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PRIORITIES, PLANS, AND PROGRESS OF THE NATION'S SPACE PROGRAM

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED TWELFTH CONGRESS

SECOND SESSION

MARCH 7, 2012

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED TWELFTH CONGRESS

SECOND SESSION

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PRIORITIES, PLANS, AND PROGRESS OF THE NATION'S SPACE PROGRAM

WEDNESDAY, MARCH 7, 2012

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, D.C.

The Committee met, pursuant to notice, at 10:04 a.m., in Room SR–253, Russell Senate Office Building, Hon. Bill Nelson presiding.

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

Senator NELSON. Good morning.

Mr. Administrator, Senator Hutchison and I just solved your problems.

[Laughter.]

Senator HUTCHISON. We look forward to working with you on it.

Senator NELSON. We are delighted that you are here.

Thank you, General Bolden, for your service to this country. A long and distinguished career in the United States Marine Corps, the Astronaut Office, and now as the Administrator of NASA, we are most appreciative of your personal service and your commitment to this country and your continuing service.

This past year has been a real busy one for NASA. What a monumental achievement it was to complete the construction of the Space Station, and now that crew members don't have to focus on assembly of the ISS, they are getting on with the important research up there. Remember, this was one of the things that John Glenn kept pounding over and over, as a Senator—it is hard to believe it has been 14 years since his retirement. But he is still at it, as you know.

And we just had the 50th anniversary of his Mercury flight celebration, and John was at it again, saying the same thing—research, research. Utilize that facility up there that we have. And we have six people up there right now.

And better cancer treatment delivery systems are being developed. We have had breakthroughs in vaccine research, and I never want to miss the opportunity to point out that we have a National Laboratory on the Space Station thanks to Senator Hutchison and that in this lab they have now developed the processes and the drugs, basically, that are now in their final FDA trials as a vaccine for salmonella and another drug that is in its initial FDA trials that is a vaccination for MRSA, which is the explosive bacteria that ravages so many hospitals that they find it very difficult to find drugs that can control it.

And so, in this space program, we have discovered techniques for performing remote ultrasounds. And recently, we have taken another great step forward, and this was something again that I give great credit to Senator Hutchison. The Alpha Magnetic Spectrometer was delivered and is measuring cosmic rays, seeking answers to some of the universe's best-kept secrets, such as the nature of dark matter.

And so, now that the station is complete, NASA then retired the Space Shuttle. And remember, why did it retire it? Because if you remember, when we lost *Columbia* in 2003, Admiral Gehman's commission that did the investigation said you fly the Space Shuttle just as long as you have to to build the Space Station because of taking up the components that have been developed to fit in the cargo bay. And once it is completed, you replace the Space Shuttle with a safer rocket.

And if you look at the designs of the commercial competition that is going on, you find that the crew is on the top of the rocket with the escape system so that if you have an explosion on the pad, you can save the crew. You can save the crew all the way to orbit by detaching the capsule and bringing the crew safely back.

NASA's very dedicated and talented workforce operated the Space Shuttles for 30 years, and it helped us open a whole new chapter in our space exploration and a window into the cosmos. We did that by launching and servicing and repairing and fixing over and over again the Space Telescope, Hubble, and protecting our way of life by deploying national security satellites and advancing our knowledge of the solar system by launching interplanetary probes.

You have heard a lot about the very moving stories of the efforts to have the final Space Shuttle mission to perfection, absolute perfection while most of that workforce knew that they were going to be laid off. Well, that is the kind of dedicated and proud workforce that America needs to continue to have in our next generation of exploration systems.

Now we know we have the SLS and the Orion programs going ahead. One of the things we are going to discuss, General, is that we don't think you have enough in your budget for Orion. You have got to be able to have an Orion, a capsule that is completed, to put on top of a rocket, the SLS.

Late this spring, major components for Orion's upcoming test flight are going to arrive at the Cape, and workers will finish assembling and testing the capsule for a 2014 launch. In 2 years, we are going to launch Orion, and it is going to go through tests that will go out into an elliptical orbit so that it can come back in a ballistic reentry and test all of those reentry systems.

The SLS program is continuing the engine testing now at the Stennis Space Center and is preparing detailed design specifications for the most powerful rocket in history. Work continues at the Kennedy Space Center as well, overhauling an historic launch pad for NASA's next steps into the solar system that was used to launch Apollo and the Shuttle programs.

And by the way, the Director of the Kennedy Space Center told me that he has something in between now and October the 1st in this fiscal year, close to $400 million of modernization of that space

center just in this period of time—that is about 8 months, 7 months—in order to get the space center ready for the new systems.

Meanwhile, NASA continues to crank out the science missions with almost 100 spacecraft either in operation or under development. And last year, we saw MESSENGER enter orbit around Mercury. It was first mission to the planet in nearly 40 years. And much, much farther away from the Sun, 11 billion miles, the Voyager, Voyager 1 spacecraft, is probing the outer reaches of our solar system.

And looking out into the galaxy, the Kepler planet-hunting telescope has discovered over 2,000 potential planets, and over 60 of them have been confirmed. We have even found a planet in the so-called habitable zone, a habitable zone of its star. And we are looking forward now, as we reach out into the cosmos, of confirming many more planets in the coming months.

And this past November, NASA launched the largest and most capable rover ever in route to an August landing of Mars. This thing is amazing. It is the size of a Volkswagen. It is going to have two eyes that pop up, and as it roves, we are going to see it real time with the delay of the transmission from as far away as Mars.

It has got a scooper that is going to go down and scoop up the Martian soil and then analyze it. It has a beam that is going to zap rocks so that we can analyze the chemical components.

NASA also continues its mission to keep watch over our home planet, seeking to understand the complicated interactions of the Earth's dynamic systems. And of course, the first "A" in NASA—is aeronautics. Aeronautics research continues as NASA continues to look for new ways to improve aviation safety and revolutionize air transportation.

Hallelujah, we finally passed the FAA bill. We can start getting moving to the next generation of air traffic control. All of that is going to come off of the satellites. Where did the satellites come from? They came from our space program.

And NASA continues to reach out to students in all 50 States, inspiring and educating our next generation in ways that only this space agency can. So today we are here to see if we can continue the progress of the past year through this next year and beyond.

The President has sent us a 2013 budget that is essentially flat with the previous year's enacted level, which, for NASA, is relatively good, given that most of the Government agencies got whacked. And so, Senator Hutchison and I are pleased to have the NASA Administrator here to talk about the President's proposal. And I am looking forward to this productive conversation.

Now we will get into the fact of the recent stories about some of the agency's sensitive data, including some of the algorithms for the International Space Station, that they were compromised and some NASA mobile devices were stolen. There has been no effect upon the Space Station, and I want the Administrator to address that.

There are also reports that foreign intelligence organizations were thought to be involved in the hackings of additional NASA computer systems, which is not unusual, by the way, because foreign intelligence operations, as well as rogue operators all over the

globe, are trying to hack into every computer system of the United States Government. And it goes on in massive numbers every day.

Space travel is an international endeavor. And having this type of information out of our control certainly could compromise NASA's status as a place where we can secure our data.

The President's request is about $2 billion under the amount this committee authorized for the agency, leaving us with some tough choices on how to preserve the balanced approach for NASA. But safety and security of information can't be on the chopping block, and we will address that.

So, looking beyond the President's address, we are very pleased to have astrophysicist Neil Tyson here for our second panel to talk about the broader context of NASA and what space exploration means to the country. Dr. Tyson has made a career out of discussing the very complex issues associated with space science and exploration in a way that educates and captivates and excites the public.

And Dr. Tyson is no stranger to the subject of our space program, having been appointed twice to presidential panels examining the future of NASA and the aerospace industry.

So I am really looking forward to the testimony of both of you all, and I turn to my partner, and I say my partner because we wouldn't have a NASA authorization bill back in the fall of 2010 had it not been for this lady right here. And we wouldn't have had the funding over the past funding cycles that has kept NASA at a much better level than a lot of other agencies than if it were not for Senator Kay Bailey Hutchison.

STATEMENT OF HON. KAY BAILEY HUTCHISON,
U.S. SENATOR FROM TEXAS

Senator HUTCHISON. Well, thank you, Mr. Chairman.

And I want to say that you are certainly downplaying your role in NASA, and the commitment that you have has been absolutely fabulous and important for our ability to pass an authorization bill, which a lot of people didn't think we could, and then further to help get the appropriations that would keep NASA in a place where it can really do the job that we are asking it to do and which we basically agreed to do. So we are here to try to keep that momentum going in the right direction.

I was out at Johnson. The Johnson Space Center has a wonderful program for Cub Scouts. It is not in NASA, but it is in the Visitors Center. And Cub Scouts come from all over Texas, and they have an overnight in the Visitors Center. And I was with a group of those Cub Scouts recently, and the question they asked me was why has America given up on space flight?

Now that was in the last week. And of course, I said we are not giving up on space flight. It is very important to move forward. But our Shuttles were wearing out. So we are now rebuilding to go beyond where we have been before.

But that is not out there in the public, and we need to do the things that assure our young people, who are the ones we want to entice into science and loving exploration and knowing what it has done for our country, to stay with us and to understand this importance.

So that brings me to the agreement that we finally got last year with this administration. And I want to say what we have agreed to. We have agreed to develop the heavy launch vehicle to carry the Orion crew exploration vehicle to destinations beyond low-Earth orbit.

We have agreed to bring to fruition the beginning of operational commercial cargo delivery flights to the International Space Station.

We have agreed to support the development of commercial capabilities to launch crew to and from low-Earth orbit, focusing initially on transporting crews for the International Space Station.

And we have agreed to support the ongoing development of the James Webb Space Telescope to not only replace the amazing Hubble Space Telescope, but also to see even more detail further into the universe.

So we agreed to all those things. But Mr. Administrator, the actions don't seem to be following the words of the agreements, and that is why I am glad that we are having this hearing and hoping that we can all have not only the words, but the actions that will take us in the direction that we have agreed we should go.

It took awhile to finally get the program offices open for Orion and the Space Launch System. And finally—late last year—we were able to come to an agreement that we would move forward on that.

The Fiscal Year 2013 budget request was our opportunity to review the actions of the administration toward providing the funding needed to meet our agreed-to activities. But reviewing that budget and the call that you made to me gives me great concern, and I have to question the degree of the commitment that we made, all of us together, to go forward for all of the things that we said were our priorities.

So now we all understand that we have fiscal challenges. But I believe within the budget that we have, which, as the chairman has said, is basically pretty flat considering the rest of our budgets, knowing that exploration is not something that can be totally prescribed and adhered to because things happen when you are breaking barriers and you are doing new things that you have to address.

But I think we have the available funds. It is a matter of how we put those funds into the actual implementation, and I have questions about the amount requested and the procurement approach that is taking place for the Commercial Crew development. I remain concerned about the loss of critical workforce and skills that we must have to continue NASA's advances forward into the future.

I want to hear what you have to say and hope we can get back on the same page where the budget meets the agreed-to goals. I am very pleased that Dr. Tyson is here because he is a scientist, and of course, that is a very crucial part of the big picture that we need to develop.

Dr. Sam Ting, who really started the whole focus on the spectrometer and who, for a Nobel Laureate, is a fighter at heart, I have to say, because he was told by a previous Administrator that there wouldn't be the ability to take the spectrometer up and that

the payload would not be able to be done. But he fought. We fought with him. We supported Dr. Ting's request because we knew that that was a future that was vital for the Space Station.

Dr. Ting made a speech to a scientific group in Texas in January, and the most graphic thing that he showed through a chart was some of the most visionary research that we have embarked on in America in the physics field. (His Nobel Laureate designation was for physics).

And he showed the things that we thought would come, the goals that we had for these visionary research projects. And he put down about six or seven. And then he put the results that we got, which were totally different from the goal and more important and better.

And that is what he foresees for the cosmic rays that we are now getting hits on in the spectrometer. Because we have already had more hits of cosmic rays on that spectrometer than ever in the history of space exploration, and he believes that the goal is to find out what the dark matter is and how can we harness it for energy that may be used for a Mars settlement or may be something that we could use on Earth, but you can only do it in space.

So he said here is our goal, but who knows what it will give us? Who knew when we went into space in the first place that we would capture satellites and use space for national security purposes? Who knew that we would find many uses for Velcro? Who knew that we would get MRIs and the huge medical breakthroughs that we have had?

So I am committed in my last year to assure that we go in the right direction, utilizing our resources wisely, and that is why I changed appropriations committees because I so believe in NASA and its potential for our country. And I wanted to make sure that while I am here that we don't fudge on human space exploration and we don't cut NASA to the quick because that is where our corporate knowledge is.

And I say "corporate" in the Government sector, but that is where our expertise and our past experiences are that will take us to the future in the most efficient way.

So I hope that we can work together to address the concerns that I have and get us on track. I am committed to commercial being a part of our future, but not at the expense of our vital NASA employee sector and the building of the next vehicle that is going to take us beyond where we are. We can't fudge on the future in that way.

So I think you know how I feel, and I hope that we will be able to work together. I don't doubt your sincerity in shared goals, but what I am very concerned about is the implementation that is reflected in the numbers of the budget that the President and the administration released just a couple of weeks ago and its relationship to our shared goal.

Thank you, Mr. Chairman.

[The prepared statement of Senator Hutchison follows:]

PREPARED STATEMENT OF HON. KAY BAILEY HUTCHISON,
U.S. SENATOR FROM TEXAS

Thank you, Mr. Chairman, for convening this important hearing on NASA's proposed budget for Fiscal Year 2013. This year marks the first year that the Com-

mittee, NASA, and this Administration are in formal agreement on the objectives and approach to future development of U.S. human spaceflight capabilities.

We have agreed to develop the heavy-lift launch vehicle to carry the Orion crew exploration vehicle to destinations beyond low-Earth orbit.

We have agreed to bring to fruition this year the beginning of operational commercial cargo delivery flights to the International Space Station.

We have agreed to support the development of commercial capabilities to launch crew to and from low-Earth orbit, focused initially on transporting crews for the International Space Station.

Finally, we have agreed that it is important to support the ongoing development of the James Webb Space Telescope, to not only replace the amazing Hubble Space Telescope, but to help us see even more detail—and further—into the universe.

We have all spoken the right words about those agreements in recent months, and that is important, because it reflects the fact that NASA does have a plan for its future. NASA is not "adrift" as some have been saying for the last 3 years—since the 2010 Budget Request put an asterisk next to the proposed funding for exploration programs, and set up the Augustine Committee to review options for the future. However, actions, as always, speaker louder than words. The Congress took action in late 2010 by passing the NASA Authorization Act, whose authorization levels are still in force for Fiscal Year 2013.

NASA has taken action in establishing the program offices for Orion and the Space Launch System, and beginning the detailed work necessary to bring those vehicles into production and operations. The Fiscal Year 2013 Budget Request represents our opportunity to review the actions the Administration has taken with respect to providing NASA the funding needed to meet all of the agreed-upon activities.

Unfortunately, as we have reviewed the proposed Budget these past several weeks, I have concerns about the degree of commitment of the Administration to meeting our shared objectives. We all recognize that this Nation has enormous fiscal challenges and that any allocation of taxpayers' dollars must be given very careful consideration and very close scrutiny. That consideration requires each of us to establish clear priorities for funding, and to identify the most efficient ways to use the funds eventually appropriated.

Despite the very real fiscal challenges we face, the United States is still capable of supporting a space program that is, as the Augustine Report suggested, "worthy of a great nation." It is as much a matter of priorities as it is one of available funds—especially if we take into account the return on the investment we make in space as a nation.

I am concerned about the funding levels for the vehicle development portion of the Space Launch System and the Orion crew vehicle. I have questions about both the amount requested and the procurement approach being taken for the next phase of commercial crew development. I remain concerned about the loss of critical workforce and skills that we will need to continue NASA's—and the nation's—advances forward into the future. I look forward to having the Administrator address these and other issues as we proceed with this hearing.

I also look forward to hearing from Dr. Neil deGrasse Tyson, our second witness today. From what I have heard and read, I am hopeful we will hear his "Big Picture" view of the Nation's space program, and especially of its direct and indirect benefit to our Nation's scientific, economic, and technological well-being. Aside from focusing on his own discipline of astrophysics, Dr. Tyson's messages have typically been directed toward students and lay people—the general American populace, whom we are all elected to represent, both in our states and as we conduct the business of the Nation.

I believe it will be important and very helpful for us to hear those messages, and I appreciate his willingness to come and share them with the Committee.

Thank you again, Mr. Chairman, and I look forward to the testimony.

Senator NELSON. And now you see why it is such a pleasure for me to work with Senator Hutchison.

And I will tell you we both have a healthy degree of skepticism about OMB because OMB has thought that it has been running the space program for over the last decade. And fortunately, I think that is starting to change so that policy can be set at the congressional level in consultation with the executive branch, and then that the space program can be run by the Administrator of NASA.

So, with that, General Bolden, welcome. Please, your comments?

Mr. BOLDEN. Mr. Chairman, Ranking Member Hutchison, Senator Udall, I would like to do something a little bit different. We submitted a statement.

Senator NELSON. I am sorry. General Bolden, I forgot. I wanted to call on Senator Udall for a comment.

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

Senator UDALL. Okay. Thank you very much.

And thank you, Chairman Nelson and Senator Hutchison, for those strong statements on the NASA budget.

I am going to have to leave in just 5 minutes here, but I wanted to just say a couple of things about the budget and as it relates to New Mexico. And hopefully, we can submit questions for the record.

But Administrator Bolden, during the Space Shuttle program, New Mexico's White Sands Test Facility played a key role in NASA's work on jet propulsion and advanced materials testing. Mr. deGrasse Tyson and his show Nova scienceNow visited my home State last year to feature WSTF's work on simulating cosmic collisions.

WSTF is testing the impact of space debris on our spacecraft shields by using a powerful gun to shoot particles at them at speeds of 20,000 miles per hour, and I know you are aware of White Sands unique assets and capabilities. There are many opportunities for White Sands to support NASA missions and to work more closely with commercial space firms.

And one of the things that I was going to ask, if I was here, for you to talk a little bit about that, but we may well have specific questions on that.

The other area I wanted to mention is NASA education and some of the New Mexico accomplishments. Your testimony speaks to NASA's educational focus on inspiring today's young people to envision futures in science, technology, engineering, and math. And as you know, these STEM fields are just absolutely crucial to us moving forward in this information age.

And in my home state, the New Mexico Space Grant Launch Program brings space into the classroom. As part of the NASA-funded Launch and Learn Program, middle school students from all over the state design and build experiments to launch into suborbital space on the Space Loft sounding rocket.

So I think other questions we will submit also will deal with the STEM fields and all the great work you are doing there, up through K–12 and beyond.

And then, just finally, on the Earth sciences, scientists today know much more about the dangers of global warming and rising sea level, thanks to NASA support for Earth Science missions. Your written statement highlights NASA's initiative to develop the Nation's next generation climate and weather missions.

In fact, many of NASA's greatest contributions to science and society have come from unmanned Earth Science missions, even though these do not always capture the headlines in the same way as human space flight. So I hope you get a chance to talk a little bit about that, and we may well submit some questions there.

But I think the strong statement by the chairman and the ranking member are very appropriate here, and it is an honor to be here. And I am sorry I am not going to be able to hear your testimony, but I have another commitment I have to run to.

Thank you, Chairman Nelson, and thank Ranking Member Hutchison.

Senator NELSON. Thank you, Senator Udall.

General Bolden?

STATEMENT OF HON. CHARLES F. BOLDEN JR., ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. BOLDEN. Thank you very much.

And Senator Nelson, Senator Hutchison, Senator Udall, because of the fact that you have presented very eloquently much of what I was going to say, as has Senator Hutchison, I would like to do something unusual, and I would like to submit my oral statement for the record and just share with you some highlights from it, if I can?

And I will also say I want to thank you for putting me before Dr. Neil deGrasse Tyson. He is a dear friend of mine. He is an incredibly eloquent presenter of everything that I would like to say, and he will actually present to you—because people always want to ask me about supposition: "What would it be like if?"

I am going to talk about what it is like, based on the difficult economic times that we face. But I think Dr. Tyson will talk about what it would be like if. And he speaks very eloquently to that.

I feel somewhat like a friend of mine who had to speak between Neil Armstrong and John Glenn recently at a tribute to Senator Glenn. So I understand I am inadequately prepared to be here, but I will try.

I will say, first of all, the President has allowed us to put together what I think is a very ambitious exploration program. It does, in fact, fit within the confines of the budget that we anticipate being able to get and that we hope we will get. And it does, in fact, live up to the promises of the 2010 Authorization Act.

And I am glad that Senator Hutchison mentioned the three priority areas for NASA and the Nation, and I will talk about that a little bit more. But I do want to remind everyone that these are very difficult times economically. And so, what we tried to present was a balanced approach to accomplishing those three priorities that the President and you all agreed upon through the 2010 authorization.

I think, as everyone knows, the budget is $17.7 billion. Everything we propose we think is critical to ensuring America's continued leadership in space exploration as well as our stewardship of the Earth. NASA, I personally am committed to making this national resource, that is the International Space Station, available to a broader scientific and commercial research communities as you have mentioned, Senator Glenn emphasizes, you talked about it, and Senator Hutchison talked about it.

And I will mention I am glad that Senator Hutchison mentioned our friend Dr. Sam Ting, and I would remind everyone, AMS, as incredible as it is, would not be bringing us one piece of data were

it not for the fact that it has a home. It is on the International Space Station.

And had it not been for the existence of the International Space Station, we might not have AMS doing what it is doing right now. So the International Space Station is critically important, and you will hear me emphasize that over and over and over again.

I am also committed to ensuring that American companies launching from U.S. soil transport our astronauts and their cargo to the International Space Station. We are on track to develop a flexible deep space launch system that will ultimately be the most capable in history.

We are pushing forward with contracting and design efforts to advance this critical next generation space exploration system, and our Fiscal Year 2013 budget request supports our plans for an uncrewed SLS test flight in 2017 and a crewed test mission by 2021. And I don't want anybody to miss that. Those are hard dates, and they are evidence that we are pushing forward with the development of the SLS and MPCV.

We are also confident that this budget supports a 2018 launch for the James Webb Space Telescope as we came up with after the replan for that particular mission.

The request also supports a portfolio of innovative science missions, and we could go on and on and on talking about them. Everyone is disappointed that we had to take a breather, if you will, but to step back from our negotiations with the European Space Agency on a program that they call ExoMars that we agreed we would participate in planning on.

However, we are now developing a new integrated strategy for Mars missions to ensure that the next steps to Mars exploration will support the science objectives that were laid out in ExoMars, the priorities established by the National Research Council's decade-old survey on planetary science, and also support our human exploration.

The Fiscal Year 2013 budget request continues to support a robust Mars program in spite of what you may have heard. Absolutely essential to obtaining our ambitious goals is the further development of aviation science and space technologies, and we have that funded in this budget.

We are going to conduct aeronautics research to enable the realization of the Nation's Next Generation Air Transportation System, or NextGen, which will provide for safer, more fuel-efficient, quieter, and environmentally responsible aircraft that will operate with NextGen.

I am really grateful, NASA as an agency is grateful to the American people and to all of you on this committee who have provided support to us in these very difficult and challenging times. But as Senator Hutchison alluded in her opening statement, priorities have to be established.

She was incredibly helpful in helping us establish the three priorities for the agency and the SLS/MPCV for exploration; the International Space Station, shored up by Commercial Crew and Cargo, which is the test bed for that exploration; and then the James Webb Space Telescope is what promises to be the most incredible

instrument for science and exploration of our universe ever known to mankind.

The SLS and MPCV are hard evidence that we are pushing forward with our exploration program. We have flown tests on MPCV. We have done drop tests. We just completed some the other day. We just finished another test firing of the J–2X at Stennis yesterday.

This is hardware. This is not design drawings. This is hardware. I contend that we are probably much farther along on SLS/MPCV than we are on any of the other two priorities. So I would really challenge anyone who says that we are stepping back from our promise. We are not doing that.

And Senator Hutchison, as I have said to you many times, I am dedicated to this, and we are doing what we promised we would do.

