what this steppingstone is in my opinion in going to the Moon and then how it relates and supports and—because I told you I'm agnostic on how you get to the—to Mars, just get there by 2033. So I felt like there needs to be more of a connection between your activities and efforts returning to the Moon and developing things there.

To change the subject just a little bit, this Gateway thing, I did have a constituent of mine who is very involved in sort of space exploration, a guy named Dr. Zubrin, who you know, who had some reservations about the Gateway sort of approach. Does that give somebody in the private arena, you know, a monopoly on leases or something like that? He was much more erudite in how he expressed his concern than I just have, but are you familiar with that kind of a critique?

Mr. GERSTENMAIER. We've heard some of that. One key thing is we're trying to develop—we call them interoperable standards. And what those are is we have an international docking standard now, which we've said—it doesn't tell you how to build a docking device, but if you can build to the standard, you can dock any spacecraft to another spacecraft. And we're using that now on our new vehicles.

We're also going to set seven other standards, atmospheric standards, power standards, data standards, rendezvous proximity operations system standards, and those will allow any spacecraft to operate with other spacecraft, so then that prevents this monopoly that you described or one of the concerns.

Mr. PERLMUTTER. Okay.

Mr. GERSTENMAIER. So by having an open architecture that anyone could build to, they build to these standards, it doesn't tell them how to build the hardware, they can be interoperable with our spacecraft moving forward. And we think that's a very powerful tool that lets us now keep everyone participating in these activities

so there's not a one unique spacecraft, one unique design owned by one company. It's effectively built to an open standard.

Mr. PERLMUTTER. Thank you. And, Ms. Singer, I'll end with you. So SLS, Orion, Marshall obviously plays a very big role there. Are you comfortable that NASA is paying attention to getting to Mars?

Ms. SINGER. Yes, sir. I see that as a top focus of—part of our ability to be sustainable and operating in deep space. The Space Launch System is the enabling workhorse that has to be there to be able not only to support Gateway but beyond Gateway and above. So, yes, we are getting the attention.

Mr. PERLMUTTER. Okay. Thank you. Mr. Chairman, I yield back.

Chairman BABIN. Yes, sir. Thank you.

I now recognize the gentleman from Florida, Mr. Dunn.

Mr. DUNN. Thank you very much, Mr. Chairman.

Mr. Gerstenmaier, as we ramp up the number of launches to Gateway, can you share with us your best estimate of the cost per launch? And if you need to stratify that by payload size or launch vehicle, please feel free.

Mr. GERSTENMAIER. Yes, if you want exact numbers——

Mr. DUNN. No, no, just a—you know, back-of-an-envelope type thing.

Mr. GERSTENMAIER. Yes, if you take a look at our budget, we're looking at probably, I don't know, $3 billion or so per year, but then it's balanced across with SLS being launched about once per year roughly as you see in the report, but then that's augmented by commercial launches for other things like supply, fuels, other pieces, so there are several commercial launches there.

So the SLS Orion system, when crew needs to be there or large components need to be there, you uniquely use the heavy-lift government system. When the smaller things can come, they can come on other pieces. So, for example, the power propulsion element, it'll be launched on a commercial launch vehicle. So we spread that across all of them so we can get the most efficient launch system to take whatever unique cargo is needed.

Mr. DUNN. So I was under the impression some of the commercial systems also are heavy launch now. My——

Mr. GERSTENMAIER. They're still on the books in terms of redesign. There is no system that is as far along in manufacture and development as the SLS. It's——

Mr. DUNN. It might very well happen, though, over the course of the next four, five years——

Mr. GERSTENMAIER. Sure, and if it does, then we'll figure out a way we can accommodate those in our architecture so our architecture isn't dependent upon one launch system.

Mr. DUNN. So Mr. Lucas asked earlier a question that really piqued my interest, which is how do you leverage the commercial—all the interested parties of the commercial side to get them really involved in the Gateway and the lunar explorations, which are in preparation for deep space exploration?

Mr. GERSTENMAIER. You know, I think, again, if we can show what we need from a NASA perspective to do this and show the vision, then I think industry can start figuring out ways to contribute and move forward in that vision. We're trying to do that very much in low-Earth orbit. We're starting to see now some com-

panies that have not done research in space, now have interest in space, which is encouraging. So I think the key thing is we can show the vision, we can show the open architecture, then it's up to the companies to figure out how they can contribute and work with us in that area.

We can also share our expertise with them. You know, where we have some unique manufacturing or processing techniques and things, we can share those with industry as well to help them.

Mr. DUNN. I certainly have been approached by some industries like that, and I know we had here during testimony one day a gentleman was talking about how to do the fuel resupply on the Moon based on commodities he could get from the Moon, hydrogen and whatnot, so that—I think that's possible.

Also for Mr. Gerstenmaier, can you confirm that NASA does not have plans to abandon American human presence in low-Earth orbit even if the details are still unclear how that—how you—what you're going to do?

Mr. GERSTENMAIER. No, our intent is to have a continuous presence in low-Earth orbit, and we're working—and our transition plan lays out the principles for that activity and we're moving forward to try to implement that.

Mr. DUNN. I thank you very much. Thank you, gentlemen, and also your flight controllers for joining us today. It's always fascinating to see NASA come in and talk to us. Thank you.

Chairman BABIN. Thank you very much.

I now recognize the gentleman from Louisiana, Mr. Higgins.

Mr. HIGGINS. Thank you, Mr. Chairman.

Gentlemen, madam, thank you for appearing before us today. I'm the seventh of eight children. I have six sisters, and they join many ladies across the country for the last several decades—I would hear them occasionally say, "If we can send one man to the Moon, why can't we send them all?"

And I join my colleagues in the goal to reach Mars by 2033. The problem could perhaps be that much of America would like to send Congress to Mars right now.

Human space exploration of course is incredibly important for the future of our world. I support it; this Committee supports it. The policies have remained relatively consistent across current and prior Administrations but minute differences concerning the planned level of lunar activity prior to going to Mars has hindered term planning as we sit right now.

Before I ask my question, I'd like to thank Ms. Singer specifically for being here today. The Michoud Assembly Facility managed by the Marshall Space Flight Center has consistently been an impressive and vitally important facility for the entire State of Louisiana. I've visited the facility, it's an incredible experience with some of the most professional men and women that I've ever met in my life. So we certainly support the mission that we are joined here on this Committee.

My question lends to the bipartisan nature of planning. I certainly understand that different Administrations at the executive level, and as the balance of power shifts in Congress, will enact certain policy changes, but do you feel that—my directors present—do you feel that if we're able to establish a bipartisan agreement

on long-term planning for human space exploration, would that not be beneficial to the space centers you operate, the mission, and potentially reduce the long-run cost and just increase overall efficiency from a planning perspective? I'd like for my directors to respond to that question, please.

Mr. GEYER. Yes, I'll start. I think you said it very well. A long—having a long-term plan allows us to plan, right? It allows us to, as Jody said, look forward to the workforce that we're going to need and make those choices so that when those different milestones happen, we have the folks we need to do the job. And so I think that's a really important part of the future.

Ms. SINGER. And yes, I would say that sustained and continuity in human spaceflight and exploration, which includes the bipartisan support, does help us because it gives us the ability to have a vision not only for the near term but for the future to come. It also helps us to be able to inspire folks. It helps us, economic base, as well as to inspire the next generation of folks that want to work on it. So yes, definitely having that gives us a lot of vision and excitement to be able to execute.

Mr. HIGGINS. Yes, ma'am.

Mr. CABANA. And I'll agree, sir. Having the consistency of a clearly laid out vision for the future and our implementation of it, the path that we're on being—having that sustainable and consistent is critical to our success.

Mr. GERSTENMAIER. And I would add also that it's a really good thing. You've just got to be careful we don't get too specific in the plan because then that causes us to stop and start. So the trick is to get it at the right level that is sustainable for a long duration and it doesn't get too specific because then that drives us to make short-term decisions, which I think are problematic to us.

Mr. HIGGINS. Yes, sir. And of course it's important that we communicate the crucial nature of the job that we do together from this Committee through Congress and through the Administration so that we can have a truly bipartisan plan that looks into the future that can transcend politics and shifts of power and changes of political affiliation at the executive branch. And if there's a committee that can make that happen, Mr. Chairman, I believe this is the one.

I thank you all for being here. I yield back.

Chairman BABIN. Thank you very much.

And now, I'd like to recognize the gentleman from Alabama, Mr. Brooks.

Mr. BROOKS. Thank you, Mr. Chairman.

Mr. Gerstenmaier, the controversial load-and-go procedure appears to expose NASA astronauts to unnecessary additional risk. In that vein I've got three questions. Is load-and-go an additional launch risk, question number one. Question number two: is load-and-go necessary because of performance challenges in getting to the International Space Station? And then question number three, if it's a cost-saving measure, is the added risk to astronauts appropriate to help save money?

Mr. GERSTENMAIER. So, again, what I think we need to do—and we're still in the process of reviewing the exact procedure of where we put the propellant on versus when we have crew get in the ve-

hicle, it's a function of the spacecraft design because you need to get the propellant in at the right time. The propellant needs to be at the right temperatures and pressures at the time of ignition of the engines, et cetera, so there's a balance of when that occurs. We're going to find the right time to put the crew on these vehicles that puts them in at the most—or the safest opportune time for the particular spacecraft that we're designing, and so we're going through that process right now. And I think we need to be careful how we do that and when we pick the time.

In the case of SpaceX, it's interesting. If we go with the standard procedure they've laid out for us today, then we'll get to see—they're roughly flying sometimes 10 to 16 launches per year. We'll get to see the actual loading of that vehicle exactly like it's going to be when the crew is on board 16 times per year. We think that's a significant safety advantage to see that operation occur repetitively 16 times per year. If we required a unique loading operation just for our crew when they're there, then you get a one-time shot per year of how you load the vehicle with crew there, and that may actually be more risky for you than it is taking the more standard procedure. So that's kind of what our logic is behind this. We get a chance to see it multiple times to make sure that it is really reliable. The folks that are doing the loading, the software that does the loading, it gets exercised multiple times per year, and that gives us experience with that software, it's up-to-date, it's not a unique, one-of-a-kind thing. So we need to be careful we don't drive the particular loading sequence for this particular design to unique aspect that actually exposes us to more risk. And that's what the teams are doing now. They're going through that detailed discussion to figure out the right way to move forward with this with SpaceX.

Mr. BROOKS. Thank you, Mr. Gerstenmaier.

Director Singer, the Chairman couldn't say it but I will. Roll Tide. Welcome to the Hill as Marshall Space Flight Center's Director, and congratulations. Being from the Tennessee Valley, you've made us all proud.

Now, the Marshall Space Flight Center's first Director, Dr. Wernher von Braun, began his tenure in 1960 with a vision of taking humanity to the Moon. This year, as we celebrate NASA's 60th anniversary, we are once again embarking on a mission to the Moon with the intent of proving the technologies that are needed for our next celestial achievement, taking humanity to Mars. As the Marshall Space Flight Center's 14th Center Director, what is your vision for Marshall, and what technical roles do you foresee as Marshall writes its future history?

Ms. SINGER. Thank you so much for that question, and thank you for the nice recognition.

I would say that from my vision as the Center Director of Marshall Space Flight Center, it's probably very similar to the vision that many Center Directors have. It's to—definitely to deliver on our commitments and our missions and making sure that the assignments that we do have, we're able to execute them and making sure that our infrastructure is in place to do that.

I think also a key part of that is strengthening our workforce. We have a very strong workforce that I'm very proud of, but invest-

ment in our workforce and making sure they remain strong and making sure they have the adequate training and resources and our ability to hire a diverse workforce is going to be critical and—as we execute the new missions.

Also, a third part of that is the criticality of our partners. I know that many of the things that we do today gives us increased flexibility, agility, and effectiveness, and I think the education of our workforce and working with our partners to make sure that we continue that partnership and our partnerships with other centers are very critical.

So I see that as my top three themes. I've talked about our expertise that we have at Marshall Space Flight Center, our ability to develop and integrate large systems, our deep space transportation activities, ascent and descent, the significant adventures that we're having in advanced manufacturing not only on SLS today but on engine parts that we're seeing that we're flying, and the ability to build in space, our ECLSS that we work on to help with life that not only has to happen on International Space Station but going forward in deep space, a lot of that is what will be key contributors.

So to me that is what makes our future so bright and why I'm so excited about being at Marshall Space Flight Center because I think we have an opportunity to not only work on traveling to and through space. I think we have an ability to work on living and working in space, as well as understanding our world with our science. So I look forward to a bright future, and I think it's a wonderful opportunity to be at NASA.

Mr. BROOKS. Thank you, Ms. Singer.

And, Mr. Chairman, I yield back.

Chairman BABIN. Yes, sir. Thank you very much for those great questions.

I just want to—I think this wraps us up. I don't see any more Democrats here, and he was the last Republican, but I just want to thank each and every one of you. I'm proud of each one of your centers and the leadership that you've given us and also, Mr. Gerstenmaier, your leadership at where you are and very proud to have you folks here telling us about our space program because I've never felt more optimistic and more excited about what's happening.

And so I want to thank each one of you. The record will remain open for two weeks for additional comments and written questions from Members. And with that, if I get my gavel out here, we will adjourn. Thank you.

[Whereupon, at 3:40 p.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. William Gerstenmaier

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future"

Mr. William Gerstenmaier, Associate Administrator, HEOMD, NASA

Questions submitted by Representative Mo Brooks, House Committee on Science, Space, and Technology

Question 1a:

I remain concerned that astronaut safety is being overlooked in regard to commercial crew missions.

Specifically, how is the risk assessment being made for commercial crew?

Answer 1a:

During the human rating process, known as "certification," the risk assessment for the Commercial Crew vehicles will be fully consistent with NASA policy and standards for all human space flight programs. Final decisions on whether the risk is deemed "acceptable" or "unacceptable" will be based on assessed compliance with NASA human rating requirements, which embody over 50 years of spaceflight experience, lessons learned, and best practices. These NASA human rating requirements include design, manufacturing, workmanship, test, verification, and operations standards used to mitigate risks inherent in human spaceflight to an acceptable level.

NASA's risk assessment for the Commercial Crew vehicles in development consists of four system-level human rating activities: (1) validation of the technical and performance requirements/standards; (2) verification of compliance with those requirements/standards; (3) consideration of relevant operational experience; and, (4) acceptance of any residual technical risk due to hazards for which design and/or operational controls will be established, or residual technical risk resulting from waivers to, deviations from, or non-compliances with requirements/standards which have received prior NASA approval.

NASA will collectively evaluate crew transportation system design changes, manufacturing (or refurbishment) process changes, and testing changes to verify that the Commercial Crew vehicle and operational mission fall within the bounds of the system requirements and that anomalies from previous missions have been addressed. NASA will decide, based on the flight readiness certification and residual risk posture, whether to authorize NASA crew to fly on the crew transportation system.

NASA certification will be granted only after review of objective evidence that demonstrates compliance with NASA requirements as well as appropriate mitigation of risks to crew safety and mission success. This includes inspection of plans and technical results associated with the design, test, verification, and past flight performance of the systems. Objective evidence will

also include the commercial partner's system safety assessments, which will be developed in accordance with the NASA Safety Review Process to assure consistent content and characterization of risk. These products will contain hazard analyses, which use both qualitative and quantitative techniques to identify and characterize all residual risks. The resulting analyses will be evaluated by NASA to assess whether design decisions as well as safety hazard mitigations and controls established by the commercial partner are sufficient to ensure crew safety and mission success. NASA approval of the commercial partner's compliance with requirements as well as system safety and reliability products and associated hazard analyses will represent NASA's formal risk assessment.

There are always risks and uncertainties associated with the design and operation of complex human spaceflight systems in the harsh environments leading to, through, and from space. NASA is committed to understanding the risks, ensuring risks have been mitigated to the maximum extent possible, communicating residual risks to stakeholders, and making informed decisions regarding final acceptance of risk. Ultimately, NASA will decide the acceptability of risk based on the best available engineering data and expert advice from across the Agency that leverages our collective human spaceflight knowledge base and lessons learned.

Question 1b:

Is that risk assessment independent of other launches by those commercial providers?

Answer 1b:

All launches of similar rockets and spacecraft used by the commercial providers for their crew transportation system are considered and evaluated in NASA's risk assessment for Commercial Crew. If there is an anomaly during a flight or test of similar hardware, the providers are required to demonstrate that the cause of the anomaly has been identified and commensurate corrective action has been implemented.

Question 1c:

If factors from other launches are included into any safety assessment for astronaut wellbeing to what degree do those other launches impact the degree of risk to the commercial crewed flight? (Please give an estimated percentage).

Answer 1c:

The results of the anomaly investigation are incorporated into NASA's risk assessment process, as described in the response to question #1a. The level of impact depends on the type and magnitude of the anomaly, its cause, and the potential effect, if any, to astronaut safety. There is no pre-set, quantitative degree of risk that is assumed by previous flight history.

Question 2a:

With the "load-and-go" fueling procedure potentially in place for the commercial crewed launch, I remain both cautious and skeptical of this process. As of right now there has not been a clear or logical explanation for why the deviation from decades of the typical process may be approved.

What is the specific justification for allowing the "load-and-go" procedure as opposed to the historical practice of fueling the vehicle before the astronauts board? (Please go into precise detail, or include explanation provided by commercial provider).

Answer 2a:

NASA considered two options for the SpaceX crew launch timeline. NASA weighed the risks of the two options, evaluating the exposure of all people – both the ground crews and flight crew – the stability of the launch vehicle and ground configuration, and when the different crew escape systems are available during the timeline. While there is no scenario without risk, NASA determined that the current baseline plan that ingresses the flight crew prior to propellant loading presents the least risk to the total number of people exposed and provides the more stable vehicle configuration. The Commercial Crew Program is continuing certification activities using SpaceX's baseline configuration; however, the final certification is contingent on verification of hazard controls, compliance with operations standards, and NASA's acceptance of any residual risk. The work to certify the baseline configuration is ongoing and must be completed prior to flying crew.