[The prepared statement of Mr. Bolden follows:]

PREPARED STATEMENT OF HON. CHARLES F. BOLDEN, JR., ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and Members of the Committee, today it is my privilege to discuss the President's Fiscal Year 2013 budget request for NASA. Our requested budget of $17.7 billion will enable NASA to execute the balanced program of science, space exploration, technology, and aeronautics agreed to by the President and a bipartisan majority of Congress.

Despite the constrained fiscal environment facing the Nation, this request supports a robust civil space program that puts us on a path to achieving a truly exciting set of goals. We are working to send humans to an asteroid and ultimately to Mars, to peer deep into space to observe the first galaxies form, and to broaden human activity in low-Earth orbit (LEO). We have completed assembling and outfitting of the U.S. segment of the International Space Station (ISS), allowing us to focus on full utilization of the Station's research capabilities. NASA is making air travel safer and more efficient, learning to live and work in space, and operating a fleet of spacecraft to investigate the Earth, the Solar system and the Universe.

The Fiscal Year 2013 request supports the implementation of key priorities for NASA.

First, since the historic construction of the International Space Station (ISS) was completed in 2011, and now that all the international partners have agreed to its extension to at least 2020, we must enhance its utilization to insure the success of this national laboratory. For over eleven years, international crews of space explorers have been living on orbit, both building the International Space Station and conducting a diverse research program continuously. NASA is committed to making this National resource available to the broader scientific and commercial research community. Key to its sustainment is the availability of a U.S. commercial crew and cargo delivery capability as soon as possible. NASA is working with American companies to establish the next generation of safe and efficient vehicles for access to LEO and the ISS. In calendar year 2012, we will see the first commercial cargo flights to the ISS, demonstrating the innovation and capabilities of our industry partners and providing a path forward to ease our sole reliance on Russian transport of astronauts. We will continue to work with our industry partners to develop end-to-end systems for transporting crew and cargo to orbit. I am committed to ensuring that American companies, launching from U.S. soil, are providing the cargo and crew transportation services that we need to keep the ISS functioning. We are making steady progress on these launch services. Later this spring and summer, we expect that both of our private company partners, SpaceX and Orbital Sciences, will complete demonstration flights of their cargo vehicles to Station and actually berth with the ISS, marking a major milestone in our goal to establish commercial space capabilities for low-Earth orbit travel. Some modification of the Iran, North Korea, Syria Non-proliferation Act (INKSNA) provisions will likely be required for the continued operation of ISS and other space programs after 2016. The Administration plans to propose appropriate provisions and looks forward to working with the Congress on their enactment.

Second, with the Fiscal Year 2013 budget request, NASA is moving out on plans to develop a flexible launch system that will ultimately be the most capable in history. The Space Launch System (SLS) rocket and the Orion Multi-Purpose Crew Ve-

hicle (Orion MPCV) will carry American astronauts beyond low-Earth orbit and into deep space within the next decade. Following a thorough analysis of alternatives, NASA has established architecture for SLS and the Orion MPCV. In recent months we have continued to push forward with contracting and design efforts to make this system a reality. At the same time, we are moving forward on a critical effort to develop the technologies and capabilities required to support our ambitious exploration goals. Our Fiscal Year 2013 budget request supports our plans for an uncrewed SLS test flight in 2017 and a crewed test mission by 2021.

Third, we plan to continue progress toward the launch of the world's most advanced telescope in 2018. The James Webb Space Telescope (JWST) will operate deep in space to orbit the sun nearly one million miles from Earth. From that vantage point, JWST will look out into space and back in time almost as far as it is possible to look. Over the past year, NASA has engaged in a thorough review of JWST, made important adjustments to management, and put the project on a sound financial footing. Since we completed this new plan, the project has met 19 of 20 Fiscal Year 2011 milestones (with one deferred without impact), and has met all Fiscal Year 2012 milestones to date on or ahead of schedule. NASA is confident that the Fiscal Year 2013 request supports a 2018 launch of JWST.

Fourth, The Fiscal Year 2013 budget request supports continued advances in new technologies. The National Research Council (NRC) has determined that future U.S. leadership in space requires a foundation of sustained technology advances, but that the U.S. space program is now living on the innovation funded in the past. Our focus on new space technologies is absolutely essential to enable NASA to achieve its ambitious goals. At the same time, NASA technology research seeds innovation, supports economic vitality and helps to create new jobs and expanded opportunities for a skilled workforce. Space technology investments address long-term Agency technology priorities and technology gaps identified by NASA Mission Directorates and within the Agency's draft space technology roadmaps. On February 1, 2012, the NRC released its final review of NASA's Draft Space Technology Roadmaps. The report, which notes that NASA's technology base is largely depleted and identifies sixteen top-priority technologies necessary for NASA's future missions, which also could benefit American aerospace industries and the nation. This NRC assessment will help guide NASA's technology priorities in the years to come.

NASA's budget request supports a portfolio of innovative science missions that will explore the diverse planetary bodies of our solar system, unravel the mysteries of our universe and provide critical data about our home planet. Currently operating missions continue to return a stream of data from orbits around the Sun, Mercury, the Moon, the asteroid Vesta, Mars, and Saturn. We now have missions on the way to Jupiter, Pluto and Mars. Sixteen Earth Science missions in orbit study the Earth as an integrated system. The Hubble, Spitzer, Chandra, and Fermi space telescopes continue to make groundbreaking discoveries on an almost daily basis. In calendar year 2011, the MESSENGER spacecraft entered orbit around Mercury, Ebb and Flow began mapping the gravity field of the Moon, and Juno launched on its way to Jupiter. Also in 2011, Aquarius produced the first global view of ocean surface salinity and the Suomi National Polar-orbiting Partnership satellite began making observations of Earth's weather and climate. In 2012, we will launch the Nuclear Spectroscopic Telescope Array to study massive black holes, supernovae and other high-energy sources in the universe, and will launch the Radiation Belt Storm Probes into Earth's Van Allen belts. In 2013, we will launch the next land observing mission (the Landsat Data Continuity Mission) and complete environmental testing of the Global Precipitation Measurement mission, the Lunar Atmosphere and Dust Environment Explorer (LADEE) and the Mars Atmosphere and Volatile Evolution (MAVEN) mission.

In view of these key priorities for NASA and of our constrained fiscal environment, we will not be moving forward with the 2016 and 2018 ExoMars missions we had been studying with the European Space Agency. Instead, NASA is developing a new, integrated strategy for Mars missions to ensure that the next steps for Mars exploration will support science and human exploration goals and take advantage of advanced space technology developments. NASA will complete this integrated plan, including the framework for a mission to take advantage of the 2018 or 2020 launch opportunities, no later than this summer and, hopefully, in time to support the Fiscal Year 2013 appropriations process. The Fiscal Year 2013 request supports this approach, and this process will be informed by coordination with the science community and our international partners. The Fiscal Year 2013 budget request continues to support robust Mars exploration including two spacecraft orbiting Mars, the Opportunity rover on the surface, a multi-year exploration of Mars by the Curiosity Mars Science Laboratory, and the MAVEN mission to explore the Mars upper atmosphere. The August landing of Curiosity will be among the most difficult

technical challenges that NASA has ever attempted and Curiosity's mission of exploration will far eclipse anything humanity has attempted on the surface of Mars in the past. We look forward to receiving a treasure trove of data from the surface of Mars to help answer questions about its past and present habitability.

With the 2013 request, NASA will conduct aeronautics research to enable the realization of the nation's Next Generation Air Transportation System (NextGen), and the safer, more fuel efficient, quieter, and environmentally responsible aircraft that will operate within NextGen. Through the aeronautics research we conduct and sponsor with universities and industry, NASA helps to develop the technology that enables continuous innovation in aviation. As a result, U.S. companies are well positioned to build on discoveries and knowledge resulting from NASA research, turning them into commercial products that benefit the quality of life for our citizens, provide new high-quality engineering and manufacturing job opportunities, and enables the United States to remain competitive in the global economy.

The request also continues NASA's dedicated efforts to inspire the next generation of explorers. NASA can provide hands-on experience and inspiration as few other agencies can. To foster the development of the U.S. workforce, NASA's education programs will focus on demonstrable results and capitalize on the Agency's ability to inspire students and educators through unique missions and the big challenges that help today's young people envision their future in science, technology, engineering and mathematics (STEM). NASA Education is one of many Federal government programs that support STEM education. NASA Education is working with other agencies through the National Science and Technology Council's Committee on STEM Education to fund coordinated and effective student and teacher opportunities. NASA will focus its resources on demonstrated areas of strength in its unique role in STEM education, freeing resources for other Agency priorities. NASA brings many assets, beyond funding, to support the Administration's emphasis on STEM education. Our people, platforms like the International Space Station, and our facilities across the Nation all contribute to strengthening STEM education.

NASA is grateful to the American people, and their representatives here on the Committee for the continued support for NASA despite the difficult resource challenges facing our Nation. A more detailed description of NASA's balanced program of science, space exploration, technology development, and aeronautics is provided below.

Science

NASA's Science Mission Directorate develops and operates innovative spacecraft missions and instruments that help researchers deliver new discoveries of the Earth, the Sun, the planetary bodies in our solar system, and the universe beyond. The Fiscal Year 2013 budget request for Science is $4,911.2 million.

NASA's *Earth Science* Program advances knowledge of the integrated Earth system—the global atmosphere, oceans, land surfaces, ice sheets, ecosystems and interactions among them. The Fiscal Year 2013 budget request for Science includes $1,784.8 million for Earth Science. In 2011, NASA successfully launched Aquarius/SAC–D, a cooperative ocean surface salinity mission conducted with the Argentine Space Agency, and with our partner the National Oceanic and Atmospheric Administration (NOAA) and the Suomi National Polar-orbiting Partnership (SNPP). SNPP is the first step in developing the Nation's next-generation climate and weather monitoring missions. During calendar year 2012 NASA will select the first small satellite mission under the Earth Venture program as recommended in the National Research Council's decadal survey for Earth science. The Fiscal Year 2013 budget will fund all three components of the Earth Venture program: this new small mission, the on-going EV–1 airborne science campaigns, and the first EV–I instrument of opportunity. Fiscal Year 2013 will see the launch of the Landsat Data Continuity Mission and the completion of environmental testing for the Global Precipitation Measurement mission. The Fiscal Year 2013 budget will also fund continued development of the first two Tier 1 decadal survey missions, Soil Moisture Active Passive mission and ICESat-2. Finally, the Fiscal Year 2013 budget will fund continued development of three key missions to assure delivery of sustained Earth observations (GRACE-Follow on, OCO–2, and the SAGE–III instrument that will fly on the ISS) and fund the continued operation of 16 missions currently in orbit as well as research using the resultant data. The Fiscal Year 2013 budget request for Earth Science sustains support for focused research, applications, and technology development activities that redeem the investment in our ongoing missions, while positioning us to accomplish essential new missions in the future. NASA's Earth Science program leads to improved prediction services by other agencies, providing direct tangible benefits to communities, businesses, and citizens.

NASA's *Planetary Science* Program explores the content origin and evolution of the solar system and the potential for life beyond Earth. The Fiscal Year 2013 budget request for Science includes $1,192.3 million for Planetary Science. In the second half of 2011, NASA launched Juno on its way to Jupiter, GRAIL to the Moon, and the Mars Science Laboratory to the Red Planet. GRAIL's "Ebb" and "Flow" spacecraft will conduct their mission to map the Moon's gravity field and interior structure during the first half of 2012. The Mars Science Laboratory rover Curiosity will land in Gale Crater on Mars on August 6. The Fiscal Year 2013 budget request funds the operation of Curiosity on Mars. The Fiscal Year 2013 budget will also fund the beginning of development of the next Discovery mission that will be selected from among three candidates completing their studies in 2012. In Fiscal Year 2013, NASA will be completing development of the LADEE mission to the Moon and the MAVEN mission to Mars for launch in late calendar year 2013/early Fiscal Year 2014. Also in Fiscal Year 2013, NASA will continue the development of the OSIRIS–REx mission to return samples from an asteroid, and will continue operation of the Dawn (the asteroid Vesta), Juno (Jupiter), Cassini (Saturn), New Horizon (Pluto), and MESSENGER (Mercury) missions. However, the resources available over the budget horizon are insufficient to enable either a future Mars or Outer Planets flagship mission as identified by last year's Planetary Science decadal survey.

NASA remains committed to a vigorous program of Mars exploration and continuing America's leadership role in Mars exploration within the available budget. As stated above, NASA is discontinuing its effort on instruments for the joint (NASA/European Space Agency) 2016 ExoMars Trace Gas Orbiter mission and the 2018 mission that NASA had been exploring with the European Space Agency (ESA). Instead, NASA will develop an integrated strategy to ensure that the next steps for Mars exploration will support science as well as long-term human exploration goals. This process will be informed by coordination with the science community and international community. NASA is developing a plan for a reformulated medium-class robotic science Mars mission, within available resources, to take advantage of the favorable location of Mars and Earth in 2018 or 2020. NASA's plan is to work with potential international partners including ESA and the science community to lay out an initial framework for this mission over the next several months and produce a mission architecture by this summer. To keep this effort moving forward in Fiscal Year 2012, resources, totaling approximately $30 million, are proposed for work towards a revised mission. The budget request includes $62 million in Fiscal Year 2013 for this mission.

NASA's *Astrophysics* Program seeks to discover how the universe works, explore how the universe began and evolved and search for Earth-like planets. The Fiscal Year 2013 budget request for Science includes $659.4 million for Astrophysics. NASA will continue to conduct science operations flights of the SOFIA aircraft in 2012 and 2013 as we upgrade its science instruments, and will continue parallel development of efforts leading to achievement of a full operational capability in 2014. The Fiscal Year 2013 budget will fund the early stages of development of the next Astrophysics small Explorer mission to be selected early in calendar year 2013. Also in 2013 NASA will complete development of its instrument contributions to Japan's Astro-H mission for launch in Fiscal Year 2014. The FY2013 budget enables NASA to continue development of the GEMS Explorer mission toward a launch in 2015. Finally, the Fiscal Year 2013 budget will fund the operation of eleven Astrophysics missions currently in operation, including the Hubble, Spitzer, Chandra, and Fermi space telescopes.

The *James Webb Space Telescope* (JWST) is an infrared telescope designed to study and answer fundamental astrophysical questions ranging from the formation and structure of the universe to the origin of planetary systems and the origins of life. The Fiscal Year 2013 budget request for Science includes $627.6 million for JWST. A scientific successor to the Hubble Space Telescope (HST) and the Spitzer Space Telescope, JWST will be used by international teams of astronomers to conduct imaging and spectroscopic observations. The Observatory will be located in an orbit near the second Sun-Earth Lagrange point (L2), approximately 1.5 million km from Earth. The telescope and instruments will be operated at a temperature of forty degrees above absolute zero (40 Kelvin) shielded from the heat of the Sun by a large sunshield, to enable the Observatory to achieve unprecedented sensitivity over its entire wavelength range. NASA completed a new baseline cost and schedule for JWST at the end of calendar year 2011, and is now implementing that new baseline. All 18 JWST primary mirror segments have been completed. NASA expects to take delivery of all four JWST instruments in Fiscal Years 2012–2013. In Fiscal Year 2013, NASA will begin sunshield fabrication and continue development of the Integrated Science Instrument Module and the ground segment.

NASA's *Heliophysics* Program seeks an understanding of the Sun, and the complex interaction of the coupled system comprising the Sun, Earth, other planetary systems, the vast space within the solar system, and the interface with interstellar space. The Fiscal Year 2013 budget request for Science includes $647.0 million for Heliophysics. Later this year, NASA will launch the Radiation Belt Storm Probes mission, and the Fiscal Year 2013 budget will fund completion of its checkout and its early operations. The Fiscal Year 2013 budget will fund completion and launch of the IRIS small Explorer mission as well as beginning of the development of the next small Explorer to be selected in early in calendar year 2013. Fiscal Year 2013 will be a peak year in the development of the Magnetospheric Multiscale (MMS) mission to be launched in 2015. The Fiscal Year 2013 budget will also fund the continued formulation of the Solar Probe Plus mission and development of the Solar Orbiter Collaboration with ESA. NASA expects to receive the new NRC Heliophysics decadal survey this spring, and will use it to shape the Fiscal Year 2014 budget request in this area.

Also during Fiscal Year 2013, NASA will continue development of environmental operational satellites for NOAA on a reimbursable basis. These include the Joint Polar Satellite System, Geostationary Operational Environmental Satellites (GOES–R series), Jason 3, and the Deep Space Climate Observatory. Funding for these programs is in the Department of Commerce budget request for NOAA.

In addition to the space missions emphasized above, the Fiscal Year 2013 budget funds NASA's Science Mission Directorate to continue to sponsor competitively-selected research by universities, industry, and government laboratories across the nation. Using data from these missions, the nation's scientific community pursues answers to profound scientific questions of interest to all humanity as well as questions that enhance our national capability to predict environmental change including severe storms, droughts, and space weather events, and thereby enhance our economic and environmental security.

Aeronautics Research

NASA aeronautics research will enable the realization of the nation's Next Generation Air Transportation System (NextGen), and the safer, more fuel efficient, quieter, and environmentally responsible aircraft that will operate within NextGen. Through the research we conduct and research we sponsor with universities and industry, we help to develop the technology that enables continuous innovation in aviation. American companies are well positioned to build on discoveries and knowledge resulting from NASA research, turning them into commercial products, benefiting the quality of life for our citizens, providing new high-quality engineering and manufacturing job opportunities, and enabling the United States to remain competitive in the global economy. NASA's Fiscal Year 2013 budget request for aeronautics is $551.5 million to continue our tradition of developing new concepts for aeronautics applications.

The Fiscal Year 2013 request for Aeronautics Research includes $168.7 million for the *Fundamental Aeronautics* Program which seeks to continually improve technology that can be infused into today's state-of-the-art aircraft, while enabling game-changing new concepts such as Hybrid Wing Body airframes, tilt-rotor aircraft, low-boom supersonic aircraft, and sustained hypersonic flight. In Fiscal Years 2010 and 2011 we conducted emissions measurements for alternative non-petroleum fuels derived from coal and biomass that showed dramatic reductions in particulate emissions in the vicinity of airports. In Fiscal Year 2013 the Program will perform emissions measurements behind aircraft operating at relevant altitudes and cruise speeds to provide the first-ever data on the impact of alternative fuels on contrail formation, an important factor in aviation climate impact. In Fiscal Year 2013 the Program will also increase its research on composite materials to enable airframe weight reductions beyond those achieved with current materials and structural design concepts.

NASA is combining hypersonic and supersonic research into a single project to focus on fundamental research for high-speed flight. Research into hypersonic flight is also relevant to the Department of Defense and NASA will retain critical core competencies and national asset testing capabilities to continue productive collaborations with DOD. Responsibility for fundamental research on entry, decent, and landing technologies will be transferred to Space Technology to increase synergy with the Agency's exploration and science missions. NASA will continue to work with DOD to maximize the efficiencies of current assets and investments and increase partnership to accomplish common goals. These realignments will enable NASA to focus on higher-priority research to improve the safety and minimize the environmental impacts of current and future aircraft and air traffic management systems. The Fiscal Year 2013 request for Aeronautics Research includes $104.0

million for the *Integrated Systems Research Program.* This program evaluates and selects the most promising environmentally friendly engine and airframe concepts emerging from the fundamental research programs for further development, integration, and evaluation in relevant environments. Last year, the Program completed a major study by three aircraft manufactures to identify the critical technologies needed to simultaneously reduce emissions, fuel burn, and noise in aircraft entering service in 2025. In Fiscal Year 2013, the Program will start a 3-year focused research effort on these technologies to advance their technology readiness. The Program is also addressing the emerging desire to integrate Unmanned Aircraft Systems (UAS) into the National Airspace System. Current Federal Aviation Administration (FAA) regulations are built upon the condition of a pilot being on-board the aircraft. The Program will therefore generate data for FAA use in rule-making through development, testing, and evaluation of UAS technologies in operationally relevant scenarios.

Reductions in environmental impact will be achieved not only through new aircraft, engines, and fuels, but also through improved air traffic management procedures, which is the focus of the *Airspace Systems Program* with $93.3 million requested for Fiscal Year 2013. Last year the Program advised the FAA on new air traffic management concepts for more efficient routing of flights during their cruise phase. We also completed evaluations of concepts for new fuel-efficient arrival procedures and will deliver requirements for those concepts to the FAA this year. In Fiscal Year 2013 the Program will begin demonstrations to verify that several new procedures for air traffic management during arrival and taxiing to the gate that are enabled by NextGen Automatic Dependent Surveillance-Broadcast (ADS–B) technology can work together seamlessly. This effort will demonstrate near-term and mid-term ADS–B application benefits and provide airlines with data to support their strategic decisions related to the significant investments they need to make to equip their aircraft with ADS–B capability.

The *Aviation Safety Program,* with $81.1 million requested for Fiscal Year 2013, conducts research to ensure that current and new aircraft and operational procedures maintain the high level of safety which the American public has come to expect. In Fiscal Year 2011, the Program advanced data mining methods that permit the discovery of flight operations and aircraft maintenance issues through automated analysis of the vast amounts of data generated during flight operations and by sensors onboard aircraft. These methods have enabled the development of new software for aircraft central maintenance computers on both business jet and large commercial aircraft that can identify the early stages of hardware faults 30 to 50 flights earlier than previously possible. This allows airline maintenance personnel to address equipment issues before they cause a disruptive maintenance delay at the airport gate. The Program also focuses on mitigating environmental hazards to aviation and in Fiscal Year 2013 will conduct a flight campaign to characterize ice water content at high altitudes in tropical regions as a first step to understanding the causes of severe loss of power due to engine icing that has occurred on a number of occasions.

U.S. leadership in aerospace depends on ready access to technologically advanced, efficient, and affordable aeronautics test capabilities. NASA's *Aeronautics Test Program,* with $78.1M requested for Fiscal Year 2013, makes strategic investments to ensure the availability of these ground test facilities and flight test assets to researchers in Government, industry, and academia. In addition to this strategic management activity, the Program will continue developing new test instrumentation and test technologies. Last year the Program completed nearly $50 million worth of upgrades to major facilities funded through the American Recovery and Reinvestment Act. These upgrades provide improved research capabilities at Glenn and Ames Research Centers for aircraft and engine icing research, and tilt-rotor designs for a new generation of rotorcraft. New capabilities were also added to the Langley 14x22 Subsonic Wind Tunnel that will enable researchers to measure noise signatures from novel aircraft designs at a fraction of the cost of noise measurement acquired by flying real aircraft over airport microphone arrays. NASA's Aeronautics Test program enables and sustains U.S. leadership in aerospace yielding high quality jobs and ultimately a productive Aerospace sector.

The *Aeronautics Strategy and Management Program* provides for research and programmatic support that benefits each of the other five Programs, and has a requested budget of $26.4 million for Fiscal Year 2013. The Program manages Directorate functions including Innovative Concepts for Aviation, Education and Outreach, and Cross Program Operations.

NASA is making meaningful contributions to the aerospace community, but we cannot do all these good things alone. Therefore, our partnerships with industry, academia, and other Federal agencies are critical to our ability to expand the bound-

aries of aeronautical knowledge for the benefit of the Nation. These partnerships foster a collaborative research environment in which ideas and knowledge are exchanged across all communities and help ensure the future competitiveness of the nation's aviation industry. They also directly connect students with NASA researchers and our industrial partners and help to inspire students to choose a career in the aerospace industry.

Human Exploration and Operations

In 2011, NASA combined the Exploration Systems and Space Operations Mission Directorates to create the Human Exploration and Operations (HEO) Mission Directorate. HEO encompasses everything from the ISS and the commercial cargo and crew vehicles that will support it, to NASA's new exploration vehicles, which will take astronauts beyond LEO. HEO also includes research and technology development efforts that will enable deep space exploration, as well as critical infrastructure and operational capabilities that ensure NASA's ability to conduct testing, launch science missions, and communicate with its spacecraft across the solar system. As NASA reformulates its Mars exploration plans, we will ensure that the next steps for Mars exploration will take into account long-term human exploration as well as science goals.

The Fiscal Year 2013 budget request includes $2,769.4 million for *Human Exploration Capabilities,* which the Agency proposes to rename *Exploration Systems Development.* This program includes development of the Orion MPCV, SLS heavy-lift launch vehicle, and the supporting ground infrastructure required for NASA's future crewed missions of exploration beyond LEO and into deep space. The amounts requested align with the plan developed and supported by an independent cost analysis performed last summer.

NASA's Orion MPCV will carry astronauts to, and support operations at, a variety of destinations in our solar system for periods of up to 21 days. NASA has recently completed a number of tests on Orion MPCV, including a test of the main parachute, and a series of water drop tests on the 18,000-pound Orion MPCV Boiler Plate Test Article. The Orion ground test article will undergo and complete acoustic, modal, and vibration environment compatibility testing at Lockheed Martin Denver during fiscal year 2012. The results of these tests will help improve the design for the actual flight vehicle. In May, the Orion Crew Module primary structure will be moved to Kennedy Space Center in Florida for the start of Assembly, Integration, and Production. NASA plans to conduct an uncrewed high-energy-atmospheric entry test mission of the Orion MPCV in Fiscal Year 2014. Designated Exploration Flight Test-1 (EFT–1), this flight test will provide critical data to influence key design decisions. EFT–1 will also validate innovative new approaches to space systems development and operations to reduce the cost of exploration missions. For EFT–1, an early production variant of the Orion MPCV spacecraft will be integrated on a Lockheed Martin-procured, heavy class launch vehicle. The flight test will provide an opportunity to significantly inform critical design elements by operating the integrated spacecraft hardware and software in flight environments that cannot be duplicated by ground testing.

On September 14, 2011, NASA announced the design of the SLS, which will initially be capable of lifting 70–100 metric tons before evolving to a lift capacity of 130 metric tons for more demanding missions. NASA has worked diligently to accomplish the contracting and design work necessary to support a 2017 initial flight mission for the SLS. In Fiscal Year 2013, SLS will continue detailed preliminary design and development and undergo a preliminary design review to evaluate the completeness/consistency of the program's preliminary design in meeting all requirements with appropriate margins, with acceptable risk, and within cost and schedule constraints. This comprehensive review will determine the program's readiness to proceed with the detailed critical design phase of the project.

The SLS will use a liquid hydrogen and liquid oxygen propulsion system, building upon the investment made by the Nation over the last forty years. The vehicle's core stage will utilize existing Space Shuttle Main Engines (SSME RS–25D) for the initial capability. NASA's use of the SSME inventory will reduce initial design costs and take advantage of an existing human-rated system. NASA plans to modify and use the existing SSME contract with Pratt & Whitney Rocketdyne to acquire RS–25D engine servicing and testing for the initial launch system.

The upper stage of the SLS needed for the full-up SLS capability will also use a liquid hydrogen and liquid oxygen propulsion system that includes the J–2X, a new upper stage engine previously planned for use in the Ares-I vehicle. NASA is negotiating a modification to the Ares I Upper Stage contract with Boeing to develop the SLS core stage and upper stage, including avionics. SLS will also utilize the existing J–2X contract with Pratt & Whitney Rocketdyne to continue developing the

upper stage engine. NASA has been running J–2X components through a series of tests. In November and December 2011, the Agency conducted three J–2X engine tests, firing the motor for a total of 680 seconds. These were the last of ten engine test firings completed in 2011. In January and February of 2012, NASA also conducted a series of J–2X Power Pack Assembly tests. These tests are part of a series of over 100 power-pack and integrated engine tests that NASA has planned to complete the engine design and certify the J–2X for use in the SLS Upper Stage.

NASA plans to use five-segment solid rocket boosters for the initial capability test flights of the SLS. We will conduct a competition to develop the follow-on boosters based on performance requirements. In support of this effort, on February 9, 2012, the Agency released a NASA Research Announcement (NRA) for Advanced Booster Engineering Demonstration and Risk Reduction. Proposals are due in April and contract awards are expected in October 2012.

On February 1, 2012, NASA also released a draft for an NRA, for advanced development of key technologies in propulsion, avionics, structures and materials, and other areas. The final release is planned for March, with proposals due in May and contract award in October 2012.

Exploration Ground Systems (EGS) will develop the necessary ground systems infrastructure at the Kennedy Space Center and operational plans and procedures to prepare, assemble, test, launch and recover the Exploration architecture elements for long-term beyond-Earth orbit exploration. EGS will focus on the life cycle of a launch complex as an integrated system (from development, activation, operations, maintenance of capabilities to manufacture, assemble, test, checkout, launch, and recover flight hardware) to enable more efficient and cost-effective ground processing, launch and recovery operations.

The Fiscal Year 2013 budget request includes $829.7 million for the *Commercial Spaceflight* theme. This effort will support commercial providers to develop and operate safe, reliable, and affordable commercial systems to transport crew and cargo to and from the ISS and LEO.

As part of the Commercial Orbital Transportation Services (COTS) program—NASA's commercial cargo effort—NASA has partnerships with Space Exploration Technologies, Inc. (SpaceX) and Orbital Sciences Corporation (Orbital) using funded Space Act Agreements. These agreements include a schedule of fixed payment performance milestones culminating in a demonstration mission to the ISS that includes vehicle launch, spacecraft rendezvous, ISS berthing, and re-entry for disposal or return to Earth. Both COTS partners continue to make progress in developing and demonstrating their systems. Based on the success of their first COTS demo flight in December 2010, SpaceX plans to fully develop and assemble their next vehicle with the capabilities and equipment necessary to complete rendezvous and berthing demonstration to the ISS, thus potentially combining milestones that had been planned for separate flights. If successful, this will accelerate the completion of the COTS Space Act Agreement and enable delivery of cargo under the Commercial Resupply Services (CRS) contract. This mission is tentatively planned for April 2012. Orbital Sciences is currently mating the main engines for its Antares vehicle to the core stage in preparation for an integrated static fire later this year. The maiden flight of the Antares is planned for the second quarter of 2012 and the COTS demonstration mission is planned for the third quarter. The pad complex at Wallops Flight Facility in Virginia is being readied and space flight hardware, including the first Pressurized Cargo Module, two Antares core sections, and a Castor-30 upper stage, has already been delivered to Wallops Flight Facility.

The Commercial Crew Program (CCP) aims to facilitate the development of a U.S. commercial crew space transportation capability with the goal of achieving safe, reliable, and cost effective access to and from low-Earth orbit and ISS. Since 2009, NASA has conducted two CCDev competitions, soliciting proposals from U.S. industry to further advance commercial crew space transportation system concepts and mature the design and development of elements of the system. During the second CCDev competition, known as CCDev2, NASA awarded four funded Space Act Agreements that are currently being executed with Blue Origin, The Boeing Company, Sierra Nevada Corporation, and SpaceX, all of which are making good progress in achieving their milestones. NASA has also signed Space Act Agreements without funding with three additional companies: Alliant Techsystems, Inc., United Launch Alliance, and Excalibur Almaz, Incorporated.

Under the CCP, NASA plans to partner with U.S. industry, providing technical and financial assistance to facilitate industry's development of an integrated crew transportation system. In the longer term, once those entities are certified, NASA plans to buy transportation services from commercial entities for U.S. and U.S.-designated astronauts to the ISS.

Congress appropriated $406 million for CCP in Fiscal Year 2012 which reflected a substantial reduction from NASA's request for this program. The Fiscal Year 2012 appropriation enables the Agency to move forward with its plans to support the development of commercial services that may eventually support crew transportation and rescue capabilities in support of ISS. However, the constrained budget environment necessitated a reassessment of NASA's overall strategy for this Program. On December 15, 2011, NASA announced a modified competitive acquisition strategy designed to make the best use of available resources and to pursue the most effective path to the achievement of a commercial crew capability. Instead of using firm-fixed price contracts for the next phase of the Program, the Agency plans to continue using multiple, competitively awarded and funded Space Act Agreements for another round of CCP. NASA will use procurement contracts to certify these capabilities before they are used to support ISS. Using competitive Space Act Agreements instead of contracts at this juncture will allow NASA to maintain multiple partners during this phase of the Program, and provide NASA with the flexibility to more easily adjust to various funding levels. This new acquisition strategy will allow NASA to preserve greater competition and maintain momentum to provide a U.S.-based commercial crew launch capability at the earliest possible time.

NASA is pleased with the steady progress of U.S. commercial providers in developing domestic cargo and crew transportation services. NASA currently has contracts for cargo services and intends to purchase crew services from U.S. providers once they are certified to our crew requirements. Obtaining needed cargo and crew transportation services from U.S. providers is NASA's preferred method for sustaining and fully utilizing the ISS. Nevertheless, given current funding levels for the development of U.S. crew transportation systems, we anticipate the need to purchase Soyuz crew transportation and rescue capabilities into 2017. As NASA has previously testified, modification of the Iran, North Korea, Syria Non-proliferation Act (INKSNA) provisions will likely be required for the continued operation of ISS and other space programs after 2016. The Administration plans to propose appropriate provisions and looks forward to working with the Congress on their enactment. NASA is evaluating how this issue impacts the development of U.S. crew transportation systems and NASA's acquisition of services for the ISS and goods and services for other NASA human spaceflight activities, given the possibility that some U.S. domestic providers will need to use Russian goods and services. In addition to the need driven by the ISS transportation requirements, NASA will require Russia-unique critical capabilities for the life of the ISS, such as sustaining engineering for the Russian built U.S. owned Functional Cargo Block, that are not available elsewhere.

The Fiscal Year 2013 budget request includes $333.7 million for *Exploration Research and Development (ERD).* The Exploration Research and Development (ERD) theme will expand fundamental knowledge that is key to human space exploration, and will develop advanced exploration systems and capabilities that will enable humans to explore space in a more sustainable and affordable way. ERD is comprised of the Human Research Program (HRP) and the Advanced Exploration Systems (AES) Program, which will provide knowledge and advanced human spaceflight capabilities. NASA's Office of the Chief Technologist (see below) coordinates closely with ERD to ensure that NASA's long range, crosscutting Space Technology research is complementary to ERD's human exploration focused work.

HRP and its associated projects will continue to develop technologies, countermeasures, diagnostics, and design tools to keep crews safe and productive on long-duration space missions. ISS crews are conducting relevant human medical research to develop knowledge in the areas of clinical medicine, human physiology, cardiovascular research, bone and muscle health, neurovestibular medicine, diagnostic instruments and sensors, advanced ultrasound, exercise and pharmacological countermeasures, food and nutrition, immunology and infection, exercise systems, and human behavior and performance. While this research is aimed at enabling astronauts to push the boundaries of exploration beyond low-Earth Orbit (LEO), NASA anticipates that investigations conducted aboard ISS may have broad application to terrestrial medicine, as well. For example, the growing senior population may benefit from experiments in the areas of bone and muscle health, immunology, and from the development of advanced diagnostic systems.

The AES Program is pioneering new approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond Earth orbit. AES activities are uniquely related to crew safety and mission operations in deep space, and are strongly coupled to future vehicle and exploration capability development. Early integration and testing of prototype systems will reduce risk and improve affordability of exploration mission elements. The prototype systems developed in the AES Program will be demonstrated

in ground-based test beds, field tests, underwater tests, and flight experiments on the ground and then on the ISS. Many AES projects will evolve into larger integrated systems and mission elements that will be tested on ISS before we venture beyond Earth orbit, thus leveraging the value of the Station as a vital exploration test-bed.

The Fiscal Year 2013 budget request includes $70.6 million for the *Space Shuttle Transition and Retirement (T&R).* In 2011, the Shuttle flew out its remaining missions safely. On February 24, Discovery launched on mission STS–133, carrying supplies to ISS, as well as the permanent a Multi-purpose Module (PMM)—a Multi-Purpose Logistics Module (MPLM) transformed to remain on orbit, expanding the Station's storage volume. On May 16, Endeavour, STS–134, carried the Alpha Magnetic Spectrometer (AMS) and attached it to the Station's truss structure. The final Shuttle mission, STS–135, launched on July 8, delivered critical supplies to the ISS. With the landing of Atlantis on July 21, 2011, the 30-year Shuttle Program was brought to a close. The Space Shuttle Program is now focused on the transition of key assets and infrastructure to future programs, and the retirement, and disposition of Program assets.

In Fiscal Year 2012, NASA is funding United Space Alliance's (USA's) Space Program Operations Contract (SPOC) Pension Liability. During the Shuttle Program, USA consistently incorporated and billed the maximum allowable costs into their indirect rates, but the deterioration of the equities and credit markets caused their plan to be underfunded by a currently estimated $522 million. The estimate will fluctuate until payout in the summer of 2012. The variance is protected in the transition and retirement budget line item. The Space Program Operations Contract, which accounts for almost all of USA's business base, is a cost-type contract covered by the Cost Accounting Standards (CAS). These standards stipulate that any costs of terminating plans are a contractual obligation of the Government (if deemed allowable, allocable, and reasonable). NASA and USA entered into an agreement under which USA froze their pension plans as of December 31, 2010, and deferred any decision about terminating their plan until after NASA received its Fiscal Year 2012 appropriation, allowing NASA to address this issue with Fiscal Year 2012 funds. If funding remains after the pension plan termination, it will be used to defray Space Shuttle closeout costs that would otherwise require Fiscal Year 2013 funding. If there is a shortfall, it will reduce available Space Shuttle funds for closeout and some activity could move later than planned. NASA will keep Congress informed as this issue evolves.

The Fiscal Year 2013 budget request includes $3,007.6 million for the *International Space Station (ISS) Program.* This funding will support ISS Operations and Maintenance, ISS Research, and ISS Crew and Cargo Transportation. The ISS has transitioned from the construction era to that of operations and research, with a 6-person permanent crew, 3 major science labs, an operational lifetime through at least 2020, and a growing complement of cargo vehicles, including the European Automated Transfer Vehicle (ATV) and the Japanese H–II Transfer Vehicle (HTV). The Fiscal Year 2013 budget request reflects the importance of this unparalleled research asset to America's human spaceflight program.

In the NASA Authorization Act of 2005 (P.L. 109–155), Congress designated the U.S. segment of the ISS as a National Laboratory, and directed the Agency to seek to increase the utilization of the ISS by other Federal entities and the private sector. NASA has made great strides in its effort to engage other organizations in the ISS program, and the Agency now has Memoranda of Understanding with five Federal agencies and Space Act Agreements with nine companies and universities. In the NASA Authorization Act of 2010 (P.L. 111–267), Congress directed that the Agency enter into a cooperative agreement with a not-for-profit organization to manage the activities of the ISS National Laboratory. To this end, on August 31, 2011, NASA finalized a cooperative agreement with the Center for the Advancement of Science in Space (CASIS) to manage the portion of the ISS that operates as a U.S. National Laboratory. CASIS will be located in the Space Life Sciences Laboratory at Kennedy Space Center in Florida. The independent, nonprofit research management organization will help ensure the Station's unique capabilities are available to the broadest possible cross-section of U.S. scientific, technological and industrial communities. CASIS will develop and manage a varied Research and Development portfolio based on U.S. national needs for basic and applied research; seek to establish a marketplace to facilitate matching research pathways with qualified funding sources; and stimulate interest in using the national lab for research and technology demonstrations and as a platform for science, technology, engineering and mathematics (STEM) education. The goal is to support, promote and accelerate innovations and new discoveries in science, engineering and technology that will improve life on Earth.

The Fiscal Year 2013 budget request includes $935.0 million for *Space and Flight Support* (SFS). The budget request provides for critical infrastructure indispensable to the Nation's access to and use of space, including Space Communications and Navigation (SCaN), Launch Services Program (LSP), Rocket Propulsion Test (RPT), and Human Space Flight Operations (HSFO). The SFS budget also includes investment in the 21st Century Space Launch Complex, whose primary objective is to modernize and transform the Florida launch and range complex at the Kennedy Space Center to benefit current and future NASA programs, along with other emerging users. Fiscal Year 2013 is an important period for NASA's Space Communications and Navigation (SCaN) Program. The Program is responsible for NASA's Tracking and Data Rely Satellites (TDRS) that provide a critical backbone for space communications. Fiscal Year 2013 will include the scheduled launch TDRS–K, an additional satellite in the system; completion of TDRS L integration; and the development of TDRS–M, which will be ready for launch in 2015. These spacecraft will refurbish this important network as aging TDRS are retired after 20 years of service to the Nation. Also under construction is a 34-meter antenna at the Deep Space Network's Canberra Deep Space Communication Complex, with plans to build a second, to replace the aging 70-meter antenna. These antennae in the Southern Hemisphere will be particularly important as the Earth's rotation brings this site into the best range for tracking NASA's deep space missions in the coming decade. In preparation for supporting NASA's space science program, SCaN is developing space communications technology, including the Lunar Laser Communications Demonstration and the Laser Communication Relay Demonstration, which will lead to the capability of handling the huge increase in scientific data expected from NASA's planned spacecraft. Additionally, this capability could enable greater bandwidth and capabilities to support expanded education, participatory engagement, and interactive exploration opportunities. SCaN also anticipates the launch of its SCaN Testbed in June on the Japanese Space Agency's HTV cargo vehicle. The test-bed, composed of three Software-Defined Radios, will provide the bridge to advance technological innovation by actual testing in the real space environment. As a pathfinder it will be made available to industry, academia and other Government agencies.

The Launch Services Program (LSP) has several planned NASA launches in Fiscal Year 2013, including the, Landsat Data Continuity Mission (LDCM), Tracking and Data Relay Satellite (TDRS)-K, and Interface Region Imaging Spectrograph (IRIS), and will continue to provide support for the development and certification of emerging launch services. In Fiscal Year 2013, the Rocket Propulsion and Test (RPT) program will continue to conduct test facility management, maintenance, sustaining engineering, operations, and facility modernization projects required to keep the test-related facilities in the appropriate state of operational readiness. The RPT program will continue to assist in rocket propulsion testing requirements definition for low-Earth orbit and in-space propulsion systems and related technologies

Technology

The Office of the Chief Technologist (OCT) coordinates the Agency's overall technology portfolio. OCT ensures that NASA's investments are cost-effective and that they are aligned with the Agency's near- and far-term goals. Over the last year, OCT has engaged thousands of technologists and innovators to develop and test cutting-edge technologies distributed across the country. While the NRC conducted its review of NASA's technology roadmaps, OCT worked with mission architecture teams to identify key technology areas requiring immediate investment. Using these internal, cross-Agency working groups, NASA selected nine technologies to receive priority funding based on their criticality in extending human presence beyond low-Earth orbit and their ability to dramatically further scientific exploration of the solar system. These "Big 9" projects are: Laser Communications Relay Demonstration, Cryogenic Propellant Storage and Transfer, Low Density Supersonic Decelerators, Composite Cryogenic Propellant Tanks, Robotic Satellite Servicing, Hypersonic Inflatable Aerodynamic Decelerators, Deep Space Atomic Clock, Large-Scale Solar Sail, and Human-Robotic Systems.

On February 1, 2012, the NRC released its final review of NASA's Draft Space Technology Roadmaps. The NRC identified sixteen top-priority technologies necessary for future missions, and which could also benefit American aerospace industries and the nation. The sixteen were chosen by the NRC from its own ranking of 83 high-priority technologies out of approximately 300 identified in the draft roadmaps. In the coming months, OCT will lead an agency-wide analysis and coordination effort to inform future technology investments on the basis of the NRC report.

The Fiscal Year 2013 request for Space Technology is $699 million and funds ongoing high-priority space technology projects that will increase the nation's capability to operate in space and enable long-term human exploration and develop effi-

ciencies for deep space science missions. In Fiscal Year 2013, NASA will begin to see major milestones achieved within Space Technology's "Big 9" efforts. Designed to deliver data rates that will enable new class of deep-space exploration missions, the Laser Communications Relay Demonstration project will begin ground validation activities of advanced laser communication systems. Enabling precise landing of higher-mass payloads to the surface of planets, the Low Density Supersonic Decelerators effort will complete three critical full-scale tests to demonstrate parachute and inflatable decelerator performance required prior to supersonic-speed flight demonstration. The Composite Cryogenic (low-temperature) Propellant Tank project will design and build a five-meter-diameter composite cryogenic propellant tank that will yield lower mass and lower cost rocket propellant tanks. The Cryogenic Propellant Storage and Transfer demonstration mission will conduct ground tests of the critical technologies required to enable long-term storage and handling of cryogenic fluids in space in preparation for a flight demonstration. While these projects will make visible individual steps in Fiscal Year 2013, they are part of a broader portfolio of activities that Space Technology will pursue in order to generate new technologies for use by NASA, other government agencies, and U.S. industry.

Within Space Technology, NASA funds Crosscutting Space Technology Development at $293.8 million to enable NASA to develop transformational, broadly applicable technologies and capabilities that are necessary for NASA's future science and exploration missions, and also collaborates on the aerospace needs of other government agencies and the U.S. space enterprise. NASA's CSTD activities are funded through a mix of competitive and strategically-guided projects to attract a broad array of participants. Investments support research fellowships, NASA Innovative Advanced Concepts (NIAC), Centennial Challenges, suborbital flight opportunities, and advancements in small satellite technologies and systems.

NASA also funds Exploration Technology Development at $202 million to invest in the long-range technologies required for humans to explore beyond low-Earth orbit. ETD technologies are higher risk investments that complement architecture and systems development efforts within Exploration by maturing breakthrough technology prior to integration with operational capabilities. As projects are matured, new projects are selected competitively to provide the opportunity to develop the best ideas, innovations, approaches and processes for the future human space exploration efforts.

Funded based on a percentage of the Agency's total extramural R&D, the Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs continue to support research and development performed by small businesses through competitively-awarded contracts. Estimated at approximately $173.7 million in Fiscal Year 2013, these programs produce innovations for both Government and commercial applications. SBIR and STTR provide the high-technology small business sector with the opportunity to develop technology for NASA, and commercialize that technology to provide goods and services that address other national needs based on the products of NASA innovation.

Partnership Development and Strategic Integration, funded at $29.5 million, comprises key Agency responsibilities managed by OCT: technology partnerships, technology transfer and commercialization, and the coordination of NASA's technology investments across the Agency through technology portfolio tracking and technology road-mapping. By providing coordination between Mission Directorates and Centers, and identifying collaboration opportunities with other government agencies and performing technology transfer, NASA can deliver forward-reaching technology solutions for future science and exploration missions, and help address significant national needs.

Within this portfolio, OCT engages in national technology development initiatives such as the National Robotics Initiative, the National Nanotechnology Initiative and the Advanced Manufacturing Partnership, and seeks partnerships with external entities for collaborative technology development. OCT engages the larger aerospace community including other Government agencies, and where there are mutual interests, develops partnerships to efficiently develop breakthrough capabilities.

Education

The Fiscal Year 2013 request includes $100 million for NASA's Office of Education to develop Science Technology Engineering and Mathematics (STEM) education activities that only NASA can provide. The funding request would allow undergraduate and graduate students to work alongside NASA scientists and engineers through internships and fellowships at NASA centers. It includes educator professional development, helping our country's educators become proficient in STEM topics, and providing them opportunities to practice hands-on investigations. NASA will also continue to support the institutions where learning takes place.

Through the Space Grant and Minority University Research and Education projects, NASA will work with hundreds of universities and community colleges, strengthening their capacity to train the next generation of scientists and engineers, encouraging student design challenges, and connecting faculty with NASA research. And, because we know inspiration doesn't just happen in a classroom, we will engage learners in NASA content at our visitor centers and in partnership with museums, science centers, planetariums and other informal education venues.

NASA is one of many Federal government programs that support STEM education. NASA is working with other agencies through the National Science and Technology Council's Committee on STEM Education to effect optimal revisions to fund coordinated and effective student and teacher opportunities. NASA will focus its resources on demonstrated areas of strength in its unique role in STEM education. NASA brings many assets to support the Administration's emphasis on (STEM education beyond funding. Our people, platforms like the ISS and our facilities across the Nation all contribute to strengthening STEM education.