The specific rationale for approving the baseline plan was multi-faceted. SpaceX adopted the baseline plan for crewed flights to minimize operational deviations for hardware common with the majority of SpaceX missions. The launch automation pedigree for crew (including operator training) is based on repeated practice of the baseline plan over several static fire operations and missions. This timeline is consistent with the fueling procedures SpaceX uses for its commercial resupply missions and satellite launches. In addition, SpaceX must demonstrate five successful propellant loading operations prior to the crewed test flight. In addition, SpaceX has accomplished several iterations of the various hazard reports associated with the baseline plan and implemented effective hazard controls. Egress capabilities are available to the ground and flight crew during the entire duration of crew ingress and propellant loading. Given all these data, analysis, and test results, the baseline plan was determined to have the fewest number of people exposed to hazards during the least amount of time. However, SpaceX must complete remaining certification work and comply with the conditions identified by NASA before this approach may be used to support crewed flight.

Question 2b:

My question is when you consider capsule weight, other total weight of the rocket and fuel, amount of fuel needed for completing the mission, what does the math show – is the Falcon 9 able to complete the mission if astronauts enter the capsule *after* the fuel is loaded into the rocket?

Answer 2b:

NASA explicitly compared the baseline plan for propellant loading against the option of crew ingress post-propellant loading for the Falcon 9 launch vehicle for crew. This comparison took into consideration several factors including an extensive review of the SpaceX ground operations, launch vehicle design (with launch vehicle performance being one factor considered), escape systems and operational history. Consideration of overall safety for our personnel led to the conclusion that the baseline plan presents the least risk to the fewest number of people and provides the more stable vehicle configuration. SpaceX is required to demonstrate that it has successfully met NASA's conditions using this approach for propellant loading before it may be used to fly crew. SpaceX will also be required to demonstrate that it can complete the entire mission profile under NASA's Commercial Crew Transportation Capability (CCtCap) contract. The crew could be placed in the rocket after fueling and the mission could still be performed. However, this loading sequence would be unique and only be used for crew missions. Loading the crew and then fuel is the same process used for all SpaceX missions. Getting a chance to evaluate system operations ~16 times per year offers significant safety advantages over a unique process used ~ once per year. As discussed above, this along with other considerations should be the baseline plan to enhance overall safety.

Question 2c:

A follow up to that question is if yes, with what level of mission risk?

Answer 2c:

There is not a quantitative mission-risk-level comparison between the two loading operations. The mission risk is assessed using all the tools and products described in the response to question #1a.

Question 2d:

Finally, does that percentage change when load-and-go is used? And if so, to what degree (again in percentages) does the level of risk change?

Answer 2d:

See answer to the previous question.

Question 3a:

This question is asking for a more ambitious date range than made in the National Space Exploration Campaign Report issued in September 2018.

In your estimate, assuming funding and resources are not an issue, how soon could NASA return astronauts to the moon?

The FY 2019 budget request supports a diversified National Space Exploration Campaign that can be sustained for decades into the future, allowing human presence to be expanded into the solar system, and that request sets NASA on a path to return astronauts to the Moon by the end of the 2020s. While planning and development of the NASA systems that will return the U.S. to the Moon are ongoing (SLS/Orion/Gateway/landers), other components of the lunar return and infrastructure development will involve agreements with international space agencies and commercial partners; these agreements are in the formulation stages but will reflect support for human landing prior to 2030.

Question 3b:

What roles do you see for the Marshall Space Flight Center as it relates to the National Space Exploration Campaign Report of 2018?

Answer 3b:

For more than 50 years, the unique capabilities and expertise at NASA's Marshall Space Flight Center (MSFC) has been used to design and build the engines, vehicles, space systems, instruments and science payloads that make possible unprecedented missions of science and discovery throughout our solar system.

Today, MSFC manages all the science work of the astronauts aboard the ISS from a 24/7 Payload Operations Integration Center, and is home to development of the Space Launch System (SLS), the most powerful rocket ever designed to carry human explorers, their equipment and science payloads deeper into space than ever before, to the Moon and Mars. Marshall also manages the Michoud Assembly Facility, where the core stage of SLS is under construction with a unique set of leading-edge tools, including the largest spacecraft welding tool in the world, the 170-foot-tall, 78-foot-wide Vertical Assembly Center.

For the Gateway Program, MSFC will play a critical role in the management of the Habitation Element. The leadership of this Gateway Element will encompass integration of all Gateway habitation modules. While specific Center program and project assignments for future activities supporting the National Space Exploration Campaign will be determined as that campaign evolves, MSFC has a critical role in moving the Nation forward, offering unique expertise in science and engineering, forging partnerships with industry, academia and other Government organizations, and continuing to help the United States lead the world in space exploration and discovery. Marshall's strengths and proven capabilities support NASA's goal of integrating science and exploration in innovative ways for maximum return on the Nation's investment.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future"

Mr. William Gerstenmaier, Associate Administrator, HEOMD, NASA

Questions submitted by Representative Bill Posey, House Committee on Science, Space, and Technology

Question 1:

The National Space Exploration Campaign Strategy gives us a vision of an open architecture for exploration that will provide opportunities for NASA to benefit from ongoing developments in the private sector. Would you please elaborate on how NASA would coordinate its development and acquisition strategies with the private sector to assure the private and government sector compatibilities to make this concept work?

Answer 1:

NASA will leverage partnerships with the rapidly advancing commercial sector and international community to lay the foundation for a future of unlimited opportunity, discovery and growth. This will be a key part of the National Space Exploration Campaign (NSEC), and supports Space Policy Directive-1, which calls on NASA to "Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system...".

Ongoing operations and research on the ISS encourage development of a robust LEO economy in which U.S. private industry matures the ability to provide goods and services – such as commercial crew and cargo transportation systems – for customers beyond NASA and other government users. By 2025, NASA intends to shift resources from its current approach to operating the ISS to purchasing services from commercial providers and providing resources to the National Space Exploration Campaign.

As we look beyond LEO to the Moon, in the near-term, NASA's Science Mission Directorate Lunar Discovery and Exploration Program will provide delivery of lunar payloads using emerging commercial landers through the Commercial Lunar Payload Services (CLPS) procurement – the defining values being speed and commercial partnership. As it relates to Gateway development, NASA has been working with commercial industry through the Next Space Technologies for Exploration Partnerships (NextSTEP) partnership activities to leverage U.S. private sector expertise to develop concepts for the Gateway. Leading up to the recently released Broad Agency Announcement (BAA) for the Gateway Power and Propulsion Element (PPE), NASA worked closely with industry through NextSTEP PPE studies and the release of a draft BAA to inform an acquisition strategy approach for PPE which leverages industry capabilities and plans as a public-private partnership. NASA released the final BAA for PPE in September 2018. Moreover, NASA recently issued a Sources Sought Notice for Gateway

logistics services which included inquiries to the private sector on acquisition approaches and strategies.

NASA will focus on continued growth of emerging commercial capabilities to enhance lunar lander capabilities and utilization of the Moon (including potential lunar communications networks). In every aspect, technology and commercial sector capabilities will feed forward and integrate with human exploration approaches.

Question 2:

Is anyone working toward a specific target date or year for new American footprints on the surface of the Moon? If it is premature to speculate on such a date, after what milestone will we be in the position to announce to the American public a date when our nation will return Americans to the lunar surface?

Answer 2:

NASA plans to conduct crewed lunar surface missions in the 2020s. As the Agency and its partners continue to make progress on the near-term science and technology goals of the NSEC, we will evolve specific milestones, and these will be reflected in future updates to the biennial NSEC and NASA budget requests.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future"

Mr. William Gerstenmaier, Associate Administrator, HEOMD, NASA

Questions submitted by Ranking Member Eddie Bernice Johnson, House Committee on Science, Space, and Technology

Question 1:

In light of the National Space Exploration Campaign Report stating that (a) the Campaign does not assume or require significant funding increases and (b) the decision on the date and method of human lunar surface return will be made in 2024, what is a reasonable estimate of the year humans will land on the Moon?

Answer 1:

NASA is building a plan for Americans to orbit the Moon, starting in 2023, and land astronauts on the surface no later than the late 2020s.

Question 1a:

Similarly, based on those two statements, is a human mission to Mars by 2033 possible? Is it likely, given the funding constraints assumed?

Answer 1a:

NASA anticipates an eventual series of crewed Mars missions. NASA will advance robotic access to Mars in preparation for human exploration, and an innovative robotic Mars round-trip sample return in the 2020s will tie directly into these efforts.

Human exploration requires a long term, sustained effort. NASA is building capabilities to create a resilient architecture featuring multi-use evolvable space infrastructure. This minimizes unique developments, with each mission leaving something behind to support subsequent missions. NASA is developing the capabilities required for deep space exploration on a schedule consistent with the available resources, technologies, and commercial capabilities, and the Agency will continue to revise its plans as it learns from the experience it will gain by accomplishing the milestones we establish in the plan.

NASA's drive to conduct robotic and human exploration of the Moon informs the development of technologies needed for future Mars missions. In the 2020s, the Moon will also serve as a stepping-stone, a training ground, and a platform to strengthen commercial and international partnerships and prepare for future human missions to Mars and other destinations. As these missions in the 2020s evolve and the technology and partnerships for missions to further

destinations become better defined, NASA will continue to focus on Mars plans that assume minimal changes to future long-term funding needs.

Question 1b:

What impact would a possible Continuing Resolution for fiscal year 2019 Appropriations have on new start human space exploration-related activities planned for FY 2019?

Answer 1b:

In FY 2019, HEO is continuing the work for Gateway, Power and Propulsion Element, Habitation and Lunar Activities begun in previous fiscal years. While Commercial LEO Development will likely be impacted under a full year Continuing Resolution, NASA will allocate some level of funding for this activity. NASA will use the results from ISS studies conducted in 2018/2019 to solicit an open competition for public and privately funded module(s) and/or platform(s) attached to the ISS or free-flying in LEO in FY 2019. It is possible that these awards may need to be executed out of ISS since Commercial LEO Development is a new program. Thus, there are no new start human space exploration-related activities planned. Under a year-long Continuing Resolution during fiscal year 2019 at a total HEO level there would be no impacts, however HEO would need the flexibility to reallocate funding between accounts to ensure funding is available to adequately fund these activities at the levels planned.

Question 2:

What is NASA assuming as a baseline annual cost for supporting the proposed lunar campaign outlined in the Space Exploration Campaign report?

Answer 2:

It is important to note that activities supporting NASA's lunar exploration are spread across multiple budget lines. For further detail, please see NASA's FY 2019 budget request at the following link:

https://www.nasa.gov/sites/default/files/atoms/files/fy19_nasa_budget_estimates.pdf

In the document, a high-level budget summary covering the FY 2019-23 runout may be found on page BUD-1, with a more detailed break-out beginning on page BUD-2.

Question 2a:

Since NASA is not assuming growth in its budget to support the proposed lunar campaign, where will you get the funding for the lunar campaign, given that the existing exploration budget needs to continue supporting the ISS, commercial crew and cargo, and exploration systems development? Does NASA plan to cut or delay any existing or planned activities in order to fund a proposed lunar campaign?

Answer 2a:

NASA believes that the lunar campaign can be fully supported within funds proposed in the President's Budget. Critical to this strategy is looking at different ways of doing business that don't result in the types of large programs and cost overruns that the Agency has faced in the past and impeded progress – including incentivizing more efficient contractor performance, developing new technologies that can make exploration more affordable, and developing more commercial opportunities in space. Changing the current way of doing business is essential to achieving U.S. exploration goals, regardless of available resources.

Question 2b:

How will you pay for starting a humans to Mars program under the assumed constrained budget, given you intend the lunar exploration program to continue indefinitely?

Answer 2b:

One of the key principles in NASA's National Space Exploration Campaign (NSEC) is sustainability, reflecting Space Policy Directive-1, which calls on the Agency:

> *"to lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit [LEO], the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations."*

The President's FY 2019 budget request for NASA supports a diversified National Space Exploration Campaign that can be sustained for decades into the future, allowing human presence to be expanded into the solar system. By leveraging partnerships in the cislunar and lunar surface environment and developing the skills, technologies and capabilities necessary for further exploration beyond the Earth- Moon system, NASA seeks to demonstrate the capabilities necessary in the lunar environment for the exploration of the Mars system.

Question 3:

Has NASA defined the tests, demonstrations, and feed forward capabilities required to send humans to Mars at a level of specificity that provides the confidence that the proposed lunar campaign is a cost-effective and timely prerequisite?

Answer 3:

Our exploration of the Moon in the 2020s will inform future crewed missions to Mars. The Agency will begin sending increasingly capable robotic missions to the lunar surface in the next two years to conduct scientific investigations, characterize resources, and provide lunar landing services to customers from America and around the world. Ultimately, these efforts will

culminate in the safe landing of U.S. astronauts on the Moon before the end of the 2020s. NASA's drive to conduct robotic and human exploration of the Moon informs the development of technologies needed for future Mars missions. The Habitation Systems technologies, such as life support, that are being tested on the ISS and are necessary for Mars missions will also feed forward to human lunar missions. The Moon will also serve as a stepping-stone, a training ground, and a platform to strengthen commercial and international partnerships and prepare for future human missions to Mars and other destinations. NASA's biennial NSEC report will reflect the evolution of specific cislunar activities as we increase our scientific and technical knowledge and prepare for human Mars missions.

Question 3a:

How long would the lunar campaign have to last to demonstrate the capabilities needed for the humans to Mars mission?

Answer 3a:

As noted above, NASA's lunar exploration in the 2020s will inform crewed missions to Mars, which the Agency anticipates beginning in the 2030s and culminating in a surface landing.

Question 3b:

Once NASA tests and demonstrates capabilities on the Moon that are required for sending humans to Mars, will NASA provide funding for continued lunar operations, including those that are carried out by commercial entities? What would be the rationale for doing so?

Answer 3b:

The NSEC has five strategic goals:

1. Transition U.S. human spaceflight in LEO to commercial operations that support NASA and the needs of an emerging commercial economy.

2. Lead the emplacement of capabilities that support lunar surface operations and facilitate missions beyond cislunar space.

3. Foster scientific discovery and characterization of lunar resources through a series of robotic missions.

4. Return U.S. astronauts to the surface of the Moon for a sustained campaign of exploration and utilization.

5. Demonstrate on the Moon the capabilities required for human missions to Mars and other destinations.

Continuing utilization of the Moon is an important part of the Campaign, though the specific missions and activities, as well as whether a given project involves Government-owned and – operated assets or the NASA purchase of commercial services, will evolve as we conduct our cislunar exploration, and will be reflected in future editions of the biennial NSEC report.

Question 4:

Under NASA's current approach to developing the Gateway, who would own the Gateway? What is the anticipated proportion of government versus non-government investment in the development of the Gateway?

Answer 4:

NASA is planning on leading a sustainable and long-term return to the Moon and the lunar surface. NASA's approach will require partnerships with domestic industry and international space agencies to ensure success in this exploration endeavor. NASA will lead the effort, guiding integration and focusing efforts for science and exploration, and the Agency will ensure specific contributions to the Gateway development and operations are recognized and reflected in the governance approach. So, while ownership is shared among the partners, NASA will be the lead organization.

Question 4a:

How would its governance be established and enforced?

Answer 4a:

NASA will be the lead architect, integrator, and operator of the Gateway. International and commercial partners will contribute Elements and Modules to the system and will participate in NASA-led decision-making boards and panels as appropriate.

Question 4b:

How would NASA prioritize the uses of the Gateway among NASA, basic research, international and commercial space partner interests?

Answer 4b:

While the specifics of Gateway research resource allocations are to be determined, the primary focus will be supporting lunar exploration.

Gateway will support a variety of Government and commercial activities in the vicinity of the Moon, including missions to the lunar surface. NASA may also leverage the Gateway for scientific investigations near and on the Moon. The Agency recently completed a call for abstracts from the global science community, and is hosting a workshop in late February 2019 to discuss the unique scientific research the Gateway could enable. NASA anticipates the Gateway

will also support the technology maturation and development of operating concepts needed for missions beyond the Earth and Moon system.

Drawing on the interests and capabilities of industry and international partners, NASA will develop progressively complex robotic missions to the surface of the Moon with scientific and exploration objectives in advance of a human return. NASA's exploration missions and partnerships will also support the missions that will take humans farther into the solar system than ever before.

Question 5a:

NASA has been consistently appropriated above-requested funding levels for the SLS, Orion, and Exploration Ground Systems programs. One aspect of the significant taxpayer investment in these systems is to ensure that NASA regains and retains expertise in human spaceflight development and operations by instituting a reasonable flight rate.

With that in mind, what does the Space Exploration Campaign assume in terms of a flight rate for SLS and Orion?

Answer 5a:

NASA's plans call for one SLS, Orion, and Exploration Ground Systems flight per year through the 2020s. The actual cadence of missions beyond Exploration Mission-2 will be defined based on mission needs, available resources, and operational costs. Reducing production and operations costs will be critical for enabling an ambitious exploration program.

Question 5b:

Does the budget plan support that assumed flight rate?

Answer 5b:

Yes.

Question 5c:

Is this flight rate sufficient to ensure high confidence in NASA's ability to enable effective safety and in production and operational efficiencies?

Answer 5c:

NASA has a rigorous, robust, and proven process, with independent authority oversight, for methodically assessing launch readiness. Exploration systems and operations are designed to safely support one flight a year.

Question 6:

In Section 4 of the National Space Exploration Campaign report, NASA describes the Campaign as including science missions beyond LEO such as OSIRIS-REx, Mars sample return, and Europa. What other science missions fall within the umbrella of the National Space Exploration Campaign? Would the inclusion of a potential science mission in the Campaign alter its chances of being funded by NASA, despite Decadal Survey decisions that may have established different mission priorities?