Recognizing that the nature of our work is inspirational to learners and educators, NASA will leverage the talents of our workforce to support the critical STEM education needs of our Nation. In collaboration with other Federal agencies, NASA will leverage unique assets like the International Space Station (ISS), to provide meaningful experiences. In March, Educator Astronaut Joe Acaba, a former middle and high school teacher, will begin a six-month mission onboard the ISS. During his time in space, he will work closely with our education team on the ground to share his experience with classrooms across America.

Cross-Agency Support

The Fiscal Year 2013 budget request includes $2,847.5 million for Cross-Agency Support, which provides critical mission support activities that are necessary to ensure the efficient and effective operation and administration of the Agency. These important functions align and sustain institutional and program capabilities to support NASA missions by leveraging resources to meet mission needs, establishing Agency-wide capabilities, and providing institutional checks and balances. Within this budget request, NASA has taken steps to reduce its administrative expenses, including a hiring slowdown and reduced travel.

NASA's Fiscal Year 2013 budget request includes $2,093.3 million for *Center Management and Operations,* which funds the critical ongoing management, operations, and maintenance of nine NASA Centers, as well as associated major component facilities. NASA Centers continue to provide high-quality support and the technical engineering and scientific talent for the execution of programs and projects. This technical expertise represents a true national resource. Center Management and Operations provides the basic support required to meet internal and external legal and administrative requirements; effectively manage human capital, information technology, and facility assets; responsibly execute financial management and all NASA acquisitions; ensure independent engineering and scientific technical oversight of NASA's programs and projects in support of mission success and safety considerations; and, provide a safe, secure, and sustainable workplace that meets local, state, and Federal requirements.

NASA's Fiscal Year 2013 budget request includes $754.2 million for Agency Management and Operations, which funds the critical management and oversight of Agency missions, programs and functions, and performance of a broad spectrum of NASA-wide activities. These programs include Safety and Mission Success activities, essential to reducing the likelihood of loss of life and likelihood of mission success in our human and robotic programs. Safety and Mission Success funding supports the maintenance of independent safety, health, medical and engineering assessments of systems and processes, as well as the performance of the broad risk assessments, mitigations, and acceptance related to critical Agency decisions. Agency Information Technology Services (AITS) encompasses Agency-level cross-cutting services and initiatives in Information Technology (IT) innovation, business and management applications, and infrastructure necessary to enable the NASA Mission. The Strategic Capabilities Assets Program (SCAP) ensure that vital Agency test capabilities and assets, such as flight simulators and thermal vacuum chambers are sustained in order to serve Agency and national needs. The Agency Management and Operations account funds salary and benefits for civil service employees at NASA Headquarters, as well as other Headquarters personnel costs, such as mandated training. It also contains labor funding for Agency-wide personnel costs, such as Agency training, and workforce located at multiple NASA Centers that provide the critical skills and capabilities required to execute mission support programs Agency-wide.

Construction and Environmental Compliance and Restoration

The Fiscal Year 2013 budget request includes $619.2 million for Construction and Environmental Compliance and Restoration. NASA Construction and Environmental Compliance and Restoration provides for the design and execution of all facilities construction projects, including discrete and minor revitalization projects, demolition of closed facilities, and environmental compliance and restoration.

The Fiscal Year 2013 budget request includes $552.8 million for the *Construction of Facilities* (CoF) Program, which funds capital repairs and improvements to ensure that facilities critical to achieving NASA's space and aeronautics programs are safe, secure, sustainable, and operate efficiently. The Agency continues to place emphasis on achieving a sustainable and energy-efficient infrastructure by replacing old, inefficient, deteriorated buildings and infrastructure with new, efficient, and high performance buildings and infrastructure that will meet NASA's mission needs while reducing the Agency's overall footprint and future operating costs. In August 2011, NASA opened the Agency's first building designed for "Net-Zero" energy operations, the Propellants North Administration and Maintenance Facility at the Kennedy Space Center in Florida. Two active programs that result in NASA achieving greater efficiencies and reduced operating costs are NASA's demolition program and recapitalization program, in which old inefficient facilities are replaced with new, efficient, consolidated facilities. Twelve horizontal infrastructure projects that sustain our major utility systems are included in this request; completion of these projects will reduce our usage of potable and process water, electricity and steam.

The Fiscal Year 2013 budget request includes $66.4 million for the *Environmental Compliance and Restoration* (ECR) Program, which supports the ongoing clean-up of sites where NASA operations have contributed to environmental problems. The ECR Program prioritizes these efforts to ensure that human health and the environment are protected. This Program also supports strategic investments in sustainable environmental methods and practices aimed at reducing NASA's environmental footprint and lowering the risk of future cleanups.

Conclusion

NASA's Fiscal Year 2013 budget request of $17.7 billion represents a substantial investment in a balanced program of science, exploration, technology and aeronautics research. Despite the constrained budget environment facing the Nation, this request supports a robust space program that keeps us on a path to achieving a truly audacious set of goals. NASA is working to send humans to an asteroid and ultimately to Mars, to observe the first galaxies form, and to expand the productivity of humanity's only permanently-crewed space station. We are making air travel safer and more efficient, learning to live and work in space, and developing the critical technologies to achieve these goals. The coming year will include the first commercial cargo flights to the ISS, a nuclear powered robot the size of a small car landing on the surface of Mars, and the launch of the Nation's next land observing satellite. We have spacecraft studying the Sun, circling Mercury, cruising to Pluto and investigating almost everything in-between. In the face of very difficult times, the American people continue to support the most active, diverse and productive space program in the world. We at NASA are honored by our fellow citizens' continued support and we are committed to accomplishing the goals that Congress and the President have laid out for us. The program described and supported by our Fiscal Year 2013 budget request represents our plan to accomplish those goals.

Senator NELSON. By the way, one of the differences between you and Dr. Tyson is you refer to it as MPCV, and he will refer to it as Orion.

[Laughter.]

Mr. BOLDEN. That is very true, and he is correct.

Senator NELSON. Senator Hutchison?

Senator HUTCHISON. Mr. Administrator, I heard what you just said, but here is how I come at my concern. I told you at our last hearing and also I have said to you in many meetings that we have had, I do support additional funding and the goal of a Commercial Crew vehicle because I think that is an important first step.

But I have always said that as long as it doesn't come from the future beyond low-Earth orbit that we are going to be on the same team. So you called me with your budget proposal that was going

to come out of the administration, and I see a $326 million combined reduction in Orion and SLS and a corresponding increase of $330 million for Commercial Crew.

And I was, frankly, floored, as you know from our conversation, that it would be so blatant to take it right out of Orion and SLS and put it into Commercial Crew, rather than trying to accomplish the joint goals that we have of putting forward both and making sure that we didn't take away from the timetables for the future to shore up the Commercial Crew. How can you explain that?

Mr. BOLDEN. Senator, the numbers that we submitted are numbers that are consistent with the plan that we had all gone over when we started talking about the development of MPCV and SLS. As I mentioned before, we had to make very difficult choices because we were $2 billion below what we thought we would be for a Fiscal Year 2013 budget.

Cuts came from everywhere. Reductions came from everywhere. What we tried to do was maintain a balanced program. In fact, what we did was submit a budget request for a balanced program.

And as I have mentioned, we have not slowed the development of SLS and MPCV. In fact, we have actually done some things that we did not know we were going to do. Our contractor, prime contractor for the Orion spacecraft has put in a 2014 test that Senator Nelson mentioned. That was not originally in our plan.

The exploration vehicle flight test, which will be flown 2 years from now in 2014, was not originally in our plan, and it is something that we have been able to find the funds to do. That will buy down significant risk on Orion, and it will keep us from having to worry about some things that we would have to either pay for or even take time to do in subsequent development.

So that is going to allow us, actually, to get to the 2017 date, which is the first uncrewed test of the integrated system, and that is very important for us. You know, more money would not change that date. That is development work that we have to do.

Getting there, I feel much more comfortable now that we have the 2014 flight test planned that Lockheed Martin is going to do on Orion.

Senator HUTCHISON. What concerns me is not those two dates, the 2014 and the 2017. But you have now put dates on a crewed launch of the Orion onboard the SLS for 4 years later at 2021. Now I have heard you say that, well, it takes longer to complete the human safety ratings for the vehicles, and we need to have catch-up time.

But 4 years gap doesn't seem to square with staying on a course for that future when the Space Station is going to be presumably shut down in 2020.

Mr. BOLDEN. Senator, actually, what we need to do is we will go through another—in this year, we will have a much better feel for where we are in terms of the progress of our development, and that date may change. But that is a date that we look at right now based on a level budget run-out.

The 2021 date is a date that is affected by budget. And given the budget run-out that we see right now, that is the date that is there. But we still have some more evaluations in our planning to do before we are able to actually make a definitive decision on the first

date for a crewed launch. But 2021 is—I am a conservative person, and 2021 is a conservative estimate for the first crewed mission on the integrated SLS/MPCV combination.

Senator HUTCHISON. Well, you said that everybody had to be cut some to make the priorities. But in fact, the Commercial Crew vehicle approach that you are taking was not cut. It was plussed up from last year's spending levels.

And yet you cut the Orion and SLS to presumably make that happen. I mean, it was almost exactly the same amount of cut in the SLS and Orion that was plussed up in your budget for the crew, which continues to come back as some sort of quid pro quo that you are overprioritizing the commercial and not being as concerned about keeping the people at NASA who would be able to stay involved to get us to that next level when the Space Station is going to be decommissioned.

Mr. BOLDEN. Senator, you commented about a number of things. Just very briefly I would say our workforce is stable. I am not doing anything that will take away from the NASA workforce.

But I do want to say that in terms of the Commercial Crew program, I do need to take us back——

Senator HUTCHISON. Are you saying that with the $330 million cut that it is not going to affect the NASA workforce?

Mr. BOLDEN. I am saying that the NASA workforce, the SES workforce, the 17,000-plus people that we have right now, as far as we see is stable to a certain point. You know, everybody, we are looking at how we move the skills around.

So our center directors right now are working to determine how they take the projects that we have assigned them and how we may need to move skills around or bring in. We want to bring in fresh blood, if you will. We are looking for how we take some of the interns and co-ops that we train and employ them.

So those are issues of workforce that we are looking at. But the civil service workforce I don't expect to be affected by this budget. This budget enables us to keep our civil service workforce relatively stable for now.

What I do want to emphasize is when we talk about Commercial Crew, it is very easy to use $406 million as a baseline. That is not the baseline. If you all will recall, my original request, my original request was over $1 billion.

We brought that down for Fiscal Year 2012 to $850 million. We were cut by half. When I was asked last year what effect does it have if you don't get $850 million, I said that directly affects the date of delivery of Commercial Crew capability. That is how we got to 2017, instead of 2015, 2016.

And any subsequent reductions from what the President has requested for Commercial Crew only serves to delay the amount of time that we have a commercial and American capability to get our crews to the International Space Station. The reason I wanted to emphasize the importance of ISS is I have to be able to support that.

You know, I am not worried about it right now for cargo because of STS–134 and STS–135 that this Congress funded after the President's request. So we all worked together to get that, and it is really important that we got STS–134 and 135 flown. Because now,

with the delays that we may see in getting to a viable crew and cargo program, we are not worried about having to de-man station.

I need to get American crews to station on American vehicles, and decreasing the amount of money below $829 million, what we request, will not help close that gap.

Senator HUTCHISON. Mr. Administrator, we agree that we need to get the Commercial Crew up so that we are not dependent on the Russians. In our authorization bill, we provided the allocations that would allow that to happen without taking from the longer term, the beyond low-Earth orbit vehicles.

The authorization level was $500 million. That was signed by the President. That is part of the agreement. So when you come in and ask for $850 million, and you take it right out of Orion and SLS, we have got a disconnect here if you are saying that is the baseline budget. No, no, $500 million is the authorized level.

So I want to ask you a question because I have been looking at this and trying to get a way forward that the crew—the Commercial Crew vehicle can go forward with a reasonable level. We can also not stop the beyond low-Earth orbit. Both the NASA employee base and the commercial vehicles can go forward. And here is the line that I would like to take and have your response.

And it is in the insistence on spreading the money out to some multiples—three, maybe more companies, commercial companies—to subsidize these companies, which some of them are not going to be able to function if they don't have these subsidies once you make a decision about who is going to do the vehicle. So we are essentially throwing a lot of money at some companies that may never be able to use it to the taxpayer advantage.

You reversed a previous decision to use a Federal acquisition regulations-based procurement for Commercial Crew in the next phase leading to the critical design review of the various systems, and you have gone back to the use of the Space Act Agreements. The Aerospace Safety Advisory Panel recently issued its report expressing some concerns about this approach and the degree to which it can enable NASA to ensure that safety standards are being met.

So I am just wondering if you are going to put off the safety-related human rating requirements to that next level, isn't there maybe an overspending at this point in the proliferating of companies that are getting the Federal subsidies?

And couldn't you, number one, make the Commercial Crew developers more accountable in the early stages if you cut back on the number of companies that you are dealing with and go back to maybe the more traditional approach of setting the designs and the standards and then going out for bids, and lowering the number of subsidies you have to do of private companies to maybe two, instead of three or more? And spend the taxpayer dollars more efficiently and be able to do the job that we want you to be able to do for Commercial Crew, and also keep the ongoing coordination with your NASA-based SLS and Orion development and have a win on both sides?

Mr. BOLDEN. Senator, let me offer this. If I had made an earlier decision to go with one of the two companies that were believed to be competitors for Commercial Crew, Boeing would not be in the competition now.

Senator HUTCHISON. And I am glad Boeing is.

Mr. BOLDEN. I am just saying——

Senator HUTCHISON. But we are where we are. We are not back there.

Mr. BOLDEN. Senator, I am just saying——

Senator HUTCHISON. And I am glad Boeing is in——

Mr. BOLDEN.—for those who would like to——

Senator HUTCHISON. That gives me comfort.

Mr. BOLDEN. For those who would like to see me make a decision on a company now or would like to have seen me go with a contract in February, as my original acquisition strategy stated, the experts, people who are considered to be experts in acquisition and funding—GAO, the NASA ASAP, my OIG—many of them said, given the budget, given you have now $406 million, we think it is prudent—this is their direction to me.

We feel it is prudent for you to review your acquisition strategy and maybe not go with the strategy that you presently have. No one was as reluctant as was I to change my mind on the acquisition strategy.

We had come to the strategy that we had after long deliberation. So to go back and say we are going to extend the use of Space Act Agreements was not something that was, you know, tops on my list of things I want to do.

However, I felt very comfortable in doing that because we had adhered to the insistence from the ASAP, from the Aerospace Safety Advisory Panel, that we put requirements and specifications in place so that any person planning to bid on a Commercial Crew system—not a vehicle, on a system—and that is what we are talking about now, would know what NASA's requirements are, would know what NASA's human rating specifications were, and would have no ground on which to stand to say, well, in this design that we developed, we didn't know you were going to.

No one can say that because there are hard requirements out there right now that anyone who gets a contract will have to follow. There are hard specifications for human rating standards that everybody knows that is what, they have them in hand. They cannot say, "I don't know."

The problem, there is no problem of safety with going to Space Act Agreements. The Space Act Agreements input program risk, not safety risk. I am responsible for safety. And as I have said from the day that I became the Administrator, I will not jeopardize safety for crews.

Safety is not being jeopardized by going to the Space Act Agreement, expanding that. We still will guarantee safety.

Senator HUTCHISON. But the budget and the future, Mr. Administrator, the budget and the future are being jeopardized. So if you say the safety is there, why not go to fewer companies now? Now that you do have the ones that are going to be the most serious contenders, why not go like they did the F–35, for instance, where you did go through two pretty comprehensive competitions and do it within the budget that we have agreed to that was in the authorization?

Mr. BOLDEN. The F–35 is not a great example. It is not a good comparison because there was a long road before getting to that

point where they came down to two competitors. They went through much of what we did.

But I need to give these companies time to learn lessons that NASA has learned through blood, and that is the advantage of extending the Space Act Agreement period of time. It is now giving Ed Mango and his Commercial Crew team an opportunity to put people in the facilities.

We have NASA employees who are onsite with the contractors, acting as consultants, seeing how they perform, seeing how they do their work, overseeing what they do in terms—or not overseeing in terms of control, but looking at the way that they carry out their design and productivity.

We are much better off having a little bit more time to look at them and determine who the real players are, such that when we finally go out with a request for proposal 14 to 20 months after this that we know we will get a good product.

We still think we are going to have a crew system available in 2017. You know, that date is set. Now that is something that more money might be able to change. But for right now, 2017 is a date that is not in jeopardy with the President's budget.

If we have to extend any other periods, then the 2017 date becomes jeopardized, and our ability to support the International Space Station with American companies on American vehicles becomes jeopardized. And that is not where I want to go.

I am going to pay the Russians $450 million a year for every year that I don't have an American capability to put humans into low-Earth orbit. And I know you don't want to do that. You and I have both agreed. But that is the price I pay, $450 million.

If you add that to $406, I am up to $850 million. So I just—you know, I am trying.

Senator HUTCHISON. Mr. Chairman? I mean, Mr. Administrator?

Mr. BOLDEN. We are not taking money away from SLS/MPCV. The SLS/MPCV——

Senator HUTCHISON. But you are. It is clear. It is in the numbers, and it is irrefutable.

If you had the passion and the concern for the SLS and the Orion that you have for protecting whatever number of commercial companies that you want to put out there——

Mr. BOLDEN. Senator, not to get personal——

Senator HUTCHISON. I just think——

Mr. BOLDEN. My passion for SLS/MPCV exceeds anybody's in this room. So I just——

Senator HUTCHISON. Well, it is not shown in the numbers, Mr. Administrator. That is the problem.

Mr. BOLDEN. Senator, I fight for SLS/MPCV just as much as I do for every other of the three priorities we have agreed upon.

Senator HUTCHISON. It took us a year to even get a contract that would even begin to be put out there. The NASA administration has drug its feet on the other of the human space flights that we have on our agenda and continues to push above the authorization levels and act like that is the baseline budget.

And I think if you just would open your mind to the possibility that you could cut down the number, but not the amount of emphasis that you have in the commercial sector that we could do both.

Mr. BOLDEN. Senator, when we cut down the number of——

Senator HUTCHISON. And I am just trying to get a way forward.

Mr. BOLDEN. When we cut down the number of competitors, we will probably drive up the cost. I am paying right now a set amount in a Space Act Agreement. We have a set amount. So I will either have $406 million for the next 5 years or I will have $406 million this year and then $829 the next that I can contribute as a partner.

Whatever it cost over that for development is coming out of the pockets of those developers. It is not—it is not accurate to think that we are subsidizing a company. We are a partner.

And whereas NASA would be paying the development cost, as we did for all of the weapon systems and everything else, we are not paying the development cost right now. The company is paying the development cost minus whatever I can give them through the COTS program, through the Commercial Crew program, through other programs.

It is really important to do that. Once we sign a contract, then I am on the hook to pay for whatever they say it is going to cost. There is no sharing anymore. It is now my cost. They don't put in a penny.

So if the bill is $1 billion, I get it. The American taxpayer gets it, and that is where it is going to be. If there are mistakes made in the design because I cut them short of this 14-month period that we are giving them right now and there are engineering changes required, I am going to get that bill. The American taxpayer is going to get that bill.

I know it doesn't seem like it, but this is going to be cheaper for the American taxpayer in the long run. We are going to get a much better product in the long run. We are doing what we can.

We took the best we had from previous programs and put them into SLS and MPCV. That is why I am so confident about that program. There are a lot of knowns in SLS/MPCV. You look at the first stage propulsion system. Those are Shuttle main engines.

You look at the upper stage rocket that we one day will have, the J–2X, we are testing that engine. We are getting confidence in that engine.

You look at the basic design of the vehicle. It is stuff that we are very familiar with. The only unknown is what the boosters are going to be because we know we have got to have advanced boosters. And industry is coming in, even as we speak, with recommendations on what those advanced boosters will be, and we are going to get the best that American industry can provide.

So I am much more confident, you know, about SLS/MPCV, and that may be the reason that it appears that I am not passionate about it. I am incredibly passionate. But I am also a lot more confident because this is something that we are lot more familiar with, to be quite honest.

Senator HUTCHISON. Thank you, Mr. Chairman.

Senator NELSON. Thank you, Senator.

General Bolden, we are going to—I want to recall for everybody here the history of how we got it to where we are on the amount of money for the commercial rockets. Remember, it was the House of Representatives that had whacked the President's request of

$800 million down to $300 million. We in the Senate had passed an appropriation of $500 million.

And so, naturally, in the Conference Committee, we were able to get it up—primarily, Senator Mikulski, the Chairman, and her Ranking Member on the Appropriations Subcommittee, Senator Hutchison—to get it up to $406 million.

Now I am very sympathetic to what you are saying, that in order to stay on a schedule of 2017 to launch Commercial Crew, you are going to need more than $406 million. So, in these constrained budget times, the question is where are we going to get that?

We certainly don't want to take it out of the big rocket or Orion. But I also am concerned about the fact that on the big rocket, it is great we are going to test it in 2014. That's in 2 years. We are going to start launching big systems in 2 years, and you are going to do a more outfitted test in 2017.

But then it takes 4 years, from 2017 to 2021, before you put the first crew onboard. Now something just doesn't seem right there. Why the delay of 4 years?

Mr. BOLDEN. Senator, as Bill Gerstenmaier has testified before this and other committees, the development program for the SLS/MPCV, for the system, is a very complex program. We are still looking at what we have to do once we fly the test on Orion in 2014. We still need to understand what challenges we have in this development program.

So it is actually—I would hate to say it is too early, but it is too early to say definitively how long it is going to take to get to first human flight. We have said before there are ways to fly earlier.

It is a matter of budget, if you talk about can you fly a year earlier or 2 years earlier? But there are other things that we just don't know yet. We don't know how well our processes are going to respond to changes that we have made. We don't know how rigorous our management techniques are going to have effect.

Efficiencies that we have tried to put into this system and its development based on lessons we learned from Constellation, it is just too early for us to know whether those have taken effect or not yet. I could assume that we are going to get the efficiency gains that we are counting on, but that would not be very good because I would find myself back in a situation as we were with Constellation where we now don't have enough money, and we don't have enough time to meet the date that I promised you.

2021 is a conservative estimate, and we feel confident we can get there with the budget that we have and the budget we are submitting for 2013 with the run-out that is there right now.

Senator NELSON. Well, remember also in the context of where we come today, the House of Representatives had also basically eliminated the James Webb Space Telescope. And in the attempt in the Conference Committee to get that money back in so that James Webb could proceed, which is going to take us back almost to the beginning of time in the universe and, therefore, is an extremely important scientific mission, but with a limited amount of money, we know we are asking you to do an awful lot.

But they came a long way to get it up to $406 million for Commercial Crew and put back the money for James Webb. So what we need to do is work with you at coming up with a number for

Commercial and not at the same time sacrifice anything on the big rocket and Orion.

For example, you have got a request of $200 million less for Orion than was enacted in 2012. So there is less money in your request for Orion than was put in for Orion in 2012, and we have just got to work this out.

Mr. BOLDEN. Yes, sir.

Senator NELSON. All right. Before I turn to Senator Rubio, let me ask you about one of the good news things, at least from the Kennedy Space Center standpoint, is the significant amount of money that is going in to redo the space center in order to accommodate all of the new rockets and the new changes.

But in the way that it is put about in the budgeting, it gets confused. It looks like 21st century is diminished when, in fact, a lot of getting ready for the 21st century space program is you can't fly a rocket unless you have a launch pad.

And so, there is a lot of construction money in this Fiscal Year between now and September the 30th of this year that is going to be going into the redoing of facilities at Kennedy Space Center. You want to comment about that?

Mr. BOLDEN. Senator, I thank you very much.

There are a number—what we tried to do in working with the staff and the Committee here is to break out funds in a method that would be much more understandable to people, and this is an area of concern when we look at—when we use the term SLS, heavy lift launch vehicle, if you look at where we were last year, that was the broad category for everything that had to do with heavy lift.

What we have tried to do in this budget and what we are doing in practicality is we break out funds that are spent on ground systems, not the vehicle itself, into what we call exploration systems, exploration ground systems and 21st century. Very simply stated, maybe oversimplifying it, 21st century deals with making the launch complex at the Kennedy Space Center a multiuse facility. So it serves both SLS and commercial—future commercial users.