Answer 6:

NASA's Exploration Campaign focuses on an approach that includes development of technologies and systems that enable a series of human and robotic lunar missions and are extensible to destinations beyond the Moon, including Mars. Science missions will continue to be selected based on the priorities of the potential science return and priorities established in concert with the Decadal Surveys although benefits to human space activities will also be considered, where applicable. Initial science missions to fall under the umbrella of the Exploration Campaign will include lunar payloads delivered to the lunar surface using commercial landers through the Commercial Lunar Payload Services (CLPS) procurement; missions which are expected to begin as early as 2019 or 2020. The Lunar Reconnaissance Orbiter (LRO), launched in 2009, also is a key element of the Exploration Campaign. LRO will not only help characterize future landing sites for robotic and human lunar surface missions, but also provide valuable surface mineralogy data when observing the plumes created during the landing events. In addition, missions such as InSight, which landed on Mars in November 2018, and the future Mars 2020 rover will help pave the way for future exploration and utilization of the Red Planet.

Question 7:

In Section 5 of the National Space Exploration Campaign report, NASA indicates that the agency has initiated a "federated core team" for the lunar portion of the Campaign that reports directly to the Administrator. What is the size of this core team and what are some of the activities it has underway? Please provide an organization chart of the core team.

Answer 7:

NASA has established a core team of agency leadership focused on Exploration Campaign implementation across the Mission Directorates. This team is still in early planning stages and the Agency is working to staff the team and scope the priority activities for execution in the near-term. As planning is still underway and the team is not fully staffed, an organization chart is not available.

Question 8a:

On September 1, 2018, in response an inquiry by Democratic Committee staff on whether NASA had any plans to notify Congress on a change to the EM-1 date (beyond what has been communication so far, i.e., June 2020 and internal date of December 2019), NASA stated that, *"NASA is holding exploration systems development programs and contractors to a June 2020 launch date for EM-1."* The National Space Exploration Campaign Report recently submitted to Congress in response to P.L. 115-10, stated that:

"The first SLS/Orion mission will be the uncrewed Exploration Mission-1 (EM-1), currently scheduled to launch to lunar orbit in FY2020, followed by the first crewed SLS/Orion mission, EM-2, no later than 2023."

Does the characterization of the launch of EM-1 date as scheduled to launch "in FY2020" effectively extend the launch date to potentially September 2020?

Answer 8a:

Recent issues (primarily due to delays in the shipment of the European Service Module from Bremen, Germany to Kennedy Space Center from July 2018 to November 2018, and impacts to the Space Launch System [SLS] schedule due to first-time production issues such as tube contamination and work flow around complex elements like the cores stage engine section at the Michoud Assembly Facility) have consumed six to eight months of EM-1 schedule margin. All other exploration elements (including the Orion Crew Module and Launch Abort System production; SLS engines, boosters and stage adaptors; and Exploration Ground Systems (EGS) construction on the Mobile Launcher, launch pad, and Vehicle Assembly Building) are on track.

Question 8b:

Does the inclusion of such dates in the National Space Exploration Campaign Report constitute formal congressional notification of EM-1 and EM-2 dates to which NASA can be held accountable to?

Answer 8b:

On April 10, 2018, in accordance with Section 103 of the NASA Authorization Act of 2005 (P.L. 109-155), NASA officially informed the Congress of the Exploration Mission 1 (EM-1) schedule. This provided notification regarding the commitments for the Space Launch System and Exploration Ground Systems programs, which had their lifecycle and Agency baseline commitment tied to EM-1. The Orion program's life cycle and agency baseline commitment are tied to EM-2, and the commitment remains for a launch no later than April 2023.

Responses by Mr. Mark Geyer

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future"

Mr. Mark Geyer, Director, Johnson Space Center, NASA

Questions submitted by Ranking Member Eddie Bernice Johnson, House Committee on Science, Space, and Technology

Question 1:
What negative impacts have your center and the surrounding communities experienced during past human spaceflight program transitions, both scheduled and unscheduled? How, if at all, has the environment changed in and around your center and do those changes make your center and surrounding communities less vulnerable or more vulnerable to unscheduled program transitions?

Answer 1:

The most recent human spaceflight program transition was the closeout of the Space Shuttle Program. The last Space Shuttle flight was in July 2011. Civil service workforce that supported the Shuttle Program transitioned to other jobs at JSC or within NASA. Contractor workforce either transitioned to supporting other human spaceflight programs or sought out employment outside of the space industry.

The technical skills that make human space exploration successful are sometimes sought out by other industries in the Houston area. When the Space Shuttle Program ended, many in the contractor workforce that supported the Space Shuttle Program were sought out by the oil and gas industry. While this lessened the impact to the Houston economy, some human spaceflight corporate knowledge was lost from the JSC community.

Ultimately, transitions can be essential for ensuring that NASA's mission objectives and workforce continue to be aligned with national objectives and the capabilities needed to succeed in the future. A stable budget and space policy enable NASA to execute its very challenging assignments with much more efficiency. NASA is focused on executing toward Space Policy Directive 1, elaborated upon in the recently-released National Exploration Campaign report, and supported by the Congress.

The challenging work that NASA executes has the added benefit of training a highly skilled and technical workforce in both the Civil Servant ranks as well as the contractor workforce. The contractor skilled workforce can also enable the United States to be more competitive in other commercial endeavors.

Question 2:

What are the challenges associated with managing the deferral of maintenance at your facilities and infrastructure and how does that impact your center's ability to support new human spaceflight initiatives? Are new authorities needed to enable needed modernization of facilities and infrastructure?

Answer 2:

JSC is challenged with managing the ongoing needs of an aging physical capital portfolio through the demands of evolving mission requirements, which bear upon the resilience and usefulness of many facilities. Facilities that are operating beyond their original design life are subject to deterioration that results in reliability problems and greater expense in terms of maintenance and energy use.

Over the last decade, JSC has made steady, measurable strides in slowing the growth of its deferred maintenance burden. This has been achieved through the primary application of available mechanisms: (1) disposal by demolition of obsolete facilities; (2) targeted maintenance and repair; and (3) replacement of obsolete facilities to meet the requirements of new and future missions and current processes and safety standards. An assertive, long-term focus on infrastructure revitalization has included disposal of excess facilities through established Federal process and strategic reutilization of underutilized Agency facilities through partnerships with Government, industry, and other entities. These efforts aid in offsetting the potential for growth in inventory of assets subject to disuse, degraded conditions and the accompanying cost to maintain them.

NASA has several Federal authorities available to JSC to support its real property and infrastructure management goals, including the goal of deferred maintenance reduction. This existing "toolkit" of authorities as sufficient and valuable, enabling agreements with public and private sector partners that positively enable reutilization of JSC facilities, leveraging them into more productive and maintained properties, maximizing asset utilization and efficiency.

JSC uses a risk-based approach to prioritize Mission Critical facilities and assets to reduce the likelihood of catastrophic failures. Mission Critical facilities comprise about 10 percent of the Center's buildings by count, and about 39 percent of the overall square footage. Mission Critical facilities receive 46 percent of the JSC scheduled maintenance funding and whatever funding is necessary to mitigate and repair unscheduled failures. As a result, JSC's remaining facility inventory may have some maintenance deferred. JSC often repairs systems that are well beyond their useful life instead of replacing them. Systems and equipment are kept in service longer, requiring frequent maintenance and repair and reduced reliability. In many cases, repairs may take longer to fix and become more expensive as equipment becomes more obsolete.

Question 3:

What, if anything, is needed to help prepare your center's workforce, contracts, contractors, and related infrastructure for a potential transition to a private low Earth Orbit (LEO) platform beyond 2024?

Answer 3:

JSC is a world leader in complex programmatic and systems integration. For example, for more than 20 years, JSC has managed the integration, assembly and operation of the ISS. The Space Station is a multi-national microgravity laboratory. JSC has also developed and implemented cutting-edge partnering strategies. The Commercial Orbital Transportation Services (COTS) program and the Cargo Resupply Services contract strategy enabled two companies to develop launch vehicles and spacecraft through public-private partnerships which now resupply critical cargo to the ISS. This initiative has shown the power and the challenges of this strategy which will be an important part of any future sustainable exploration plan. JSC is well positioned to contribute to the transition to the next phase of operations in low-Earth orbit (LEO), which will be led by U.S. industry. The specific demands on JSC workforce, contracts, contractors, and infrastructure will depend partially on the development and operations strategies pursued by the operators of commercial LEO platforms.

Question 3a:

How would your center be impacted by a gap in access to LEO should another platform not be operational at the time ISS operations are ended?

Answer 3a:

NASA will have significant requirements for access to LEO in the foreseeable future. These include continued microgravity research as well as Astronaut acclimation and training. It is essential that there not be a gap in access to LEO, which is why the Administration's policy is to maintain continuous access to LEO throughout the transition of NASA's funding for its LEO requirements.

Question 4:

What are the projected roles and responsibilities of your center in developing technologies that would directly reduce the risks of going to Mars? Have these roles and responsibilities been formally assigned yet?

Answer 4:

The Johnson Space Center stands ready to support the Human Exploration and Operations Mission Directorate (HEOMD) and work in partnership with the other NASA human spaceflight centers to enable humans going to Mars. JSC is also home to NASA's Astronaut Corps and is responsible for training space explorers from the United States and our Space Station partner

nations. JSC leads NASA's flight-related scientific and medical research efforts and strives to make revolutionary discoveries and advances to benefit not only our ability to live and work in space but all humankind. The Johnson Space Center also has unique expertise in Extravehicular Activity (EVA) suit development and operations. As stated previously, JSC is a world leader in complex programmatic and systems integration.