Things very simple, like putting in the flame trench a movable deflector, so that the rocket used, we can move the deflector to one position for an Atlas, if you were to put it there, and another position for a Falcon 9.

The exploration ground systems deal strictly with SLS/MPCV. So they are divided into three other systems. One of them has to do with command and control. I need those systems in place before we fly the 2017 mission. I need those systems in place for the folk at Kennedy to be able to go through simulation so that when we bring the vehicle down and we decide we are going to launch, they have been through simulation training and the like.

Some of it has to do with the infrastructure itself. So there are three different categories of the exploration ground system. So you will see now, and I don't have it memorized, but I think we actually have budget lines now for exploration ground systems, for SLS, for 21st century, and then for SLS, which is vehicle development itself.

So we hope it will make things clearer to people when we look at it that way.

Senator NELSON. Well, I just want to make clear for the record, for those elsewhere in the country that are questioning the construction projects at the Kennedy Space Center, those other areas of the country that are building rockets, that you can't launch rockets unless you have the launch pad. And so, you have to do one in order to do the other.

Senator Rubio?

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

Senator RUBIO. Thank you.

[The prepared statement of Senator Rubio follows:]

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

Thank you, Mr. Chairman.

I want to start by thanking Administrator Bolden and Dr. Tyson for appearing today before our committee. Thank you both for the work you are doing for our Nation's space program.

I think it is safe to say that all of us here today are strong supporters of our space program. We know what NASA is capable of, and we recognize the unique and irreplaceable asset that is our space workforce.

We want the United States to maintain the lead in human spaceflight, and we all believe in the space program and what it provides for our country.

So the question is how we find a budget that accomplishes all of these things. We know that cuts have to be made to NASA's budget. They have to be made to every agency's budget.

Because the bottom line is that our Nation faces a debt crisis in the near future because, quite frankly, politicians in both parties have spent recklessly for many decades and been unwilling to reform and save crucial safety net programs that are simply going bankrupt.

This will require Washington to finally live within its means and for leaders to make tough choices about what our Nation's priorities are.

NASA is no exception. It will not be about spending more. It will be about spending wisely. It will be about balancing priorities.

Everything we discuss at today's hearing, whether it's commercial space activities or going to Mars, is all tied to, and affected by, our national debt.

We often hear about how our debt is a burden that hangs around the government's neck. Or even worse, that it saddles future generations of Americans—my children and future grandchildren—and what they will be able to accomplish in the future.

This is a fact, and our debt will certainly have the same impact on NASA. All of our future exploration plans and technology investments will be impacted by our national debt and by our government's ability to solve this crisis.

I hope that we discuss these issues today, and I look forward to hearing from Administrator Bolden on how our fiscal crisis is affecting the agency's ability to plan for the future and accomplish the big things that we know NASA can do.

Mr. Administrator, I hope that you, NASA and Congress can work together to answer these questions.

Thank you, Mr. Chairman.

SENATOR RUBIO. And my first question was along those lines, too. We have heard some of the same observations made by some that why are we spending so much money on the 21st century launch complex if we don't have a system in place yet?

And I think you touched upon it. You may want to add to that because the notion of how we need to do those simultaneously is so critical—could you touch upon why it is so important we do both at the same time?

Mr. BOLDEN. What we are trying to do, and even when you look at the vehicle development itself, SLS and Orion, we want to be able to reach a date in the future when everything comes together.

It doesn't do us any good to have an Orion vehicle that is ready to fly a year before I have a launch vehicle.

It doesn't do me any good to have a launch vehicle ready a year before I have a crew module to put on it. And it definitely doesn't do me any good if I have Orion and SLS teamed together ready to launch, sitting in the VAB because the launch facility is not complete.

So we are running programs in parallel. The ground systems development, the 21st century, SLS, MPCV—they are four separate entities, but we are running them and funding them in parallel so that they all come together at a critical time for us. That critical time right now is 2017.

And the way that we have submitted the budget, the way that—if you look at our PERT charts that some people used to use a long time ago. But if you look at our planning charts, which is the schedule, you will see that we are moving along such that everything comes together in time to support a 2017 launch.

And that is oversimplification, but hopefully, that helps.

Senator RUBIO. On the overall topic as we talk about funding today, I mean, clearly, the issue that hangs over the space program is the fact that at a time of growing national debt and fiscal constraints, we are trying to figure out a way to keep our leadership in space, but do so with limited resources that—and I don't think there has ever been a good time to waste money—more than ever before requires us to look at every penny that we spend.

And so, in that debate, we have heard a lot of conversations, rightfully so, about what role NASA is going to play and our own launch operations. But we are on the verge of what I think is an historic milestone, and that is both SpaceX and Orbital Sciences and others that are about to do some of these test launches for cargo missions.

I think there is no doubt that that is going to be an inevitable part of our space program. The commercial component is going to be a part as we move forward and, in fact, may free up NASA to do some other things in deep space and otherwise by allowing us to rely more on those sorts of things.

Can you talk a little bit about that? Because I think, obviously, those of us who are familiar with the space program hear about it every day. But there is a real lack, I think, of public information, and it is no one's fault, but I am shocked at how many people don't realize that we are on the verge of that launch, which I think is now scheduled for SpaceX?

Mr. BOLDEN. SpaceX is now the end of April-ish and Orbital sometime in the summer.

Senator RUBIO. What do those launches mean from a historical perspective?

Mr. BOLDEN. They are historical milestones, very simply put. We have never had a private company launch a rocket with a capsule on it for any purpose, put it in orbit, rendezvous with another vehicle that has humans in it, station keep, be attached to that vehicle, which is the International Space Station, such that it becomes an integral part of the International Space Station. Take the all-important step of opening the hatch, okay? Opening the hatch.

Which means that now the existence of the International Space Station is dependent upon the structural integrity of Dragon or of Cygnus. That is an historical milestone. When we can open the hatch on a private vehicle and have everything stay intact and still useful and people breathe, that is pretty important.

And that is what is going to happen when SpaceX flies at the end of April, and that is what will happen again when Cygnus flies in the summer. That is critical. And if I were talking to the Cub Scouts that Senator Hutchison had, Senator, I thank you so much for spending your time. I know you got a lot of things you could do.

You could do nothing more valuable than spending your time with the Cub Scouts because that is the future. One of them is going to be sitting here in this chair, trying to demonstrate that they are passionate about this stuff to somebody who is going to succeed Senator Hutchison. But they are not going to do it if I don't have a program for them to be inspired by.

And so, what you talk about, this that is going to happen this spring and summer is a critical first step. It says American companies can, in fact, do what foreign companies do. We know we can do that. We have done it throughout history. But we don't have the capability to do it right now, you know?

We don't have an American company that has demonstrated its ability to launch, rendezvous with, and be berthed to the International Space Station.

Senator RUBIO. But that leads to the follow-up question because I am out of time, and it is not really a question. It is more of asking for your observation of what that means from the mission statement of NASA at this point.

For example, it is my guess now and a lot of these issues are issues we have now been confronting for a couple of years at the Federal level, although I am familiar from my state experience of the importance that these launch capabilities are to Florida. So now you are assuming that a couple of years out, we begin to have a very reliable private sector, commercial capability to do certain things, that frees up NASA to do what?

Mr. BOLDEN. That frees us up to spend our time and effort on completing the development of the exploration vehicles that Senator Hutchison is so—about which she is so passionate. It frees us up to focus our efforts on getting humans beyond low-Earth orbit to places like an asteroid, where the President has told us to go in 2025, to the Martian environment in the mid-2030s. It frees us up.

Most importantly, though, a thing that we don't talk about very often. In fact, we probably never talk about it. In the National Space Act that established NASA in 1958, even back then, people were smart enough to know that NASA's job is to create technologies that can be transferred into the private sector for the benefit of the American economy.

The big thing that Commercial Crew and Cargo are going to bring to this country is the ability to provide a market for people all over the world who want to take things to low-Earth orbit. They won't have to go to Ariane. They won't have to go to Russia. They won't have to go to China.

They won't have to go anywhere. They can come back to American shores and put their spacecraft on an American rocket and get it to low-Earth orbit. That is the economic benefit of what we are about, and that is one of our priorities in the National Space Policy of 2010 that was signed into law by the President.

And it is a very important part of the 1958 Space Act and its attendant modifications through the years. But we don't talk about that very often.

Senator NELSON. We will wrap this up with one additional thing that I want to ask you, Mr. Administrator.

The NASA Inspector General, Paul Martin, recently testified before the House that NASA has been the subject of numerous cyber attacks, some potentially stemming from foreign intelligence agencies and organized criminal enterprises. And he stated, and I quote, "Skilled and committed cyber attackers could choose to cause significant disruption to NASA operations, as IT networks are central to all aspects of NASA's operations."

Now let me just say that we have spent a great deal of time on this in the Intelligence Committee, and of course, the attacks are attempted every day, as I mentioned earlier. And they are attempted at all Government agencies, and thus far, with the national security agencies, we have been able to protect against those cyber attacks. There are state actors out there. There are nonstate actors that every day are trying to penetrate the computers.

But with regard to NASA, in light of your IG's report, I want to ask you three questions. Have there been any instances where a cyber attack has resulted in disruption of a NASA mission?

Mr. BOLDEN. Senator, there have never been any that we have been able to find.

Senator NELSON. Second question. Have there been any cases where you suspected a cyber attack impacting a mission?

Mr. BOLDEN. Senator, to my knowledge and in my query of my folk, there have never been any that we suspected that there was anything that would have had an effect on a mission.

Senator NELSON. So the loss of the algorithms with regard to some of the functions on the Space Station, there is no evidence that that had any effect upon the operation of the station?

Mr. BOLDEN. Senator, there was no effect on the loss of anything on station. But I do need to elaborate a little bit, if I may?

No one is as concerned about cybersecurity and IT security as I. And you have heard this from the head of the NSA, from the Chairman of the Joint Chiefs of Staff, from the Secretary of Defense, this is a serious threat.

There are three areas when we talk about IT that concern us all. One is thefts and losses, and we talked about this a little bit before. One of the things that I am doing is emphasizing to our employees that they have to be vigilant. They can't leave a computer, a laptop—you know, a laptop that has NASA information on the front seat of a car.

Locking the car with a NASA laptop is not sufficient security. They can't put it down when they go to an airport. That is personal discipline and the like, and we can affect that. You know, we can't affect someone breaking into an office at NASA headquarters and stealing a laptop or a computer.

The other one is hacking and intrusion. That happens to all of us, and I don't know that we are ever going to stop that. But what we do is we put safeguards in place. If you are talking about the International Space Station, it is not impossible to do anything. But right now, we are confident that we have a system of encryption. Any command that goes to the International Space Station, any critical command goes through an elaborate system of encryption.

So, first of all, there would be no commands on a laptop that would be—that someone would be carrying around. So that I am not concerned about. But any commands that are going to go from a console, whether it is at Huntsville or Moscow or anywhere, has to go through a system of encryption at the Johnson Space Center.

In the case of disasters where we would transfer responsibility to Huntsville, Alabama, it would go through the same encryption at the Marshall Payload Operations Center, which would assume control.

So the third area is encryption. And that, again, is personal behavior and discipline. And if you are—what we will tell our employees, if you are going to put what we consider to be critical information on a laptop, encrypt it. It is very simple. Just encrypt it such that if your laptop falls in the hands of someone else, they have at least got to go through some effort to get it.

They don't just open up the laptop, turn it on, and there is everything, as the IG, I think, may think happened in this case. But I don't know that that really happened. We haven't had an opportunity to look at the report and the evidence that he has to even determine whether someone really did have vital data that was readily available on a laptop.

Senator NELSON. So you think the algorithms were lost because they were on a laptop?

Mr. BOLDEN. Senator, I don't—again, what I have to say is the issue that Paul Martin raised is in a pending report that I have not seen. So I would rather not comment on the contents of what was in his report.

I have checked in my organization, and to my knowledge—but I will take it for the record—we have not seen the report to which he referred. So we definitely have not seen the information that he has or the evidence that he has. So I would not even—I can't even say that there were algorithms on the laptop. But I will take that question for the record and get back to you.

Senator NELSON. But you can assure this committee that were the algorithms to get into some third party's hands that wanted to do something bad, that they couldn't because you encrypt any of the commands that go to the station?

Mr. BOLDEN. Senator, I can assure you that if, in the unlikely event, someone ended up with a laptop that had critical commands for the International Space Station or any of the payloads onboard, if that unlikely occurrence happened, they would still have to get through another set of firewalls at the Johnson Space Center because everything that goes to the International Space Station, as it did with Shuttle, is encrypted prior to transmission.

And we have verified that. So they would not be able to get commands to the International Space Station.

Senator NELSON. OK. As you are doing your investigation, you might also find out why only 1 percent of NASA laptops and portable devices are encrypted versus a Government average of 54 percent?

Mr. BOLDEN. And Senator, that is the encryption issue that I mentioned that I can take action there, and I intend to do so. I can make it a policy or reemphasize the policy that when critical information goes onto a laptop or a personal device that it is encrypted or it not go on that device. That is a matter of behavior and personal discipline. That is not a foreign entity.

Senator NELSON. But it is also a matter of policy.

Mr. BOLDEN. That is a matter of policy, sir.

Senator NELSON. And that is why is NASA so far behind the rest of the Government in securing the data on its portable devices?

Mr. BOLDEN. Senator, I will try one more time. Prior to this week, it was my impression that I had established a policy that said no one would do what they did. So, once again, it is the leader who thought something was done and now has to go back and find out whether it was really done.

Senator NELSON. And so, the way we can wrap this up is if you will just give us a full briefing——

Mr. BOLDEN. Yes, sir.

Senator NELSON.—classified if necessary, once you have reviewed the IG's report.

Mr. BOLDEN. Yes, sir.

Senator NELSON. And then in that briefing tell us the procedures and what you do to investigate those occurrences that are mentioned in the IG's report.

Mr. BOLDEN. Senator, I will be certain to do that.

Senator NELSON. OK.

Senator Boozman?

STATEMENT OF HON. JOHN BOOZMAN, U.S. SENATOR FROM ARKANSAS

Senator BOOZMAN. Thank you, Mr. Chairman and Ranking Member.

I apologize for not being here earlier. I had a couple of people from Arkansas that I had to introduce at another committee. But I think in the interest of time that I will go ahead and just listen.

[The prepared statement of Senator Boozman follows:]

PREPARED STATEMENT OF HON. JOHN BOOZMAN, U.S. SENATOR FROM ARKANSAS

Thank you, Mr. Chairman. I am glad that Administrator Bolden and Dr. Tyson can be here today to discuss with us NASA's proposed budget for Fiscal Year 2013 and the direction of this nation's civil space program.

It is important for us to have this hearing, not only to focus on the primary challenges and issues NASA is facing in maintaining active and balanced science and aeronautics programs, but also because we are in the midst of a dramatic shift in NASA programs and priorities, especially regarding the future of U.S. human spaceflight.

Since its establishment in 1958, NASA's flagship programs have targeted exploration, beginning with Mercury and Apollo programs and extending through the Space Shuttle, the International Space Station, space telescopes like the Hubble, Mars rovers and other planetary observations.

With the final flight of the Space Shuttle last year and the initiation of the Orion and Space Launch System programs, NASA's human space flight programs have been undergoing a major transition, with a rebalancing of priorities and workforce.

I share Senator Hutchison's concern that the Fiscal Year 2013 budget request for NASA, while reflecting what may appear to be a reasonable top-line amount in the context of anticipated cuts in many parts of the federal budget, does not closely adhere to and in fact could undermine in some cases, the very careful balance established in the 2010 NASA Authorization Act.

The budget request provides funding for the SLS (rocket) and Orion/MPCV(capsule) at levels that represent a combined total of $1.77 billion below the amounts authorized for Fiscal Year 2013—a 44 percent differential—and about 12 percent less than was appropriated in Fiscal Year 2012. I am concerned that this may not only serve to delay the actual vehicle development, but also increase NASA's risk for a successful and timely return to Human Exploration capability.

I continue to believe that the nation needs both a robust heavy-lift and crew exploration vehicle development to enable us to go beyond low earth orbit, and new commercial capabilities to launch crews to the ISS—but consistent with a balanced approach, as required by the 2010 Act.

The space program, of course, is more than human exploration, as critical as that is. The budget request raises concerns regarding the funding levels and future plans in the areas of Space Science, and in the realm of instrumented Mars Exploration, including potential U.S. withdrawal from planned cooperative missions with the European Space Agency.

Some of these adjustments, according to budget briefings, have been necessitated to accommodate increased funding for the James Webb Space Telescope (JWST) project. Other adjustments stem from the completion of prior Mars Exploration missions (Rovers Spirit and Opportunity, for example) and the ramp-down of their operational tempo and associated costs.

NASA officials have indicated to the Committee, and explained in the Budget Request justification documents, that they are taking advantage of this draw-down in activity to re-plan future missions, including new cooperative projects with other nations. That review is anticipated to be completed in the middle of this year, and reflected in the Fiscal Year 2014 and subsequent Budget Requests.

Notwithstanding those assurances, there are still concerns that the proposed adjustments in the funding and program priorities will have an adverse effect on this important area of NASA's overall mission and responsibilities.

I look forward to hearing from Administrator Bolden on these topics.

I also look forward to the testimony of Dr. Tyson and a discussion of the broader issue of the role and value of space exploration. I believe that a nation such as ours, that once led pioneered space exploration, and reaped the economic and cultural rewards of technological advancement, cannot and should not voluntarily cede that role to other nations.

Thank you again, Mr. Chairman, and I look forward to the testimony.

Senator NELSON. Thank you, Senator.

Senator Hutchison, any further comments from you?

Senator HUTCHISON. I think I have made my point, and I think he has made his point. And we just have to work together to, hopefully, get more flexibility.

Mr. BOLDEN. Yes, ma'am.

Senator NELSON. I think the long and short of it, of what we are saying up here, is that we want to see that Orion is getting sufficiently funded so that it is ready by the time the big rocket is ready, and not vice versa. And the other thing that I will say is that I think that we are going to have to have more money than this year's level into the commercial rockets so that we can at least keep on that 2017 schedule for launching humans to the Space Station.

And of course, my preference and I think most people's preference is if there is any way we could get those into 2016, which was the original target.

Mr. BOLDEN. Yes, sir.

Senator NELSON. So, with that, Mr. Administrator, thank you——

Mr. BOLDEN. Senator, thank you very much.

Senator NELSON.—very, very much.

And I would like to call up the second panel, Dr. Tyson.

[Pause.]

Senator NELSON. Dr. Tyson, we have already given you a glowing introduction and if you would please proceed?

We are looking forward to your testimony.

STATEMENT OF NEIL DEGRASSE TYSON, PH.D., ASTROPHYSICIST, AMERICAN MUSEUM OF NATURAL HISTORY; DIRECTOR, HAYDEN PLANETARIUM, NEW YORK CITY

Dr. TYSON. Thank you. Thank you, Mr. Chairman.

Senator Hutchison, Senator Boozman, thank you for your attention here.

I want to just preface this by saying I was born the same week that NASA was founded. And while that specific point is of little relevance to the words of my testimony, I would say it is of great relevance to the feeling with which I deliver these words, having the same life span.

I want to start off with a quote from a famous aviator, French aviator Antoine Saint-Exupery. This quote may be known to some of you, but I think it bears repeating often.

"If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work. But rather, teach them to long for the endless immensity of the sea."

So that is a point of view that will matter for what follows here.

Right now, NASA's Mars science exploration budget is being decimated. We are not going back to the Moon. Plans for astronauts to visit Mars or anywhere beyond low-Earth orbit are delayed until the 2030s on funding not yet allocated, overseen by a Congress and a President to be named later.

When I think of our golden era of space exploration, the late 1950s right on up through the early 1970s, over that time, very few weeks would go by before there would be an article in a newspaper, in a magazine where a cover story would extol the "city of tomorrow," "transportation of tomorrow," "the home of tomorrow," even "food of tomorrow."

And in spite of this optimism, that was a decade that was perhaps our most turbulent in a century since the Civil War itself. We all felt threatened from the Cold War, total annihilation, in fact. There was a hot war going on, losing 100 servicemen a week. The civil rights movement, assassinations, and the like.

The landscape was poisoned that decade. Yet one of the jewels in the American crown was our exploration of space. From what I can tell, the people who did the dreaming back then were the scientists, engineers, and technologists. And it is a community of people who were formally trained to discover.

They are discoverers. And what inspired them? Ask them. Every one, to a person, will tell you it was America's bold and visible investment in a space frontier.

Now, I happen to know, and we all have had this experience, exploration of the unknown doesn't always make a priority for people. I can tell you, however, that audacious visions have the power to alter mind states, to change assumptions about what is possible.

And when a nation allows itself to dream big, these dreams prevail in the citizens' ambitions. They energize the electorate.

During the Apollo era, you didn't need Government programs trying to convince people that doing science and engineering was good for the country. It was self-evident. And even those not formally trained in technical fields embraced what those fields meant for the collective national future.

Remember, that was the climate that birthed the New York World's Fair, which was all about tomorrow, and the iconic Unisphere, which donned three rings, evoking the three orbits of John Glenn in the Friendship 7 capsule.

During that age of space exploration, any jobs that went overseas were the kind nobody really wanted anyway. Those that stayed in this country were the consequence of persistent streams of innovation that could not be outsourced because other nations couldn't yet figure out how to do what it was we were doing. In fact, most of the world's nations stood awestruck by our accomplishments.

Let us be honest. Of course, over that period, we went to the Moon because we were at war. It is not a secret. To think otherwise would be delusional, and has lead some people to suppose we got to the Moon by 1969, of course, we are going to be on Mars by 1980.

No. Not if you went to the Moon because you were at war. And after you establish that the Soviet Union is not also going to the Moon, everything ends.

But ending the program came with a cost. Yes, war can get you to go to the Moon, even get you to go to Mars. But there is another driver that exists, another driver of great ambitions, and it is almost as potent as the need to protect your security. And that is the promise of wealth.

Nobody wants to die, of course, but nobody wants to die poor. Fully funded missions to Mars and anywhere beyond low-Earth orbit, commanded by astronauts who today would be in middle school, would reboot America's capacity to innovate as no other force in society can.

What matters here, in fact, are not spinoffs, although there are plenty of spinoffs that are fun to read about. NASA, every couple of years, puts out a document—NASA Spinoffs. I recommend everyone here review those publications if you haven't seen them.

But beyond the spinoffs, what matters are the cultural shifts in how the electorate views the role of science and technology in our daily lives. Because as the 1970s drew to a close, we stopped advancing a space frontier. The "tomorrow" articles faded. And we spent the next several decades coasting on the innovations conceived by earlier dreamers.

They knew that seemingly impossible things were possible, and others among them, those who saw what the previous generation had enabled, witnessed the Apollo voyages to the Moon, even though they were not a participant. And this is the greatest adventure there ever was. Yet if all you do is coast, eventually you slow down while others catch up and pass you by.

We have got symptoms in society today. We are going broke. We are mired in debt. We don't have as many scientists as we want or need, and jobs are going overseas. I assert that these are not iso-

lated problems, that they are the collective consequence of the absence of ambition that consumes you when you stop having dreams.

And the NASA portfolio, it is multidimensional. It taps the frontiers of biology, which we look for life on Mars; chemistry, physics, astrophysics, geology, atmospherics, electrical engineering, mechanical engineering. These are the classic subjects that are the foundation of the STEM fields—of course, science, technology, engineering, and math. And they are all represented in the NASA portfolio.

Epic space adventures plant seeds of economic growth because doing what has never been done before is intellectually seductive, whether or not we deem it practical. And when you conduct those exercises, the innovation follows, just as day follows night. And when you innovate, you lead the world, you keep your jobs, and concerns over tariffs and trade regulations evaporate.

The call for this adventure would echo loudly across society and down the educational pipeline. At what cost? The spending portfolio of the United States currently allocates 50 times as much money to social programs and education than it does NASA.

So the old argument, "why are we spending money up there and not down here?" is simply false. We are indeed spending money down here, to the credit of lawmakers who understand the breadth of priorities that face us.

Consider, however, that the half a penny budget that NASA receives, if you double it, twice that, as unthinkable such a step would be to so many, I assert that we can transform the country from a sullen, dispirited nation, weary of economic struggle, to one where it has reclaimed its 20th century birthright to dream of tomorrow.

And I ask you, how much would you pay to launch our economy? And from my scientific heart, I ask how much would you pay for the universe?

A slightly longer version of these notes have been submitted for the record. And thank you for your attention, Senator.

[The prepared statement of Dr. Tyson follows:]

PREPARED STATEMENT OF NEIL DEGRASSE TYSON, PH.D., ASTROPHYSICIST, AMERICAN MUSEUM OF NATURAL HISTORY; DIRECTOR, HAYDEN PLANETARIUM, NEW YORK CITY

If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea.—Antoine St. Exupery

Currently, NASA's Mars science exploration budget is being decimated, we are not going back to the Moon, and plans for astronauts to visit Mars are delayed until the 2030s—on funding not yet allocated, overseen by a congress and president to be named later.

During the late 1950s through the early 1970s, every few weeks an article, cover story, or headline would extol the "city of tomorrow," the "home of tomorrow," the "transportation of tomorrow." Despite such optimism, that period was one of the gloomiest in U.S. history, with a level of unrest not seen since the Civil War. The Cold War threatened total annihilation, a hot war killed a hundred servicemen each week, the civil rights movement played out in daily confrontations, and multiple assassinations and urban riots poisoned the landscape.

The only people doing much dreaming back then were scientists, engineers, and technologists. Their visions of tomorrow derive from their formal training as discoverers. And what inspired them was America's bold and visible investment on the space frontier.

Exploration of the unknown might not strike everyone as a priority. Yet audacious visions have the power to alter mind-states—to change assumptions of what is possible. When a nation permits itself to dream big, those dreams pervade its citizens'

ambitions. They energize the electorate. During the Apollo era, you didn't need government programs to convince people that doing science and engineering was good for the country. It was self-evident. And even those not formally trained in technical fields embraced what those fields meant for the collective national future.

For a while there, the United States led the world in nearly every metric of economic strength that mattered. Scientific and technological innovation is the engine of economic growth—a pattern that has been especially true since the dawn of the Industrial Revolution. That's the climate out of which the New York World's Fair emerged, with its iconic Unisphere—displaying three rings—evoking the three orbits of John Glenn in his Mercury 7 capsule.

During this age of space exploration, any jobs that went overseas were the kind nobody wanted anyway. Those that stayed in this country were the consequence of persistent streams of innovation that could not be outsourced, because other nations could not compete at our level. In fact, most of the world's nations stood awestruck by our accomplishments.

Let's be honest with one anther. We went to the Moon because we were at war with the Soviet Union. To think otherwise is delusion, leading some to suppose the only reason we're not on Mars already is the absence of visionary leaders, or of political will, or of money. No. When you perceive your security to be at risk, money flows like rivers to protect is.

But there exists another driver of great ambitions, almost as potent as war. That's the promise of wealth. Fully funded missions to Mars and beyond, commanded by astronauts who, today, are in middle school, would reboot America's capacity to innovate as no other force in society can. What matters here are not spin-offs (although I could list a few: Accurate affordable Lasik surgery, Scratch resistant lenses, Chordless power tools, Tempurfoam, Cochlear implants, the drive to miniaturize of electronics . . .) but cultural shifts in how the electorate views the role of science and technology in our daily lives.

As the 1970s drew to a close, we stopped advancing a space frontier. The "tomorrow" articles faded. And we spent the next several decades coasting on the innovations conceived by earlier dreamers. They knew that seemingly impossible things were possible—the older among them had enabled, and the younger among them had witnessed the Apollo voyages to the Moon—the greatest adventure there ever was. If all you do is coast, eventually you slow down, while others catch up and pass you by.

All these piecemeal symptoms that we see and feel—the nation is going broke, it's mired in debt, we don't have as many scientists, jobs are going overseas—are not isolated problems. They're part of the absence of ambition that consumes you when you stop having dreams. Space is a multidimensional enterprise that taps the frontiers of many disciplines: biology, chemistry, physics, astrophysics, geology, atmospherics, electrical engineering, mechanical engineering. These classic subjects are the foundation of the STEM fields—science, technology, engineering, and math—and they are all represented in the NASA portfolio.

Epic space adventures plant seeds of economic growth, because doing what's never been done before is intellectually seductive (whether deemed practical or not), and innovation follows, just as day follows night. When you innovate, you lead the world, you keep your jobs, and concerns over tariffs and trade imbalances evaporate. The call for this adventure would echo loudly across society and down the educational pipeline.

At what cost? The spending portfolio of the United States currently allocates fifty times as much money to social programs and education than it does to NASA. The 2008 bank bailout of $750 billion was greater than all the money NASA had received in its half-century history; two years' U.S. military spending exceeds it as well. Right now, NASA's annual budget is half a penny on your tax dollar. For twice that—a penny on a dollar—we can transform the country from a sullen, dispirited nation, weary of economic struggle, to one where it has reclaimed its 20th century birthright to dream of tomorrow.

How much would you pay to "launch" our economy. How much would you pay for the universe?

Note: The views above are derived from *Space Chronicles: Facing the Ultimate Frontier,* W W Norton 2012.

Senator NELSON. Well, of course, you are not only preaching to the choir, you are preaching to the preachers.

[Laughter.]

Senator NELSON. And you have just done it so eloquently, so incisively, and I couldn't help but think as you were speaking to be re-

minded of the event that we just had down at the Cape on the occasion of the 50th anniversary of John Glenn's historic space flight. And as Scott Carpenter, who is the only other living of the original seven astronauts, made his speech—and you remember that Scott Carpenter was the fellow in the antiquated blockhouse that as John was just about to lift off said, "Godspeed, John Glenn."

And then Scott ended up being the second one to ride the Atlas rocket, this time for a lot more than just three orbits, which John Glenn had done. But in Scott's speech at this ceremony commemorating the 50th anniversary, he recalled a column that had been written in the New York Times calling John Glenn the last great American hero.

And that column had rekindled a lot of what you have just articulated, Dr. Tyson. That this was a heady time. It was. We were in the great space race with the other superpower. So much was hanging on the success of this program.

And then during that time that you talked about, the 1960s, not only did we launch Glenn after the Soviets had beat us into space, but then we took over and we took care of business and did it against an extraordinary backdrop. And we were, we were the envy of the world.

And in this column, as Scott is talking about this—was John Glenn the last great American hero?—he quickly then said no. We are going to come to this point again because it is going to be the commander of that mission when it goes to Mars and lands and returns.

And so, our objective is how do we get from there to there?

Dr. TYSON. If I may react to that? I think any nation at any time has the capacity to create a hero. It just has to have ambitions with goals set so that one among us then steps forward, accepts those risks. Some of those who go forward don't come back, and this is an understood risk, in fact, of the history of our species. But those who do, who succeed, they get remembered forever.

And I would assert that I would claim that the conversation needs to be taken to a new place because, apparently, the argument that science is important or the argument that exploration feeds the energy of our DNA, I have not seen that be as successful as it should have been over these years when NASA comes back to the White House and to the Congress, hat in hand looking for money.

But what I have noticed is that NASA, as an engine of innovation, not simply by the innovation that occurs within the agency, but by the culture of innovation that it spreads into the land, it is that culture that is responsible for economic growth. And so, if people see NASA as a charity agency for the satisfaction of some engineers and scientists, they are not understanding the actual role that NASA has played in the growth of this Nation, in the economic growth of this Nation.

So this half a penny on a dollar, I say take it to a penny. Find that other half a penny somewhere. Recognize that penny on a dollar, penny on a dollar as an investment with a return that will so outweigh that one penny that you put in that you would be kicking yourself wondering why that investment wasn't made earlier.

And I am not talking only about spinoffs. And there are great spinoffs from power tools without cords and perfecting Lasik surgery, making it cheap and affordable and precise, and the grooved pavement. The list is long. There are low-tech solutions and high-tech solutions.

My concern is without that as a driving force within our culture, everything else we do are just band-aids. Oh, we need more scientists? Let us train some more teachers. That is a band-aid.

Oh, we need more jobs on shores? Let us try to bring factories in and incentivize them. That is a band-aid.

The moment the culture wants to innovate and we recognize that, that penny on a dollar becomes an investment, and it is not simply an investment in our identity, which it is, in our character, in our pride, it is all of the above. But what I have found in my read of the history of cultures, that if you can find an investment that returns economically, you take it. You do it.

And the pathway from the investment to the returned dollar takes a little longer than an elevator ride to explain how you get that. Innovations take place. Patents are granted. Products are developed.

The culture of innovation spills over. Everyone feels like tomorrow is something they want to invent and bring into the present. That is the Nation that many of us in this room grew up with, and that is the culture that so many who read about it want to resurrect going forward.

And so, without this, we just move back to the caves because that is where we are going to end up anyway as the rest of the world passes us by.

Senator NELSON. You have very accurately articulated our character as a people. We, as Americans, have always had a frontier. We have always been pressing that frontier, and as a result, we have always been explorers and adventurers. We don't want to ever give that up or else we deny our character as a people.

Senator Boozman?

Senator BOOZMAN. Thank you, Mr. Chairman.

Again, I want to echo that you are very articulate and, I think even more important, very enthusiastic about the subject. It is easy to tell that this certainly is a passion, and we really do appreciate that. We need a lot more of that.

With regard to America's scientific and technological workforce, a substantial portion is foreign-born and American-educated. In previous interviews, you mentioned that America is beginning to lose our technological workforce conduit as the rest of the world is catching up and providing technology opportunities for this workforce to leave America.

How can we in Congress encourage or create more or better opportunities to retain our edge? And I guess what are your recommendations for the Committee? How can we specifically help you in that regard?

Dr. TYSON. Other than doubling NASA's budget.

[Laughter.]

Dr. TYSON. I think a bit about the foreign-born nationals getting graduate degrees in the sciences and engineering here, that has been going on basically since the 1980s. There might have been a

trickle of it in the 1970s. But it happened in large measure in the 1980s and 1990s. It is still going on.

In the early days, we were simply the best opportunities. We had the best science, the best engineering, and their home countries did not. And so, it was expected that when they came here, they would stay, and nearly all of them did. I don't have a problem with that.

So much of our national character and identity was enriched because of how open our shores were to the creativity of immigrants that come through for the past century and a half. So that became a boon to our Nation intellectually because we were getting the smartest people in the world.

But what happens back in their home countries? They begin to develop. The countries recognize what we had recognized for so long that investments in their infrastructure and in their own science and technology creates opportunity.

My great fear was that we would now educate them, and then they would go back to their home countries, and we would lose the contributions they would have made had they stayed. That is, in fact, already happening.

The third stage in this is they become the professors, the educating class in their home countries, and then they never have to come here at all. By the way, that was the state back before the Manhattan Project. Most of the principal scientists of the Manhattan Project that were here in this country were foreign nationals, all educated in European countries. We did not quite have the physics infrastructure to sustain that kind of intellectual capital to actually engage the Manhattan Project.

So we not only tapped foreign nationals, they were all foreign educated. Once we developed that infrastructure here and that intellectual foundation, we became the target for people to become educated from all around the world.

I would say that when a nation—not to sound like a broken record here, but when a nation dreams big and has fully funded projects visible to everyone, where a frontier is getting advanced daily, innovations attract smart, clever people. The prospect of innovation attracts them.

And dare I say if you stand up in front of an eighth grade class and say, "Who wants to be an aerospace engineer so that you can design a plane that is a few percent more fuel efficient?" that doesn't really work as well as saying, "Who wants to be an aerospace engineer because we need a plane that will navigate the rarefied atmosphere of Mars?"

You are going to attract the very best of those students. And the solutions to that problem in every case I have ever seen have improved life back here on Earth.

And so, if you don't have the projects on the other side of the educational pipeline, why should anyone even do it? Why should anyone even stay? You can't just say, "Become a scientist because we need more scientists." You compel people to long for the open seas.

And when you do that and the open sea is in reach because the Government has declared that that is the next frontier, everything falls into place, everything. We have seen it happen already. It can happen again, this time without the tandem military budget that

was required in the 1960s to conduct a Cold War and a hot war. Imagine what that return will be going forward.

Senator BOOZMAN. Well, thank you, Mr. Chairman.

And again, thank you very much for your testimony.

Senator NELSON. We are singing from the same hymn book. In your talk about a lot of the value that NASA provides by inspiring and motivating children, which you have made that case very, very strongly, in these tight fiscal times, how do you make that value better understood by the average American person?

Dr. TYSON. That is the multibillion dollar question. That is an important question. I mean, I am trying.

First of all, I can tell you, based on my life experience—and I am sure, if you reflect on it, on your life experience as well—you never actually have to train kids to think scientifically. They are always experimenting, always. They are turning over rocks. They are poking at objects that the adults don't want them to poke at.

And we spend a lot of our effort as adults squashing that creativity and that exploratory drive that every child has within them. So when I am asked what do we do to excite children, my first answer is, first, get out of their way because that will be a natural part of their curiosity as a child.

And the real problem with the science literacy and the embracing of what science and technology will bring is not, I don't believe, in that next generation. It is in the current generation of adults who far outnumber children, who vote, who run the country.

I am not going to turn around and say the country has problems because we are not training our children. I am going to say the country has problems because not enough adults understand what these arguments are.

And I would like to believe that no one wants to go to the poorhouse. So the economic argument needs to be lifted above all others. It needs to be lifted above the DNA argument, the urge to explore argument. That it is in even, with due respect, Senator, the legacy of Americans as explorers. I just have not seen that work on the soup line when someone can't feed their home, and they are working with a foreclosed—can't feed their family, and they have got a foreclosed home.

But the prospect that tomorrow they will be wealthier than today, that works. It works every time, and it transcends partisan politics. Because at the end of the day, we are a capitalist democracy. We have all kind of bought into the idea that tomorrow we should be wealthier than we are today.

And so, if we make the economic argument above all else, there may be a chance that people will understand the actual role that NASA has played and not the one that the dreamers say about it because I think NASA should be fully funded because I am a scientist. But I don't require others to feel the same way. When it comes to money, that is something we can all agree on.

Senator NELSON. Well, you have said it pretty well. Science literacy is going to be our future, and somehow we need to translate that into overcoming these obstacles. And you have laid out the case as good as anyone. Now we have just got to keep on keeping on to get the message through.

Dr. TYSON. And I will say if you want to do the homework, check out the GDP per capita in the 1960s into the 1970s, 1980s, and 1990s. It is in the 30 percent across that decade, the 10-year rise in the GDP per capita. Just watch it drop as the decades unfold, and that is us coasting on it.

And if you average the 1990s with the 2000s, it is basically flat. And so, the future—as goes the future of NASA, so, too, does the future of this Nation.

Senator NELSON. And with that poignant thought, thank you.

And the hearing is adjourned.

[Whereupon, at 11:58 a.m., the hearing was adjourned.]

A P P E N D I X

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO HON. CHARLES F. BOLDEN, JR.

Question 1. Given sustained SLS funding—what additional systems could be tested on either the 2014 or 2017 test flights, instead of waiting until the first human flight?

Answer. The primary objective of the 2014 test flight is to obtain high-velocity reentry data for the Orion MPCV spacecraft, though NASA will also use this mission to test mission operations concepts. The SLS Program is designing the spacecraft adapter for this flight. Sustained SLS funding will continue to support this effort. No additional SLS systems are applicable to this early test flight. For the 2017 test flight—which is an Agency Priority Goal—sustained SLS funding will provide greater confidence in meeting the necessary milestones leading up to the 2017 flight. The SLS launch vehicle for the 2017 flight is the same launch vehicle configuration that will be used for the first human flight in 2021. No additional SLS systems will be developed for the 2021 flight.

Question 2. Would accelerating the first human flight—earlier than 2021—lower the overall cost of a human capable SLS-Orion system?

Answer. Accelerating the first human flight would not necessarily lower the overall cost of a human-capable SLS-Orion system. NASA has implemented an executable plan to develop these systems to support the first human flight in 2021. The estimated budget to execute this plan has been phased to meet the fiscal budget requirements. If the first human flight was to be accelerated, the funds associated with accelerating the development of the necessary systems would have to be taken from the later years and re-phased into the earlier years.

Question 3. We've recently heard that flights for NASA ISS commercial cargo providers have slipped—SpaceX to April and Orbital Sciences to this summer. How much have these COTS flights slipped since they were originally planned?

Answer. When NASA signed the original Space Act Agreement (SAA) with Space Exploration Technologies (SpaceX) in August 2006, their first, second and third COTS demonstration flights were planned for September 2008, June 2009 and September 2009 respectively. SpaceX successfully flew the first demonstration mission in December 2010, launching a Dragon capsule into orbit on a Falcon 9 rocket and recovering it off the coast of California. On May 22, 2012, SpaceX launched its second COTS demonstration flight, and 3 days later, the Dragon spacecraft was berthed to the ISS. The mission, which accomplished the remaining COTS demonstration goals for SpaceX, was brought to a successful conclusion on May 31, with the deorbiting and splashdown of the Dragon capsule.

When NASA signed the original SAA with Orbital Sciences Corporation (OSC) in February 2008, the single demonstration flight was originally planned for December 2010. Currently, Orbital is planning the maiden launch of their newly named Antares launch vehicle (previously referred to as "Taurus II") no earlier than June 2012, and the COTS demonstration flight to the ISS no earlier than September 2012.

Question 4. What do we need to get done and when to keep research progressing on the International Space Station? At what point do further slips of SpaceX or Orbital affect operations aboard the ISS?

Answer. There is sufficient margin in logistics, consumables and systems spares through 2012 so that ISS operations will not be impacted by a delay in the start of commercial cargo delivery. Commercial Resupply Services (CRS) flights will augment existing resupply capability needed to support NASA, ESA, Canadian Space Agency, and JAXA astronauts. Those needs continue to be met through the ESA-provided ATV, the Roscosmos-provided Progress and Soyuz, and JAXA-provided HTV vehicles now that the Space Shuttle has been retired. SpaceX just successfully demonstrated its ISS resupply capability and Orbital Sciences is in the process of bringing their vehicles on-line to provide the needed resupply capability. Recog-

nizing the challenges of initial flights and bringing a new vehicle into operations, NASA and its partners previously delivered additional supplies to create a schedule margin.

The commercial strategy does not rely on a single flight or provider. To date, SpaceX has successfully flown three missions using the Falcon 9 launch vehicle, including two Commercial Orbital Transportation Services (COTS) demonstration flights. The first of these demonstrated launch, orbit and successful recovery of a simplified Dragon spacecraft. On May 22, 2012, SpaceX launched its second COTS demonstration flight, and 3 days later, the Dragon spacecraft was berthed to the ISS. The mission, which accomplished the remaining COTS demonstration goals for SpaceX, was brought to a successful conclusion on May 31, with the deorbiting and splashdown of the Dragon capsule.

Orbital Sciences Corporation is scheduled to fly its COTS demonstration mission in calendar year 2012, and its first CRS mission in Fiscal Year 3.

Question 5. Phil McAllister, a NASA commercial crew manager, said in a recent interview that if NASA's commercial crew program gets significantly less than requested this year, the program may need complete re-thinking. As is probably clear from the 2012 appropriation, there is quite a bit of work to be done to get the appropriation for commercial crew up anywhere near the request. Can you please clarify Mr. McAllister's comments—what does it mean to completely re-think the program, and at what funding level for Fiscal Year would such an action be necessary?

Answer. Mr. McAlister referred to the "strategy" for the Commercial Crew Program, not the program itself. Whenever a NASA program is appropriated significantly less funding than requested, the Agency must perform an assessment to determine the impacts from the lower than anticipated budget and determine if any adjustments to the program are appropriate. NASA would have to take a similar action for Commercial Crew if the Agency receives significantly less than requested amount. Those actions are typically taken when final budgets are established.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BARBARA BOXER TO HON. CHARLES F. BOLDEN, JR.

Planetary Science

Question 1. I understand the difficult budgetary environment we are in but I am very concerned that Planetary Science programs received a 21 percent cut in the FY 2013 budget while the proposed cut to NASA's overall budget is 0.3 percent. Why was this disproportionately large cut made to Planetary Science?

Answer. NASA's FY 2013 budget request identifies four key priorities to be funded in this constrained fiscal environment: ISS sustainment and utilization; Space Launch System and Orion Multi-Purpose Crew Vehicle; James Webb Space Telescope; and new technologies. In view of these four key priorities for NASA and of our constrained fiscal environment, we will not be moving forward with the 2016 and 2018 ExoMars missions that we had been studying with the European Space Agency. Instead, NASA is developing a new, integrated strategy for Mars missions to ensure that the next steps for Mars exploration will support science, as well as longer-term human exploration goals, and take advantage of advanced space technology developments. NASA will complete this integrated plan; including the framework for a mission to take advantage of the 2018 or 2020 launch opportunities, no later than this summer. The FY 2013 budget request funds several exciting missions that will greatly advance our understanding of the solar system. These include:

- The Mars Science Laboratory Curiosity rover will land on Mars on August 6 of this year and will begin a five-year investigation in the area of Gale Crater in an attempt to determine if Mars could have been a habitable environment for life in the past;
- The Mars Atmosphere and Volatile EvolutioN (MAVEN) mission will launch in 2013 to determine the role that loss of volatile compounds (like water, carbon dioxide, and nitrogen), from the Mars atmosphere to space has played over time, giving insight into the history of Mars atmosphere and climate, liquid water, and planetary habitability;
- The Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS–REx) will launch in the 2016 time-frame on a mission to return a sample from an asteroid;
- The Discovery 12 mission will be selected later this year from among three competing candidates, with the winner entering into formulation for launch in the 2016 timeframe;

- Several missions currently in operation or on their way to their distant destinations, including GRAIL at the Moon, MESSENGER at Mercury, Cassini at Saturn, New Horizons on its way to Pluto (2015), and Juno on its way to Jupiter (2016).

Question 2. The Mars missions of the past have proven very successful, the next rover is on its way, and NASA had an agreement to work with the European Space Agency (ESA) on the 2016 and 2018 Mars missions. Unfortunately, due to the large cut to Planetary Science, NASA has indicated that it will no longer participate in the next Mars missions. Are you planning to join ESA on future Mars missions? If so, in what time frame? What are the future plans for the workforce of the Jet Propulsion Laboratory (JPL) which has been working on the Mars missions? How will you maintain the core capabilities of this group so that the skills developed at this lab are not lost?

Answer. As you noted, due to current and future budgetary constraints and other higher Agency priorities, NASA will not be able to participate as originally planned in the Joint Mars Exploration missions conceived with ESA for 2016 and 2018. NASA had an agreement with ESA to begin study and design work for the2016 and 2018 missions, but had not yet executed a follow-on agreement for full mission implementation. If the European missions go forward, NASA will likely support ESA in some manner. We continue to have mutual interests in the exploration of Mars, and we anticipate and hope that NASA and ESA will find new opportunities to collaborate. NASA has established a Mars Program Planning Group that will initially focus on a NASA Mars robotic mission in the 2018–2020 timeframe. We plan to actively engage our bilateral partners from ExoMars, namely ESA and the Canadian Space Agency, in the next few weeks, seeking their input and engagement with the Mars Program's reformulation as early as practicable. We also intend to engage the broader international community in the near future through the established International Mars Exploration Working Group (IMEWG), an ad hoc organization of Space Agencies that was formed in 1993 to facilitate coordination among the world's Mars-faring nations.

Landing large masses on the Martian surface remains a necessary part of any strategy for Mars exploration. Therefore, while a loss of some skilled personnel after the landing of the Mars Science Laboratory is anticipated, NASA will work to retain critical skills and capabilities sufficient to sustain our skills in entry, descent, and landing prior to the next landed mission to Mars. The total JPL workforce is currently slightly over 5,000, down by several hundred over the last several years. JPL's current best estimate is that the workforce can be maintained in FY 2012 at about 5,000 but may need to be reduced by approximately 300–400 in FY 2013. A reduction of that scale (6 percent) could be largely handled through attrition. Some mitigation of the losses may occur through a new Mars mission for the 2018/2020 opportunity in the restructured program, and the fact that JPL is working on one of the three currently competing Discovery mission proposals. JPL is also forecasting an increase in non-NASA work. The current uncertainties should diminish over the rest of this year.