Center roles and responsibilities for a future mission to Mars have not yet been assigned.

Question 5:

How can Congress help your center keep human spaceflight programs and projects on track? What, if any, are the program management and oversight challenges unique to your center? Can additional policies and tools help NASA balance accountability and enforcement of contract provisions with the need to maintain a trusting, team-oriented relationship with its contractors and partners?

Answer 5:

NASA works to present a President's Budget request that supports the development and operations of human spaceflight programs and projects. As the economy expands to include LEO, NASA is working with established partners and new companies to create new strategies to more effectively provide the capabilities needed to support the United States' space requirements. These strategies will be essential to achieving national space exploration objectives. NASA has provided the knowledge gained from 60 years of spaceflight operations to many companies to assist them in their quest to become spaceflight service providers and enhance the United States' economic leadership in space.

Responses by Ms. Jody Singer

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future"

Ms. Jody Singer, Director, Marshall Space Flight Center, NASA

Questions submitted by Representative Mo Brooks, House Committee on Science, Space, and Technology

Question 1a:

I want to go into more detail about the specific and historic capabilities at the Marshall Space Flight Center as NASA moves forward in the planning stages of future missions.

Would you go into detail regarding how the specific expertise that is available at the Marshall Space Flight Center?

Answer 1a:

At Marshall Space Flight Center (MSFC), we have a storied history of expertise in developing and integrating large, complex human-rated systems on behalf of the Agency and our country. The institutional knowledge that MSFC has developed to support generational accomplishments, from Apollo, Skylab, Hubble Space Telescope, Spacelab, Space Shuttle, Chandra, and the International Space Station (ISS), is being focused on the current Space Launch System (SLS) Program leadership and moving towards Exploration Mission-1 (EM-1) and beyond. MSFC maintains primary and supporting roles in Human Exploration and Space Operations and Space Technology Missions, as well as select crosscutting technical capabilities.

Question 1b:

How do you see the skills at the Marshall Space Flight Center as it relates to the future planned missions across the board?

Answer 1b:

These historically grounded roles and capabilities highlighting MSFC skills represent future progress that promises to be equally diverse: Environmental Control and Life Support Systems (ECLSS), advanced manufacturing, launch vehicle development such as SLS, large, complex human-rated systems, in-space propulsion in the fields of chemical, cryogenic, and nuclear thermal, as well as space environmental effects. Finally, MSFC is working with commercial partners and other NASA field Centers on a number of robotic and human lander development programs. In addition to past skills and capabilities, it is vital that NASA workforce adapt as the skills and technologies needed for space exploration change.

Question 1c:

As NASA moves toward future space exploration, how to you see the workforce making the best contribution to the planned Lunar Orbital Platform-Gateway?

Answer 1c:

Marshall's workforce has a rich history of developing large, complex systems on behalf of our Nation's space program. It began with Apollo, then expanded to Skylab, Spacelab, Space Shuttle and the ISS. Our workforce created and built the Unity node and the U.S. Destiny Laboratory for ISS in the same Marshall facilities where the Saturn V was first manufactured. Marshall also designed and developed the Environmental Control and Life Support System (ECLSS), which provides water and oxygen for the ISS crew.

How the expertise of our workforce can support the Gateway architecture or other aspects of the National Space Exploration Campaign will develop over time.

Question 1c-i:

i. Can you go into detail regarding the expertise at the Marshall Space Flight Center may best be able to contribute to the factors imposed by this mission?

Answer 1c-i:

MSFC's existing primary and supporting roles are positioned to assist with the Gateway.

Marshall has the lead role for the development of technologies in the following areas: Systems Engineering and Integration, Environmental Control and Life Support Systems (ECLSS), cryogenic fluid flight systems, launch vehicle development, including the SLS Program, in-space propulsion, chemical propulsion (including nuclear thermal propulsion and in-space cryogenic fluid management for chemical and nuclear), advanced manufacturing, polymer matrix composite processing, and astrophysics research.

Marshall partners with other Centers on the development of technologies in the following areas: crewed destination systems (specifically, habitation and mobility), chemical propulsion flight integration, space environments testing, and vehicle structures and materials technology.

Question 1d:

As NASA moves toward future space exploration, how to you see the workforce making the best contribution to the planned Lunar Lander (also known as Moon Lander)?

Answer 1d:

NASA's workforce is a true asset for lander development with the skills to develop, test, and fly the lander architecture proposed in response to Space Policy Directive 1, which provides for a U.S.-led, integrated program with private sector partners for a human return to the Moon. NASA's Lunar Cargo Transportation and Landing by Soft Touchdown (CATALYST) effort has

established a functional model of NASA expertise working with industry partners in the development and testing of small landers. In the CATALYST program, each Center has provided expertise and worked alongside industry in the process of developing small commercial landers. NASA will begin working with industry partners to also develop large cargo and human landers in FY 2019.

It is anticipated that Center roles in the proposed Lunar Lander Program will be defined in the spring of 2019. In the meantime, a cross-Agency team is formulating a human lunar lander architecture that takes advantage of capabilities, such as the Gateway and expected commercial capabilities, to establish a sustainable, reusable lunar lander system. The reusability will come in stages as capability is established. NASA's workforce is performing the necessary analysis to determine feasible approaches.

Question 1d-i:

i. Can you go into detail regarding the expertise at the Marshall Space Flight Center may best be able to contribute to the factors imposed by this mission?

Answer 1d-i:

"Landing is a launch in reverse," requiring similar expertise from an overall vehicle controllability perspective. After landing on the lunar surface, human-rated missions must then "launch" crew for the return to the Gateway. MSFC has the programmatic and technical capability to contribute to the development of launch and landing vehicles.

Marshall has led an integrated Mighty Eagle multi-Center team, where these ground demonstrations trace to subsystems used in CATALYST landers today. Marshall has a strong history of leading, managing, integrating, and operating overall complex systems, as well as leading, managing, and performing detailed design of subsystems. The systems and skill sets include multi-element systems and subsystems, including large complex structures; propulsion; guidance, navigation, and control; sensors; cryogenic fluid management; thermal analysis; and overall vehicle integration. Integration of these subsystems are exercised as part of the SLS development and will transition to the human lander systems development.

As the lead for the Lunar CATALYST program and through our work on engineering design and development for Resource Prospector, Marshall has integrated multi-Center, multi-discipline teams while developing partnerships across the emerging lander industry. MSFC has led technology maturation on small and large propulsion systems to support future NASA and industry needs, ranging from an advanced storable bi-propellant engine with Department of Defense heritage to an advanced liquid oxygen/liquid methane lunar lander engine. Marshall has performed a dual role, in the best interest of NASA and in support of the commercialization of space, by being a smart partner with the U.S. commercial sector. These roles strongly overlap as we foster commercial capabilities for the U.S. economy, as well as the goals of NASA.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future"

Ms. Jody Singer, Director, Marshall Space Flight Center, NASA

Questions submitted by Ranking Member Eddie Bernice Johnson, House Committee on Science, Space, and Technology

Question 1:

What negative impacts have your center and the surrounding communities experienced during past human spaceflight program transitions, both scheduled and unscheduled? How, if at all, has the environment changed in and around your center and do those changes make your center and surrounding communities less vulnerable or more vulnerable to unscheduled program transitions?

Answer 1:

During the previous transition in 2010 with the Constellation cancellation and Space Shuttle closeout, MSFC experienced a significant reduction in contractor staffing levels as contracts were closed out. The Center issued notifications to 21 companies who in turn eliminated contract employees. Civil service staff levels were not affected.

Predicting changes to the environment for MSFC and surrounding communities during future transitions would likely prove difficult. This is due to the high degree of uncertainty during such times and the unknown timeframe for requirements to support any potentially realigned programs and sustain minimum technical capability. NASA has since developed primary and supporting Center roles across the Agency. Those assignments as currently positioned would likely decrease vulnerability in terms of maintaining a minimum level of technical capabilities across designated primary and support areas of expertise. Ultimately, the success of long-term spaceflight projects is dependent on holding ourselves accountable for performance, and maintaining the kind of constancy of focus and purpose provided by Space Policy Directive 1, proposed in the President's budget requests, elaborated upon in the recently-released National Exploration Campaign report, and supported by the Congress.

Question 2:

What are the challenges associated with managing the deferral of maintenance at your facilities and infrastructure and how does that impact your center's ability to support new human spaceflight initiatives? Are new authorities needed to enable needed modernization of facilities and infrastructure?

Answer 2:

MSFC is challenged with managing the ongoing needs of an aging physical capital portfolio through the demands of evolving mission requirements, which bear upon the resilience and usefulness of many facilities. Facilities that are operating beyond their original design life are subject to deterioration that results in reliability problems and greater expense in terms of maintenance and energy use.