Commercial Space

Question 3. In its FY 2013 request, NASA is seeking a total of $830M for the Commercial Crew program. Last year, as you know, Congress appropriated $406M for the program, about $100M less than the authorized level. How will the requested amount enable NASA and the Commercial Crew providers to close the U.S. human spaceflight gap more quickly?

Answer. NASA's original request for the Commercial Crew Program was:

($ in millions)	2011	2012	2013	2014	2015
FY 2011 BUDGET	500	1,400	1,400	1,300	1,200

With this budget, NASA estimated that a commercial crew capability could be in place by 2015. However, the amount appropriated in 2011 was $312 million ($188 million less than requested) and NASA was precluded from initiating a "new start." Thus, NASA adjusted its strategy and initiated CCDev Round 2 which focused on maturing elements of the systems instead of overall integrated crew transportation systems. The combined impact of the lower than expected budget and shifting to focus on elements of the system instead of an integrated system was that it delayed NASA's estimated expected operational date of commercial crew to 2016.

The amount appropriated in 2012 was $406M ($444M less than the newly requested amount of $850M). This resulted in a further slippage of NASA's expected operational date to 2017. The requested funding levels in the President's FY 2013

request of $830M will support the expected operational date of 2017 for regaining U.S. human spaceflight launch and return capability to and from LEO.

NASA is planning for commercial crew capability to be in place in 2017; but the Agency's plans will not preclude earlier availability of services. Many of the potential commercial providers have stated they can have services available earlier.

Question 4. The Commercial Crew program is designed to achieve, at a lower cost, an accelerated human spaceflight capability to the International Space Station. How is maintain a competition important to the long-term sustainability, cost and success of the program? Does NASA intend to maintain at least two or more competitors in order to drive innovation and provide best value to the taxpayer throughout both the development and procurement stages, as it did with the Commercial Orbital Transportation Services (COTS) and Commercial Resupply Services (CRS) program?

Answer. NASA believes that having multiple companies competing against each other at this stage of the Commercial Crew Program will result in lower overall costs for the Government. In a traditional program with a single prime contractor from the start using a cost-plus contract, the NASA–Air Force Cost Model (NAFCOM) cost estimates are approximately $8–11B for the development of an ISS crew transportation capability. Using the current, innovative approach of competing Space Act Agreements will result in multiple awards to industry with fixed Government costs. NASA estimates being able to cut the development costs substantially and deliver an ISS capability for around $5B. Maintaining competition is a key factor in achieving these savings.

While the Agency has not established a specific number of awardees for the next phase of the Commercial Crew Program, referred to as Commercial Crew Integrated Capability (CCiCAP), NASA plans to have fewer companies in CCiCAP than are currently in CCDev2. There are seven partners in CCDev2 (four funded and three unfunded partners). NASA would like to maintain as much competition as it can for as long as possible.

Removing competition by developing a single system from various companies' system elements would eliminate most of the commercial aspects of the program. With only one provider from which NASA could purchase services, there would be little incentive for the companies to expand their commercial market base by selling services to any other customers or to maintain reasonable prices. There would also be no incentive for the companies to share in the development costs. Having industry share in the cost of development and selling seats to other customers in addition to NASA will likely decrease NASA's costs for crew transportation services in both the short and long-term.

Question 5. Are you confident that the use of Space Act Agreements and ultimately a Federal Acquisition Regulation (FAR)-based acquisition at the end of the process will ensure that NASA's safety requirements are met in these new commercial systems?

Answer. NASA plans to use Federal Acquisition Regulation (FAR)-based contracts for certification of commercial systems prior to flying crew on these systems. NASA intends to structure the certification phase following the CCiCAP effort to permit the Agency to fully evaluate the proposed systems and accommodate any necessary redesign to ensure compliance with NASA safety, performance, and mission success requirements. The provider(s) awarded a certification contract will not only be required to meet the NASA requirements in order to fly NASA personnel, but they will also have to show verified compliance of how the design and hardware will meet these requirements. Thus, there will be no reduction in the safety expectations or requirements as a result of this change in acquisition strategy.

NASA is addressing the issue of compliance with certification requirements in several ways. First, NASA has released the baseline set of safety, performance, and mission success requirements to all of industry. NASA also has made these requirements available to all providers as reference under the CCiCAP effort. Although compliance with these requirements is optional for industry under a funded SAA, NASA anticipates that providers will use the NASA requirements to inform their development activities, thereby reducing the technical risk associated with the lack of NASA oversight under an SAA. Because NASA plans to have more than one company in the next phase of SAAs, we believe the competitive environment provides strong incentive for the companies to align with NASA's certification requirements in order to remain competitive in the future certification and services phases.

Third, NASA included an "Overall Safety Goal" in the CCiCAP Announcement for Proposals (see page 3 of the Announcement) which states:

"Successful commercial human space flight demands the highest commitment to safety; therefore NASA has the goal of fostering a safety culture in the commercial

space flight industry that ultimately will minimize the risks associated with human space flight to LEO. NASA's goal is for Participants to demonstrate safety processes that include strong inline checks and balances, healthy tension between responsible organizations, value-added independent assessments and appropriate data archival, which will increase Government confidence in the Participant's approach to safety."

As a result, NASA will have a great deal of insight into the providers' approach to safety during CCiCAP as the providers meet their milestones associated with the CCiCAP agreements.

Question 6. We heard from NASA that the Commercial Crew program is a "must have" not a "nice to have" and that the U.S. has a choice: it can invest more in U.S. commercial crew capabilities now, or spend more on Russian crew services later. How much are we paying Russia for crew transport today and over the next several years? Given recent launch failures of the Russia Soyuz and other systems, can you comment on the level of insight and oversight NASA currently maintains over Russian vehicles that carry our astronauts? How does this compare to your oversight of the U.S. companies developing new systems?

Answer. NASA has purchased six seats from Russia at the cost of $51M per seat in 2012 for a total cost of $306M. Please note that this cost is phased over multiple years.

In March 2011, NASA signed the most recent modification to the current International Space Station (ISS) contract with the Russian Federal Space Agency for crew transportation, rescue and related services from 2014 through June 2016. The firm-fixed price modification, valued at $753 million, covers comprehensive Soyuz support, including all necessary training and preparation for launch, flight operations, landing and crew rescue of long-duration missions for 12 individual space station crew members.

NASA has been purchasing transportation and rescue services from Russia for many years as a customer, and the Russians have proven to be consistently reliable partners. For example, in the aftermath of the Columbia accident, the Russians provided the Soyuz and Progress spacecraft necessary to keep the ISS operational. In terms of NASA's insight into technical systems and issues, the Russians have kept NASA officials very well informed regarding anomalies experienced (*e.g.,* Soyuz ballistic re-entries, the Progress 44P anomaly). The Russian Federal Space Agency (Roscosmos) is responsible for resolving technical issues related to anomalies and coordinating with all of the International Partners, including NASA. This coordination is formally manifested in meetings of the Space Station Control Board, Multilateral Coordination Board, and ISS Mission Management Team, as well as the partners' participation in the standard Stage Operations Readiness Reviews and Flight Readiness Reviews. NASA is satisfied with this level of insight.

As noted in the response to question #5, NASA will have significant insight into U.S. commercial providers' designs during CCiCAP. When the Commercial Crew Program begins a Federal Acquisition Regulation (FAR)-based contract, the Agency will have the level of insight and interaction typical of such a contract.

Question 7. Assuming the Commercial Crew program delivers crew capability on time and on schedule, how will more frequent and affordable access to ISS for scientists and researchers lead to better utilization of ISS?

Answer. The ISS will benefit from frequent and affordable access. Cargo vehicles will ensure that the laboratory facilities will be provided with research samples (and that they can be changed out); that ISS research and operational equipment can be maintained and repaired; and that NASA and its Partners will be able to deliver the supplies and consumables needed to maintain the nominal six-crew complement.

NASA Workforce

Question 8. During this time of transition, strategic management of the agency's workforce poses a challenge. How is the agency planning to maintain core technical competencies as the current generation of employees retires?

Answer. While NASA's mission has been in a time of transition, its workforce has been relatively stable. At less than 5 percent attrition each year, NASA has a very low rate of attrition compared to other Federal agencies and to the private sector. Based on its workforce profile, NASA does not project an increase in the rate of retirement losses in the near- and mid-term future large enough to disrupt the planned transition of core technical competencies to workforce that will be sustained and the in-coming generation of NASA employees.

NASA plans to enhance its already robust intern programs and active recruitment of recent graduates with the coming implementation of the Pathways Program. After they join NASA, these employees have access to a wide array of training opportunities, including formal in-person and on-line training, informal on-the-job training, mentoring, and rotational or detail assignments in order to develop indi-

vidual capability in the Agency's core technical competencies. On an on-going basis, employees and NASA organizations have access to an extensive knowledge management capability was well as lessons learned databases—both designed to support the continuity of core technical competencies.

Question 9. What funds have been identified to support the strategic hiring needed to make sure that NASA's technical excellence remains second to none through the 21st century?

Answer. NASA's workforce FTE levels are projected to remain relatively stable in the coming years, with only modest reductions currently anticipated. This means that the current level of civil service labor funding largely will be sustained. As current employees attrit from the Agency rolls, replacement hiring will be on-going to fill key positions, and the workforce will be replenished with new talent. Given NASA's very low attrition rate and the Agency's modest FTE reductions, NASA actively makes prioritization decisions within its hiring program. "Replacement" hires are not necessarily made into the vacated position of each person who leaves—replacement FTE are more typically redirected to new or different positions; because of this process, the Agency is able to continually adapt its current high level of technical excellence to meet new mission challenges. In implementing the Pathways Program, NASA plans to significantly enhance recruitment for interns and recent graduates with the addition of new Agency-level leadership focus and activities.

International Space Station

Question 10. With the assembly of the International Space Station completed, NASA can now focus on utilizing the laboratory to continue scientific research. How much funding will go towards life and physical research in the coming fiscal years? How does NASA intend to implement the recommendations of the National Academies' Decadal Survey?

Answer. Please see below table showing life and physical sciences research funding in the FY 2013 budget request. The Decadal Survey provided NASA with over 60 "highest priority" research recommendations, and eight potential prioritization criteria. All of NASA's current ISS research portfolio is within the highest priority recommendations of the Decadal Survey. The NASA Office of the Chief Scientist is coordinating a NASA response to the Decadal Survey that will describe a strategy for implementing the priorities within the context of schedule and budget constraints. Within the limits of NASA's budget constraints, we will closely consider the recommendations of the Decadal Survey in decisions on investments in new research facilities and capabilities for the ISS, in a research program that balances the pursuit of significant new scientific discoveries and the construction of a foundation of knowledge that supports future human exploration missions.

Human Exploration and Operations—FY 2013 Budget

Space Life and Physical Sciences Research and Applications Division (SLPSRA)

	Notional					
	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017
Total SLPSRA Budget (in $M)	231.0	240.0	236.5	237.8	240.4	240.1
Exploration Appropriation	*157.7*	*164.7*	*164.7*	*164.7*	*164.7*	*164.7*
Human Research Program	157.7	164.7	164.7	164.7	164.7	164.7
Space Operations Appropriation	*73.3*	*75.3*	*71.8*	*73.1*	*75.7*	*75.4*
Biological & Physical Research	58.3	60.3	56.8	58.1	60.7	60.4
Non-Profit Organization	15.0	15.0	15.0	15.0	15.0	15.0

*Note the Multi-User System Support (MUSS) budget, including National Laboratory Enabling, is managed by the ISS Program and therefore is not included in the above data.

Arc Jet

Question 11. We understand that NASA is planning to consolidate all Arc Jet testing capabilities at Ames Research Center (ARC) because it will require only minimal cost in upgrades to the facility and the Agency expects this consolidation effort to result in operational cost savings. What are some of the long-term efficiencies that can be gained from consolidating Arc Jet at Ames?

Answer. Annual operating efficiencies: consolidating NASA arc jet capabilities at Ames allows the Agency to save the ongoing annual costs of operating and maintaining the lower-power arc jet facility at Johnson Space Center with minimal impact to near-and long-term mission needs. Recent, extensive reports sponsored by both the NASA Office of the Chief Engineer and the JSC Orion MPCV program have concluded that: (1) the capabilities provided by the ARC arc jets are the minimum set necessary to meet present and anticipated Agency test requirements; (2)

modifying the JSC arc jet infrastructure so that it is physically capable of matching the technical capability already operating at ARC would require hundreds of millions of dollars in new infrastructure investment—essentially, would require razing and rebuilding a new upgraded capability from scratch; and (3) actual operations costs at ARC on a per-test productivity basis are lower than JSC's and are comparable to those of other commercial and DOD arc jet facilities. In FY 2010, the NASA OCE determined the annual operations and maintenance costs of operating the JSC arc jet at $6.2M/per year. Approximately 60 percent of the annual cost of an arc jet facility is fixed costs. Over the 30-year life expectancy of a modern industrial test facility, consolidating test capability at Ames would save up to $111.6M in the fixed costs of operating the JSC arc jet facility.

Test execution efficiencies: the cost-per-test of operating at ARC is lower than at JSC. The recent study chartered by the Office of the Chief Engineer found that the FY 2010 average cost per test at JSC is $32.3K; at Ames, $16.3K. On average the JSC facility executes approximately 200 tests per year. Executing those tests at ARC would save the Agency approximately $3.2M per year.

Future capability upgrade efficiencies: Mission scenarios for planetary science missions to Mars, Venus, the gas giants, comet and asteroid sample return, and crewed missions to the Moon, Mars, and near-earth asteroids will require increased performance from arc jet infrastructure. Higher temperatures are needed to simulate the condition associated with atmospheric entry (at the destination) and reentry (to Earth) for missions of this scope. Efficiencies can be realized through concentration of infrastructure maintenance and upgrade resources on a single facility. The underlying infrastructure at Ames is designed to support very high power (up to 150 MW) arc jet operations. The corresponding infrastructure at JSC is limited to supporting low power (up to 10 MW) operations. Recent studies (ARES Corporation, *Arc-Heated Test Facility Investment & Risk Reduction Study for Orion Heat Shield,* May 2007) have shown that the most cost- and time-efficient approach to meeting upgraded arc jet performance requirements is to install upgraded equipment within the Ames infrastructure. This approach obviates investments in JSC infrastructure that already exist at Ames, and leverages the Agency's considerable recent infrastructure investments in the Ames facility.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK WARNER BY HON. CHARLES F. BOLDEN, JR.

Question 1. It is my understanding that from 2006 to 2012 funding for NASA's Aeronautics Hypersonics Project was decreased by 75 percent from $95M to $25M. The proposed FY 2013 Budget further reduces funding from $25M down to $7M—another 72 percent reduction. However, I also understand that the results of hypersonic research achieve our national security goals by increasing our global reach, responsiveness, and survivability. What was the basis for decreasing hypersonic programs to only 7 percent of the FY 2006 funding level?

Answer. Most of the decrease in funding for the Hypersonics Project prior to FY 2012 was due to accounting changes and the elimination of one-year Congressional augmentations. The reduction from $50M in FY 2011 to $25M in FY 2012 and proposed reduction in FY 2013 reflect content changes due to required priority setting within a very tight budget environment. The Hypersonics Project had two main emphases in its portfolio: 1) fundamental research and technology development for air breathing hypersonic propulsion systems and 2) fundamental research in Entry, Descent, and Landing (EDL). With the reduction in FY 2012, the EDL-related flight experiment of inflatable re-entry system was transferred to the Office of Chief Technologist (OCT). In FY 2012, NASA prioritized funding for other, higher priority areas within the aeronautics portfolio, including research in airspace management, composites structures, and aviation safety. With the proposed reduction in FY 2013, the Agency will transfer all remaining EDL work to the Office of Chief Technologist (OCT). In FY 2013, technology development effort in air-breathing hypersonic propulsion systems such as combined cycle engines and structurally integrated thermal protection systems is planned to be phased out while retaining the Langley 8–Ft High Temperature Tunnel and research capability to support DOD's hypersonic programs. Further, NASA will effectively combine the hypersonics and supersonics research into a single project that will be focused on high-speed flight. The DOO will continue to support a larger hypersonics R&D program aimed at achieving national security goals.

Question 1a. What results have been achieved to date through the Aeronautics Hypersonics Project?

Answer. Recent NASA hypersonics results have largely been accomplished in partnership with the DOD. These accomplishments include validation of hypersonic vehicle design methods and ground-to-flight scaling laws resulting from X–51 wind tunnel testing in the Langley 8–Ft High Temperature Tunnel and DOD flight-testing combined with NASA–Air Force Research Lab (AFRL) Computational Fluid Dynamics (CFD) analyses. Another accomplishment is the NASA development of the scramjet engine payload to be flown as Flight 2 of the HIFiRE (Hypersonic International Flight Research and Experimentation) Program with the Air Force Research Laboratory. The Hypersonic Project also conducted the first flight test of an inflatable heat shield as well as the associated materials and computational tools to allow these new systems to be further developed. Additional technical detail can be provided upon request.

Question 1b. What is NASA's plan for achieving the same national security goals on this drastically reduced budget?

Answer. NASA Aeronautics responsibility to the national security goals related to hypersonics is to support the DOD. NASA will work with the DOD to coordinate and minimize the impact by the changes in the NASA hypersonics research on their missions. Discussions to date with DOD officials indicate that the remaining NASA hypersonics investment is aligned with their highest priorities.

Question 2. Without the long-term research that will be eliminated under the propose FY 2013 budget, what will be the impact to NASA's Space Technology and DOD's DARPA projects and to future launch vehicles? How will this critical NASA capability for NASA and DOD be maintained beyond FY 2012?

Answer. NASA will maintain specifically the hypersonic scramjet propulsion research and support capability associated with the NASA Langley 8-ft High Temperature Tunnel. The reason that NASA is focusing its remaining hypersonic investment around this wind tunnel is that it is key to supporting both NASA and DOD missions. Discussions to date with DOD officials indicate that the remaining NASA hypersonics investment is aligned with their highest priorities. Military applications will be the first steps toward eventually maturing the technology sufficiently to enable civilian uses such as transportation or space access. The primary impact would be to limit future opportunities to move beyond traditional rockets for such applications. At this time, NASA does not have plans or funds to build such a launch system, so there is not an immediate impact. Additionally, alternatives to conventional rockets are not just limited to hypersonic air-breathing propulsion options, and include horizontal launch options that cover the spectrum from sub-sonic to supersonic air-breathing first stage vehicles, to other more innovative and advanced concepts. However, it is anticipated that there could be an impact in supporting external research in this area and developing future engineers and scientists with skills in this area. NASA's Space Technology Program FY 2013 budget request of $699M incorporates the responsibility for the fundamental research in the area of Entry, Descent, and Landing (EDL). The actual FY 2013 appropriated funding level for Space Technology may impact all areas in Space Technology including EDL research.

Question 3. Hypersonic air-breathing propulsion is a key component of advanced propulsion systems for launch vehicles that the National Research Council recently selected as the highest priority during their review of Space Technology Roadmaps. It takes years to develop the subject matter and expertise and the required facilities. As other countries including China, France and England more forward with robust hypersonic air-breathing projects and move into a position to capitalize on this technology as it matures for both economic and military benefits, what impact will reduced funding levels have on our national security?

Answer. The National Research Council (NRC) report called out many high priority technologies, including the 16 highest priorities. The report ranked turbine- and rocket-based combined cycle propulsion technologies the highest in the Launch Propulsion Systems technical area.

For decades, both NASA and the Air Force have invested substantial resources in these two areas. For example, the National Aerospace Plane program of the late 80s and early 90s was an effort to refine and implement these technologies. As recognized in the NRC report, both technical areas pose technical challenges that are difficult and expensive to overcome. The NRC prioritized these but added: "However, a significant number of challenges were also identified for each, and the Committee believes that it will take decades of research and development and a large and sustained financial investment to makes these technologies feasible."

NASA is conducting a thorough assessment of how the Agency's current technology development efforts align with the priorities identified in the NRC report. The Office of the Chief Technologist is leading an Agency-wide gap analysis and strategic planning effort to address the recommendations made by the NRC and

work with NASA Mission Directorates to determine what is possible within the Agency's current budget profile.

NASA is working with DOD to minimize the impact to their mission. For example, we are maintaining some critical national capabilities related to scramjet propulsion and the LaRC 8-ft High Temperature Tunnel to provide continued support to DOD missions.

While NASA is reducing research related to air-breathing hypersonics systems including propulsion technologies and structurally integrated thermal protection systems, the Agency decided that, in order to maintain core capabilities needed for spacecraft development, the Space Technology program will assume responsibility for the fundamental research associated with Entry Descent and Landing that had previously been conducted in the Aeronautics Research Mission Directorate. This change also creates synergies with development projects Space Technology is conducting in this technology area.

Question 4. What has been the extent of coordination with DOD on the Aeronautics Hypersonics Project? With the proposed cuts to the NASA program, what kind of changes in the relationship and coordination with DOD do you anticipate?

Answer. NASA is actively working with the DOD to coordinate and minimize the impact of these decisions on their missions. There are some elements of research that NASA will no longer be able to support, and NASA has already met with senior DOD officials who agree that the remaining NASA investment does align with the highest hypersonic priorities in the DOD. Specifically, NASA Aeronautics is focusing its remaining hypersonic research on efforts that directly support the DOD. We are also maintaining some critical national capabilities related to scramjet propulsion to provide support for both Agency and DOD missions. NASA is aware of the DOD plans to expand research in hypersonic flight systems and is continuing to discuss options to optimize this collaboration. In the same way that NASA supported the development of the USAF X–51 system, we expect DOD collaboration and coordination to continue.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. TOM UDALL TO HON. CHARLES F. BOLDEN, JR.

Question 1. I know you are aware of White Sands' unique assets and capabilities. I appreciate hearing from you about NASA's goals and priorities for FY 2013. Could you speak about some of the opportunities for White Sands to support NASA's missions? How can we take full advantage of White Sand Test Facility's capabilities in FY 2013 and beyond?

Answer. As a preeminent resource for testing and evaluating potentially hazardous materials, space flight components, and rocket propulsion systems, White Sands Test Facility (WSTF) is well positioned to support NASA mission requirements. The facility conducts simulated mission duty cycle testing to develop numerous full-scale propulsion systems. WSTF is also formally certified to perform precision cleaning and depot-level refurbishment of flight-critical propulsion systems components. Further, the scientific investigation of explosion phenomena at WSTF is aimed at improving safety at launch facilities and other areas where hazardous materials are used. WSTF is a center of technical excellence in the fields of high-pressure oxygen systems/materials and rocket propellant safety. Further, the laboratory services at WSTF are available to NASA, the Department of Defense, other Federal agencies, universities, and commercial industry.

In the area of hazardous testing, WSTF offers a set of state-of-the-art/world class lab and propulsion test facilities specializing in hazardous/non-hazardous operations and performing tests on propulsion systems, components, and materials, including: hypergolic fueled propulsion systems and components; green fuel propulsion systems and components; oxygen compatibility; hypervelocity impact in hazardous atmospheres; and standard materials testing for human space flight environment compatibility.

In addition, WSTF can perform propulsion testing of components, engines and systems at ambient (up to 60,000 lbs. thrust) and simulated altitudes of 120,000 ft (25,000 lbs. thrust) for hypergolic, liquid oxygen/liquid hydrogen, and liquid oxygen/liquid methane fuels.