Over the last decade, MSFC has made steady, measurable strides in slowing the growth of its deferred maintenance burden. This has been achieved through the primary application of available mechanisms: (1) disposal by demolition of obsolete facilities; (2) targeted maintenance and repair; and (3) replacement of obsolete facilities to meet the requirements of new and future missions and current processes and safety standards. An assertive, long-term focus on infrastructure revitalization has included disposal of excess facilities through established Federal process and strategic reutilization of underutilized Agency facilities through partnerships with Government, industry, and other entities. These efforts aid in offsetting the potential for growth in inventory of assets subject to disuse, degraded conditions and the accompanying cost to maintain them.

NASA has several Federal authorities available to MSFC to support its real property and infrastructure management goals, including the goal of deferred maintenance reduction. This existing "toolkit" of authorities as sufficient and valuable, enabling agreements with public and private sector partners that positively enable reutilization of MSFC facilities, leveraging them into more productive and maintained properties, maximizing asset utilization and efficiency.

At MSFC, one of the targeted maintenance and repairs tools that NASA uses is the Mission Dependency Index (MDI). MDI is a prioritization approach for unique facilities. It enables MSFC to focus infrastructure resources on mission critical facilities. This becomes part of a multi-tiered approach to identify and prioritize projects. MDI, coupled with a facility condition assessment of the MSFC prioritized list of critical projects, ensures infrastructure and systems are operational in support of the NASA mission.

A specific example of challenges associated with managing the deferral of maintenance at MSFC involves pressure systems. These allow for the movement of commodities needed to conduct mission operations; they range from compressed air for power tools to nitrogen for purging lines, from oxygen to propellants such as hydrogen. Many systems date to the Saturn era, but what was cutting-edge technology in the 1960s is difficult to bring within current safety standards as systems reach the end of their design life. MSFC considers the mission, condition, and safety risks while utilizing innovative inspection techniques to determine safety and replacement. The long-term renovation plan for pressure system components led to a reduced risk to personnel and property.

Question 3:

What, if anything, is needed to help prepare your center's workforce, contracts, contractors, and related infrastructure for a potential transition to a private low Earth Orbit (LEO) platform beyond 2024?

Answer 3:

Marshall Space Flight Center has already taken steps to prepare our workforce for the transition to commercialization of International Space Station (ISS) payload operations in low-Earth orbit (LEO) by consolidating two payload operations contracts. Currently, the Huntsville Operations Support Center (HOSC) contract provides system development and operations and maintenance services to ISS program requirements and the Mission Operations and Integration (MO&I) contract provides support and products for the development and execution of spaceflight operations performed by the Payload and Mission Operations Division.

The new solicitation *Marshall Operations Systems, Services and Integration (MOSSI) Acquisition* bundles the HOSC and MO&I requirements into one contract vehicle. The selected contractor will provide operations support for all mission phases—for payload operations in support of the ISS Program and as required for new or evolving NASA programs including Space Launch System (SLS) and other satellite projects.

Question 3a:

How would your center be impacted by a gap in access to LEO should another platform not be operational at the time ISS operations are ended?

Answer 3a:

The Administration's policy is to maintain continuous access to LEO. Marshall anticipates that commercial enterprises will play a larger role in directing activities in LEO when direct Government funding of ISS operations ends. Whether it is the ISS or another platform within LEO, there will still be a need for operations support. Marshall is positioned to maintain its institutional knowledge in payload operations, planning, and utilization support going forward. While the size of the workforce may not need to be up to current staffing, there will still be the need to provide support for continued technology demonstrations, science research and discoveries. This includes development of an advanced Environmental Control and Life Support System (ECLSS), materials research science, physical sciences, life sciences, and human research.

Question 4:

What are the projected roles and responsibilities of your center in developing technologies that would directly reduce the risks of going to Mars? Have these roles and responsibilities been formally assigned yet?

Answer 4:

Yes. MSFC existing primary and supporting roles as currently assigned are positioned to assist with many of the technological considerations and corresponding risk reductions for deep space exploration.

Marshall has the lead role for the development of technologies that will directly reduce the risk for human exploration missions to Mars in the following areas: Systems Engineering and

Integration, Environmental Control and Life Support Systems (ECLSS), cryogenic fluid flight systems, launch vehicle development, including the Space Launch System Program, in-space propulsion, chemical propulsion (including nuclear thermal propulsion and in-space cryogenic fluid management for chemical and nuclear), advanced manufacturing, polymer matrix composite processing, and astrophysics research.

Marshall partners with other Centers on the development of technologies that will directly reduce the risk for manned exploration missions to Mars in the following areas: crewed destination systems (specifically, habitation and mobility), chemical propulsion flight integration, space environments testing, and vehicle structures and materials technology.

Question 5:

How can Congress help your center keep human spaceflight programs and projects on track? What, if any, are the program management and oversight challenges unique to your center? Can additional policies and tools help NASA balance accountability and enforcement of contract provisions with the need to maintain a trusting, team-oriented relationship with its contractors and partners?

Answer 5:

Space Policy Directive 1 provides the latest roadmap to keep MSFC human spaceflight programs and projects on track. MSFC exploration enables human expansion across the solar system with missions beyond LEO, as we return to the Moon to study the next steps in long-term exploration and utilization, followed by human missions to Mars and other destinations. Funding proposed in the President's Budget helps NASA to inspire the Nation, support an economic base, and encourage the next generation Americans that want to work for NASA and MSFC.

Responses by Mr. Robert Cabana

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future"

Mr. Robert Cabana, Director, John F. Kennedy Space Center, NASA

Questions submitted by Representative Bill Posey,
House Committee on Science, Space, and Technology

Question 1a:

Under your tenure leading Kennedy Space Center, you have overseen numerous changes and met many challenges. You and I both know that Florida is the preferred go-to destination to launch into space. Just as filmmakers around the world aspire to make movies in Hollywood, everyone knows that America's Space Coast is the premier location to launch.

Can you describe how KSC has adapted to accommodate more space entrants, and offer a snapshot on the exciting developments planned at KSC for the near future in line with the *National Space Exploration Campaign Strategy*?

Answer 1a:

Kennedy Space Center (KSC) has evolved into the world's most active and diverse multi-user spaceport, with five commercial companies and two federal Government agencies actively engaged in providing Government and commercial launch services. In addition to launch vehicle and payload processing services and other components of the space-launch value chain, there are over a dozen commercial space companies and three federal entities concurrently operating at KSC. Over the last eight years, KSC has made significant investments to accommodate more space entrants and support KSC as a multi-user spaceport. These upgrades helped modernize and enhance the launch and range assets and infrastructure at KSC and Cape Canaveral Air Force Station to enable future exploration of the solar system.

By establishing KSC as a multi-user spaceport, the Center is fulfilling the sense of Congress and the National Space Policy to ensure America's future in space by enabling both Government and commercial access to space. KSC is achieving this goal by identifying creative means for making underutilized NASA facilities and infrastructure available to commercial and other Government entities, while transforming our safety and operational concepts to support a multi-use paradigm. KSC has also organized itself to provide a focus on attracting new partners and also operating the spaceport to manage, integrate, and provide services to those partners. Moving forward, NASA anticipates continued growth of space operations from KSC, as the Commercial Crew and Space Launch System (SLS) programs bring the launch of astronauts back to American soil. Additionally, we anticipate the launch rates of our commercial partners to continue increasing, driving a greater need for integrated operations and coordination across the spaceport. KSC looks forward to continuing to enable new commercial and international partners to work effectively as part of our multi-user spaceport, as we all work to achieve the goals of the National Space Exploration Campaign strategy, including the Commercialization of

Low Earth Orbit (LEO) and Moon to Mars using the American-built Orion spacecraft and SLS as well as commercial rockets.

Question 1b:

Could you reiterate how sufficient funding for ground systems is critical to American leadership in space exploration?

Answer 1b:

Funding levels requested in the President's Budget for the Exploration Ground System (EGS) program are critical in enabling integration, processing, and launch of the SLS and Orion spacecraft. EGS is developing the necessary ground systems while refurbishing and upgrading infrastructure and facilities required for assembly, test, and launch of SLS and Orion, along with the landing and recovery activities of Orion. This includes Pad 39B, the Vehicle Assembly Building (VAB), the crawlerway, the Mobile Launcher and other facilities to support exploration missions. The modernization effort maintains flexibility on Pad 39B and in the VAB in order to accommodate other potential users if they were to be identified. Additionally, a second Mobile Launcher is being planned and the VAB and the Launch Pad will undergo modifications to accommodate the eventual use of an upgraded SLS Block 1B. Upon completion, the KSC launch site will be able to provide a more flexible, affordable, and responsive national launch capability, which is critical to American leadership in space exploration.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"60 Years of NASA Leadership in Human Space Exploration: Past, Present, and Future"

Mr. Robert Cabana, Director, John F. Kennedy Space Center, NASA

Questions submitted by Ranking Member Eddie Bernice Johnson, House Committee on Science, Space, and Technology

Question 1:

What negative impacts have your center and the surrounding communities experienced during past human spaceflight program transitions, both scheduled and unscheduled? How, if at all, has the environment changed in and around your center and do those changes make your center and surrounding communities less vulnerable or more vulnerable to unscheduled program transitions?

Answer 1:

During the Space Shuttle retirement and transition period from FY 2010 to FY 2015, KSC experienced impacts to staffing, capabilities, personal property and facilities that were typical of any major program termination. As contracts were closed out, associated on-site contractor staffing decreased, roughly 46 percent from approximately 14,100 to 7,600. Civil service workforce was unaffected. All technical capabilities were assessed and reduced by 30 percent to reflect revised requirements. Over 150,000 line items of personal property were processed for transfer or excess. Facilities that were no longer needed (approximately 25% of active facilities) were inactivated to minimize costs while awaiting determination of the final disposition. While these transitions can of course be very challenging for an organization and its workforce, they also present important opportunity to reassess priorities and direct efforts toward the capabilities that will support the most vibrant future for space exploration.

In recent years, KSC has experienced a resurgence in activity tempo, primarily due to the advancement of commercial space partnering and the Exploration Ground Systems (EGS) development in support of the Space Launch System (SLS) and Orion Programs. Additionally, the surrounding area has seen robust growth with more active and diverse set of companies and workforce. The civil service workforce required to oversee and manage both traditional and commercial launch services contracts also has different skill set needs than were required to operate a Government-owned vehicle like the Space Shuttle. The Center has implemented a program of retraining and critical hiring to rebuild an appropriately skilled workforce. Ultimately, the success of complex spaceflight programs is dependent on maintaining the kind of constancy of focus and purpose provided by Space Policy Directive 1, elaborated upon in the recently-released National Exploration Campaign report, and supported by the Congress.

Question 2:

What are the challenges associated with managing the deferral of maintenance at your facilities and infrastructure and how does that impact your center's ability to support new human spaceflight initiatives? Are new authorities needed to enable needed modernization of facilities and infrastructure?

Answer 2:

KSC is challenged with managing the ongoing needs of an aging physical capital portfolio through the demands of evolving mission requirements, which bear upon the resilience and usefulness of many facilities. Facilities that are operating beyond their original design life are subject to deterioration that results in reliability problems and greater expense in terms of maintenance and energy use.

Over the last decade, KSC has made steady, measurable strides in slowing the growth of its deferred maintenance burden. This has been achieved through the primary application of available mechanisms: (1) disposal by demolition of obsolete facilities; (2) targeted maintenance and repair; and (3) replacement of obsolete facilities to meet the requirements of new and future missions and current processes and safety standards. An assertive, long-term focus on infrastructure revitalization has included disposal of excess facilities through established Federal process and strategic reutilization of underutilized Agency facilities through partnerships with Government, industry, and other entities. These efforts aid in offsetting the potential for growth in inventory of assets subject to disuse, degraded conditions and the accompanying cost to maintain them.

NASA has several Federal authorities available to KSC to support its real property and infrastructure management goals, including the goal of deferred maintenance reduction. This existing "toolkit" of authorities as sufficient and valuable, enabling agreements with public and private sector partners that positively enable reutilization of KSC facilities, leveraging them into more productive and maintained properties, maximizing asset utilization and efficiency.

KSC is the largest NASA center by land area, and has the largest share of the agency's facilities by number, square footage and Current Replacement Value (CRV). KSC is also carrying approximately $475M in deferred maintenance. This figure represents approximately 18 percent of the agency's total deferred maintenance, and is the second largest in the agency. Examples of infrastructure requiring maintenance or modernization include: utility plants and associated distribution systems that supply power, chilled water, high temperature hot water, and compressed gases to spaceport customers. Other challenges revolve around improving utility systems to support the growing needs of our vital NASA Programs and commercial spaceport customers (e.g., SpaceX, Blue Origin, Boeing, Lockheed-Martin, and Northrop-Grumman). NASA's EUL authority allows NASA to leverage NASA's underutilized infrastructure to help manage deferred maintenance while supporting the growing demands of commercial spaceport customers. Net proceeds from EULs can be used to repair, sustain and upgrade the infrastructure that facilitates NASA's and commercial launch activities.

Question 3:

What, if anything, is needed to help prepare your center's workforce, contracts, contractors, and related infrastructure for a potential transition to a private low Earth Orbit (LEO) platform beyond 2024?

Answer 3:

In 2010, KSC made the transition to a multi-user spaceport, one fully capable of supporting a multitude of Government and commercial users needing a variety of launch site services, including payload processing, spacecraft assembly and launch operations. The KSC culture has evolved and adapted to working closely with a variety of commercial space partners, including SpaceX, Blue Origin, Boeing, Lockheed-Martin, Northrop-Grumman, and others working hand-in-hand with KSC civil servants and contractors. Through the use of Federal Acquisition Regulation (FAR) contracts, Space Act Agreements (SAAs), Commercial Space Launch Act (CSLA) and other contracting mechanisms and agreements, KSC is capable of supporting commercial endeavors like private low-Earth orbit (LEO) platforms.

Additionally, KSC has undergone a vast facilities transformation to support commercial users, as well as NASA's EGS program. With the high interest in KSC's user-friendly environment, access to transportation, and geographical location, KSC is experiencing a high volume of users. The development of new capabilities, including new processing areas, and additional launch sites and contractual provisions allowing the Government to include commercial partners' needs in the requirements determinations for its planned contracting actions would be needed to expand KSC's role in a new LEO platform.

Question 3a:

How would your center be impacted by a gap in access to LEO should another platform not be operational at the time ISS operations are ended?

Answer 3a:

KSC plays a key role Plant Life Sciences research. The environment provided by the International Space Station (ISS) allows the baseline science of how biological systems respond to sustained exposure to microgravity. A microgravity platform where science research in LEO is conducted will be critical in planning long-duration human missions. If the Nation doesn't have access to a LEO platform, this could result in lost technology and development opportunities. The science community has been engaged and the necessary equipment is in place on ISS to conduct the necessary investigations, which will take several more years to complete. A gap in access to LEO could extend the schedule of all exploration initiatives, postpone the use of microgravity science discoveries on Earth with its associated economic and societal benefits, and will cause a loss/atrophy of the critical skills and unique capabilities and equipment that support LEO access.

With the significant expansion of commercial LEO services, it is important to define what the Government's role will be to enable success. The only way to maintain world-class proficiency

and stability of the NASA workforce is with continuous access to LEO. Access to LEO science platforms is important for NASA to help enable commercial business cases in LEO and beyond.

Question 4:

What are the projected roles and responsibilities of your center in developing technologies that would directly reduce the risks of going to Mars? Have these roles and responsibilities been formally assigned yet?

Answer 4:

The projected roles and responsibilities of KSC in developing technologies that would directly reduce the risks of going to Mars involve the development of In-situ Resource Utilization technologies, including generation of propellants and breathing air from the Martian atmosphere; generation of propellants and breathing air from Lunar and Martian water ice; construction of landing pads and other infrastructure from Lunar and Martian regolith; development of state-of-the-art real-time adaptive radiation detection devices to protect Astronauts; the development of technologies to insulate cryogenic propellants in space and surfaces of the Moon and Mars.

Other technologies include development of state-of-the-art ground processing and launch infrastructure technologies. KSC also has significant expertise in Ground Systems which is necessary for future surface missions to the Moon and Mars. KSC envisions its commercial acquisition expertise role being able to serve multiple science and exploration platforms, not just the Gateway, as NASA continues to evolve sustainable science and operations in deep space.

Question 5:

How can Congress help your center keep human spaceflight programs and projects on track? What, if any, are the program management and oversight challenges unique to your center? Can additional policies and tools help NASA balance accountability and enforcement of contract provisions with the need to maintain a trusting, team-oriented relationship with its contractors and partners?

Answer 5:

The President's Management Agenda lays out a long-term vision for modernizing the Federal Government in key areas that will improve the ability of agencies to deliver mission outcomes, provide excellent service, and effectively steward taxpayer dollars on behalf of the American people. To drive these management priorities, the Administration leverages Cross-Agency Priority (CAP) Goals to coordinate and publicly track implementation across Federal agencies. For information on NASA's performance plan and most recent performance updates across five Agency Priority Goals, please access the link below:

https://www.performance.gov/NASA/NASA.html

NASA appreciates Congressional support for its efforts to achieve these CAP goals.

Appendix II

Additional Material for the Record

DOCUMENT SUBMITTED BY NASA

Material requested for the record on page 43, line 886, by Chairman Babin during the September 26, 2018 hearing at which Mr. Gerstenmaier, Mr. Geyer, Ms. Singer, and Mr. Cabana testified.

Please see table below.

	International Space Station	
Workforce	Civil Servant	Contractor
Armstrong Flight Research Center	0	1
Ames Research Center	33	36
Glenn Research Center	57	122
Goddard Space Flight Center	4	35
NASA Headquarters	7*	0
Jet Propulsion Laboratory	0	0
Johnson Space Center	962	3,840
Kennedy Space Center	88	210
Langley Research Center	1	0
Marshall Space Flight Center	202	576
Stennis Space Center	0	3
Total	1,348	4,822

* NOTE: The ISS Division at NASA HQ consists of seven civil servants which are not included in the numbers above. They are considered part of Agency Management and Operations and are funded out of the Security & Mission Services (SSMS) account.

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