Current and Future Activities:

- Continued improvements in safety, reliability, and efficiency through the execution of prioritized projects in the propulsion test facilities (Propulsion Test Area Intercom System, Altitude Simulation Vacuum System Controls, Bulk Propellant Storage)

- Specific test programs:
  - Oxygen compatibility testing for International Space Station components and materials;
  - Hypervelocity testing in support orbital debris and micro-meteoroid mitigation;
  - Space Shuttle Transition and Retirement activities to restore test stands to a neutral test state;
  - Space Shuttle post program decontamination activities;
  - Continued support to the Agency vision for space by testing hypergolic fueled propulsion components for Space Launch System and Orion Multi Purpose Crew Vehicle;
  - Support to Department of Defense and other Government organizations by safing the U.S. Air Force Peacekeeper stages, testing the U.S. Air Force Minuteman missiles, and critical Missile Defense Agency projects;
  - Support to commercial space developers and providers by testing hypergolic propulsion systems.
- Specific to NASA's commercial crew and cargo development efforts, partners may request use of NASA facilities, equipment, or services that are unique or not commercially available. Partners planning to use such NASA resources must enter into separate reimbursable agreements directly with the appropriate NASA Center(s). Any decision to use NASA facilities, equipment, or services shall be at the Participant's discretion and risk.

The WSTF propulsion test assets are managed through the Human Exploration and Operations Mission Directorate (HEOMD) Rocket Propulsion Test (RPT) Program. The RPT Program represents the single-point interface for NASA's rocket propulsion test facilities located at Stennis Space Center (SSC), Marshall Space Flight Center (MSFC), Johnson Space Center-White Sands Test Facility (JSC–WSTF), and Glenn Research Center-Plum Brook Station (GRC–PBS). The RPT sustains and improves Agency-wide rocket propulsion test core competencies (both infrastructure and critical skills), ensures appropriate levels of capability and competency are maintained, and eliminates unwarranted duplication. The program strategy is to fund and maintain core competencies of skilled test and engineering crews and test stand facilities; consolidate and streamline NASA's rocket test infrastructure; establish and maintain world-class test facilities; modernize test facility equipment; provide non-project-specific equipment and supplies; and develop effective facility/infrastructure maintenance strategies and performance.

Question 2. I am pleased that NASA's budget request includes funding for the Flight Opportunities Program. This initiative provides relatively low-cost access to reduced-gravity environments that is useful for scientific research and developing new space technology. By competitively securing commercial flight services, NASA's Flight Opportunities Program leverages private investment in suborbital spacecraft and parabolic aircraft. This helps expand access to suborbital space for researchers and others seeking to conduct microgravity experiments. Could you share some of your thoughts on the importance of this relatively small program on achieving NASA's goals in the areas of science, technology, and exploration?

Answer. The Flight Opportunities Program (authorized as the Commercial Reusable Suborbital Research Program) was proposed by NASA in FY 2010 in response to the National Academy of Sciences report: Revitalizing NASA's Suborbital Program: Advancing Science, Driving Innovation and Developing Workforce. The intent of this program is to facilitate access to near-space for a variety of users with greater frequency and affordability, and with more reliability. To accomplish these goals, this relatively small program effectively leverages private investments made by multiple companies in the emerging space sector. The program does not fund their flight vehicle development, but purchases commercial flights offered by these entrepreneurial companies.

NASA recognizes the importance of commercial reusable parabolic and suborbital flights for development of future Science and Exploration workforce capabilities. One of the greatest challenges NASA faces in advancing cutting-edge technologies is bridging the gap between testing a component or prototype in a laboratory or ground facility environment, and demonstrating the technology or capability in a mission-relevant operational environment. The cost of access to space remains prohibitively expensive with launch costs to low-Earth orbit ranging from $10,000 to $15,000 per pound for small payloads. Adding these launch costs to the cost of demonstration hardware and operations capability presents a major hurdle in the matu-

ration of compelling space technologies. Without an ability to perform these critical relevant environment tests, not only do these new technologies remain on the shelf, but the workforce that might otherwise gain the experience to employ these new approaches remains underutilized and untrained. A key parameter for space capabilities is proving performance in a microgravity environment. It is this gap between non-microgravity ground-based testing and very expensive orbital demonstrations, where commercial reusable suborbital launch vehicles offer an enormous potential. Microgravity flights provide the potential for relevant environment testing at a small fraction of the costs required for orbital flights.

As noted in the legislative mandate for this program, and by the NRC review of NASA's Suborbital Program [1], utilizing suborbital platforms provides critical training opportunities needed to sustain a skilled aerospace workforce capable of meeting our Nation's exploration and technology development objectives. In the process of cultivating the next generation of researchers and technologists, and moving technology through the critical, flight testing phase, Flight Opportunities begins to establish a stable customer base for an emerging commercial suborbital market in the purchase of space transportation services.

Question 3. I am aware that NASA is realigning some of its educational activities in accordance with the Office of Science and Technology Policy (OSTP) five-year STEM strategic plan. Could you preview plans for any of NASA's STEM programs aimed at K–12 and university students, and speak about NASA's increased collaboration with other agencies on these efforts?

Answer. NASA is working to align its programs with the priorities identified in the five-year STEM strategic plan issued by the National Science and Technology Council (NSTC) Committee on STEM Education. NASA Education is actively engaged with Federal partners through the Committee on STEM (Co-STEM), the EPSCoR Interagency Coordinating Committee, and through collaborations with the Department of Education, Department of Defense Education Activity (DODEA), National Science Foundation, and NOAA among others.

Consistent with the status report on the NSTC Five-Year Federal STEM Education Strategic Plan released by the National Science and Technology Council, NASA will align its portfolio of activities over the next three years. In Year one, NASA will work with the Co-STEM to finalize criteria for success, develop common evidence standards, evaluation and research toolkits, and identify efficiency and productivity opportunities. In Years two and three, the Agency will establish baselines and increase alignment with the adopted criteria. NASA will align its future evaluation strategy with the Status Report on the NSTC Five-Year Federal STEM Education Strategic Plan. Successful STEM education practices and strategies identified through STEM education research studies and evaluations will also be used to guide NASA investments in STEM education. NASA will continually adjust the design of STEM education investments to align with best practices in STEM education derived from existing and new evidence from education research and evaluation.

The Aerospace Research and Career Development program strengthens the research capabilities of the Nation's colleges and universities and provides opportunities that attract and prepare increasing numbers of students for NASA-related careers. The student programs serve as a major link in the pipeline for addressing NASA's human capital strategies. The programs build, sustain, and effectively deploy the skilled, knowledgeable, diverse, and high-performing workforce needed to meet the current and emerging needs of NASA and the Nation. The research conducted contributes to the research needs of NASA's Mission Directorates and advances the Nation's scientific and technology innovation agendas.

The STEM Education and Accountability program provides competitive opportunities for NASA Centers, visitor centers, institutions of informal education, schools, universities, and non-profit organizations. These groups develop lessons, materials, research opportunities, and hands-on activities that draw on NASA's unique missions. The program includes learners from kindergarten through graduate school, educators in the classroom and in informal learning environments, college faculty, and the general public. The program emphasizes undergraduate participation in STEM research and education, preparing future scientists and engineers to enter the STEM workforce. Consistent with input received from the National Science and Technology Council Committee on STEM, NASA will provide middle school pre-service and in-service educators with NASA-themed experiences that build critical instructional STEM skills, and better enable them to motivate students in STEM. NASA activities and experiences spark interest in STEM and expose students to

[1] "Revitalizing NASA's Suborbital Program: Advancing Science, Driving Innovation, and Developing a Workforce" *http://www.nap.edu/catalog/12862.html*.

new career paths. Educators, both in schools, and in museums, science centers, and in community-based education organizations, will enhance their teaching practices with NASA-themed materials, experiences, and teaching strategies. NASA will engage learners of all ages through its missions, engineering challenges, and scientific discoveries.

Question 4. With the retirement of the Space Shuttle, NASA currently relies on Russia to provide access to the International Space Station. The NASA budget request for the Commercial Crew program designed to replace this capability is below the FY 2012 request and the authorization level. Will this funding level delay our Nation's ability to service the ISS with American launch vehicles?

Answer. NASA's original request for the Commercial Crew Program was:

($ in millions)	2011	2012	2013	2014	2015
FY 2011 BUDGET	500	1,400	1,400	1,300	1,200

With this budget, NASA estimated that a commercial crew capability could be in place by 2015. However, the amount appropriated in 2011 was $312M ($188M less than requested). Thus, NASA reduced its expected progress and initiated CCDev Round 2 which only matured elements of the systems instead of overall integrated crew transportation systems. The combined impact of the lower than expected budget and having to focus on elements of the system instead of an integrated system was that it delayed NASA's expected operational date of commercial crew to 2016.

The amount appropriated in 2012 was $406M ($444M less than the newly requested amount of $850M). This resulted in a further slippage of NASA's expected operational date to 2017, given the requested funding levels in the President's FY 2013 request and reasonable technical progress on the part of the commercial providers.

NASA is planning for commercial crew capability to be in place in 2017; but, the Agency's plans will not preclude earlier availability of services. Many of the potential commercial providers have stated they could provide services earlier than 2017. How much does NASA expect to ultimately pay Russia to fly astronauts to low Earth orbit before we achieve a new commercial crew capability?

Answer. In March 2011, NASA signed the most recent modification to the current International Space Station (ISS) contract with the Russian Federal Space Agency for crew transportation, rescue and related services from 2014 through June 2016. The firm-fixed price modification, valued at $753M, covers comprehensive Soyuz support, including all necessary training and preparation for launch, flight operations, landing and crew rescue of long-duration missions for 12 individual space station crew members.

Question 5. New Mexico is at a high elevation and relies on snowpack water sources for irrigation and drinking water. My state is highly susceptible to variations due to weather and climate patterns and I am particularly concerned about effects of climate change. I am pleased to learn about NASA's plans for the Earth Venture program and progress developing next-generation climate and weather monitoring missions. Could you elaborate on the goals of these missions, and the implications their findings could have for our understanding of climate change?

Answer. NASA is operating or has made significant hardware contributions to16 Earth observing satellites that are providing data on a wide variety of interactions among the oceans, atmosphere, land surface, ice sheets and biota that compose the Earth system. These data enable research that improves our scientific understanding of and enables improved prediction of climate, weather, and natural hazards. Additionally, the satellites return valuable scientific data that drive climate and weather research and provide decision support information and tools through NASA's Applied Sciences Program.

The list of currently operating satellites and their status is given in the table below. "Extended" means the mission has met all its top-level science requirements and continues to provide vital science data. "Prime" means the mission is still in its primary operating phase, collecting data on the way to meeting its top-level requirements.

Mission*	Launched	Phase	Scientific Issues (Goals)
Tropical Rainfall Measuring Mission (TRMM)	11/27/97	Extended	The first-time use of both active and passive microwave instruments have made TRMM the world's foremost satellite for the study of precipitation and associated storms and climate processes in the tropics.
Landsat 7	04/15/99	Extended	Landsat 7 is a joint mission of NASA and USGS to gather Earth resource data, and is the most recent in a long series of Landsat satellites going back over 35 years to 1974.
Quick Scatterometer (QuikSCAT)	6/19/99	Extended	The SeaWinds instrument on the QuikSCAT satellite is a specialized microwave radar that measures near-surface wind speed and direction under all weather and cloud conditions over Earth's oceans.
Terra	12/18/99	Extended	Terra simultaneously studies clouds, water vapor, aerosol particles, trace gases, terrestrial and oceanic surface properties, biological productivity of the land and oceans, the interaction among them and their effects on atmospheric radiation and climate.
Active Cavity Radiometer Irradiance Monitor (ACRIMsat)	12/20/99	Extended	The ACRIMSAT spacecraft carries an instrument which measures the Sun's total energy output, continuing a database started in 1980. ACRIMSAT data can be correlated with possible global warming data, ice cap shrinkage data, and ozone layer depletion data.
Earth Observer-1 (EO-1)	11/21/00	Extended	Earth Observing-1 (EO-1) is an advanced land-imaging mission that demonstrates new instruments and spacecraft systems. The hyperspectral instrument called Hyperion is the first of its kind to provide images of land-surface in more than 220 spectral colors.
Jason	12/7/01	Extended	Jason is an oceanography mission to monitor global ocean circulation, improve global climate predictions, and monitor events such as El Niño conditions and ocean eddies. The mission helps increase understanding of ocean circulation and seasonal changes and improve forecasting of climate events like El Niño.
Gravity Recovery and Climate Experiment (GRACE)	3/17/02	Extended	The primary goal of the GRACE mission is to accurately map variations in the Earth's gravity field over its lifetime. The science data from the mission is used to estimate global models for variable Earth gravity field approximately every 30 days.
Aqua	5/3/02	Extended	Aqua was launched with six state-of-the-art instruments to observe the Earth's oceans, atmosphere, land, ice and snow covers, and vegetation, providing high measurement accuracy, spatial detail, and temporal frequency.

Mission*	Launched	Phase	Scientific Issues (Goals)
Solar Radiation and Climate Experiment (SORCE)	1/25/03	Extended	SORCE provides state-of-the-art measurements of incoming x-ray, ultraviolet, visible, near-infrared, and total solar radiation. The measurements specifically address long-term climate change, natural variability and enhanced climate prediction, and atmospheric ozone and UV–B radiation.
Aura	7/15/04	Extended	Aura's objective is to study the chemistry and dynamics of the Earth's atmosphere with emphasis on the upper troposphere and lower stratosphere (0-30km) by employing multiple instruments on a single satellite. Each instrument makes daily global observations of Earth's atmospheric ozone layer, air quality, and key climate parameters.
Cloudsat	4/28/06	Extended	CloudSat is designed to fly in formation with CALIPSO to provide a comprehensive characterization of the structure and composition of clouds and their effects on climate under all weather conditions.
Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)	4/28/06	Extended	CALIPSO flies three instruments in formation with Aqua to obtain coincident observations of radiative fluxes and atmospheric conditions. This enables new observationally based assessments of the radiative effects of aerosol and clouds that is greatly improving our ability to predict future climate change.
Ocean Surface Topography Mission (OSTM)/Jason 2	6/20/08	Extended	OSTM/Jason 2 measures sea surface height by using a radar altimeter mounted on a low-Earth orbiting satellite. Measurements of sea-surface height, or ocean surface topography, reveal the speed and direction of ocean currents and tell scientists how much of the sun's energy is stored by the ocean.
Aquarius	6/10/11	Prime	By measuring sea surface salinity over the globe with such unprecedented precision, Aquarius will answer long-standing questions about how our oceans respond to climate change and the water cycle. Monthly sea surface salinity maps will give clues about changes in freshwater input and output to the ocean associated with precipitation, evaporation, ice melting, and river runoff.
Suomi-NPP	10/28/11	Prime	NPP is the bridge between the EOS satellites and the forthcoming series of Joint Polar Satellite System (JPSS) satellites. NPP data will be used for both climate research and operational weather prediction.

*Information on the measurements these missions make and the research and applications that they enable is available at:*http://nasascience.nasa.gov/earth-science/missions/*.

The following missions are in development or formulation:

Mission	Planned Launch Readiness Date
Landsat Data Continuity Mission (LDCM)	2013
Global Precipitation Measurement (GPM)	2014
Orbiting Carbon Observatory-2 (OCO–2)	2014
Stratospheric Aerosol and Gas Experiment (SAGE III on ISS)	2014
Soil Moisture Active/Passive (SMAP)	2014
ICESat-2	2016
Gravity Recovery and Climate Experiment-Follow-on (GRACE–FO)	2017

Several other missions are in a pre-formulation study phase.

Venture-Class

Venture-Class is a Tier-I Decadal Survey recommendation and is a program of regular competitive solicitations designed to enable science-driven, PI-led, cost-and schedule-constrained, innovative orbital and suborbital missions from academia and private industry as well as from NASA Centers. The Venture-class investigations complement the systematic missions identified in the Decadal Survey, and provide flexibility to accommodate scientific advances and new implementation approaches.

Venture-Class is fully funded, with 3 "strands"

- EV–1: suborbital/airborne investigations (5 years duration)
  - Solicited in FY 2009 (selections in FY 2010) *and every 4 years*
  - 5 investigations selected; flights began in FY 2011
- EV–2: small complete missions (5 years duration)
  - Solicited in FY11 (selections in FY 2012) *and every 4 years*
  - Small-sat or stand-alone payload for MoO; $150M total development cost
  - AO released 17 June, proposals received 29 Sept 2011, under review
- EV–Instrument: Spaceborne instruments for flight on MoO (5 years dev.)
  - Solicited in FY 2011 (selections in CY12) *and every 15–18 months thereafter*
  - Final AO release Feb 7; proposals due May 8, ~$90M development costs, accommodation costs budgeted separately

NASA's Research and Analysis programs and the Applied Sciences Programs, generate the research understanding and the efficient data products that users need to redeem the Nation's investment in the flight missions.

The Earth Science R&A activity is built around the creation of new scientific knowledge about the Earth system. The analysis and interpretation of data from NASA's satellites form the heart of the R&A program in the Earth Science Research Program, although a full range of underlying scientific activity needed to establish a rigorous base for the satellite data and their use in computational models, including those for assimilation and forecasting, is also included. The complexity of the Earth system, in which spatial and temporal variability exists on a range of scales, requires that an organized scientific approach be developed for addressing the complex, interdisciplinary problems that exist, taking good care that in doing so there is a recognition of the objective to integrate science across the programmatic elements towards a comprehensive understanding of the Earth system.

Through the Applied Sciences Program, NASA develops and demonstrates practicable applications of its research satellite observations and model results for use by decision makers. NASA works directly with decision makers throughout the development of applications.

Two recent examples of NASA Earth Science Research and Applications follow.

NASA's GRACE Data enhances North American Drought Monitors

Many regions in the United States experienced record-breaking drought in 2011. To better understand drought so that decision makers can accurately manage the best uses of a limited water supply, an Applied Sciences-funded project in the Water Resources Program is using GRACE (Gravity Recovery and Climate Experiment) data to enhance the U.S. and North American Drought Monitors, the premier decision support tools for drought monitoring purposes.

To address the need for better drought information and enhanced decision support tools, an Applied Sciences-funded project led by Matt Rodell, hydrologist at NASA's Goddard Space Flight Center, is working with NOAA, the National Drought Mitigation Center at the University of Nebraska Lincoln, and a team from the University of California Irvine to develop new drought indicator maps using Earth observations from GRACE and other missions.

GRACE—paired satellites that travel approximately 137 miles apart and detect small variations in the Earth's gravitational field—data is useful because it provides valuable information on water stored both on top of and below the land surface. This includes snow, soil moisture and groundwater. Having a complete picture of all these water types gives a much more accurate picture of drought.

Prior to the addition of GRACE data and other satellite observation into the drought monitors, the maps lacked information on soil moisture and groundwater storage—two areas that GRACE has been able to enhance greatly.

But GRACE's spatial and temporal resolutions are low. Because of this, GRACE data alone would not provide the complete picture necessary for sound water management decision-making. Rodell's team uses the GRACE data and combines it with a long-term meteorological data-set—including precipitation and temperature, satellite based solar radiation data, and high resolution land surface modeling to produce a continuous record of soil moisture and groundwater that goes back to 1948. The soil moisture and groundwater record is used to produce weekly maps of wetness conditions in the soil and aquifers.

To view the weekly maps, visit *http://www.drought.unl.edu/MonitoringTools/NASAGRACEDataAssimilation.aspx.*

NASA's efforts to assess snowpack for improved snow-water run-off forecasts

NASA is addressing the challenge of assessing seasonal water supply estimates from snow melt on three fronts. Improved land surface models from better observations, improved scientific knowledge, and advanced computing capabilities, sensor and model improvement from airborne observatories and campaigns, and better space observations leading to persistent measurements of snow cover and snow depth.

NASA Water Resources Program is supporting numerous projects building on a NASA modeling and modeling framework capabilities. These capabilities have expanded the use of scientific models to wide audiences of researchers and decision-makers. One example is with NOAA/National Weather Service (NWS) National Operational Hydrologic Remote Sensing Center (NOHRSC) to develop North American information for Alaska. This project is now expanding the effort to assess the impact on the NWS Alaska-Pacific River Forecast Center's region.

Airborne and spaceborne observations of snow-based reservoirs have greatly increased in quality and quantity of the past few years. NASA has been improving upon initial MODIS (on Terra and Aqua) algorithms to detect snow cover and have an improved product that allows better monitoring during the critical snowmelt phase of some snowpacks. NASA has also been exploring the use of hyperspectral remote sensing information, current available using NASA aircraft instruments, as well as in discussion for a future satellite recommended by the decadal survey (HyspIRI), to better understand the effects of (blown) dust on snow melt rates. As an example, various observations were combined in 2010 that allowed NASA scientists to warn particular water districts in Colorado that blown dust would significant enhance melt rates allowing them to better manage the (eventual) water capture system of this precious resource.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. KAY BAILEY HUTCHISON TO HON. CHARLES F. BOLDEN, JR.

Exploration

Question 1. Space Launch System (SLS) and Orion/Multi-Purpose Crew Vehicle (MPCV) Funding Levels: NASA's long-term future is beyond low-earth orbit. Yet, once again, we see that the proposed commitment of funds to develop the vehicles that will take NASA there is less than inspiring. In fact, the proposed funding levels for actual vehicle development for the Orion/MPCV) and the SLS are less now that the Administration has formally endorsed both programs than the amounts reflected in the Independent Cost Assessment last year and, presumably, submitted as part of NASA's request to OMB for FY 2013. How do you explain that the Administration's formal endorsement of SLS in September resulted in less money for these programs?

Answer. For FY 2012, the Congress appropriated $1.943B for SLS and associated ground systems, $15 M above the ICA profile when adjusted to include civil service labor. Also for FY 2012, the Congress appropriated $1.200B for Orion MPCV, $181 M above the ICA profile when adjusted to include civil service labor. The FY 2013 funding request for Orion MPCV represents a further increase over the FY 2013 budget estimates that were included in the ICA report. For SLS and associated

ground systems, the FY 2013 request is $1,885 million, 99 percent of the ICA profile NASA is committed to the development of the Space Launch System (SLS) and Orion Multi-Purpose Crew Vehicle (MPCV). Our budget formulation for FY 2013 took into account the FY 2012 Appropriation s. The requested funding will enable the Agency to develop, test and launch the SLS and Orion MPCV first uncrewed flight in 2017 and the first crewed flight in 2021. Concurrently, the Agency continues to aggressively pursue cost-savings initiatives to increase schedule confidence and robustness and reduce development costs.

Question 2. SLS Governmental Applications: The SLS is intended to provide the capability to launch and conduct missions to Asteroids, or the Moon, or Mars and other destinations for which NASA missions will be developed, but it certainly will have a capability that can be used for other purposes. What discussions are you having with other government agencies, for example, regarding potential use of the SLS in either its core configuration or in its fully-developed configuration, to meet needs they might have?

Answer. NASA is primarily focused on developing the SLS launch vehicle and the Orion MPCV spacecraft to provide the United States with a human capability to explore space beyond Earth orbit by 2021. NASA acknowledges this capability will be a national asset, one that can be used to the benefit of other national interests. With this capability in work, NASA has reached out to the science and military communities, providing estimated lift capability of the SLS launch vehicle. Potential requirements from these communities are being discussed and will continue to be assessed as the launch vehicle development progresses and more detailed capability information can be shared.

Question 3. SLS and MPCV Flight Milestones: During the hearing you stated that you may not talk about SLS and Orion/MPCV development as much as you may discuss Commercial Crew development, at least in part because SLS and Orion/MPCV programs are based mostly on known technology and relatively familiar, proven systems, and you have high confidence in their successful development. Later, in response to a question regarding the gap between the first expected uncrewed flight in 2017 and the first expected crew flight in 2021 by saying there were difficult challenges and uncertainties that would have to be addressed. Please explain that seeming contradiction. Is it not true that the 2021 date could be accelerated to an earlier date by the provision of sufficient funding levels, as opposed to any real concern about technological challenges?

Answer. NASA has developed an executable plan to develop the SLS and Orion MPCV systems to support the first human flight in 2021. The estimated budget to execute this plan has been phased to meet the fiscal budget requirements. This plan is based upon leveraging heritage hardware and developing new, efficient and cost-effective systems to enable an affordable and sustainable U.S.-developed human exploration capability. Exploration Flight Test-1 (EFT–1) (slated for 2014) and the first uncrewed flight of SLS and Orion MPCV (slated for 2017) are constrained by manufacturing capacity; additional funding would not accelerate these planned milestones. NASA will continually re-evaluate the projected 2021 launch date over the next few years to assess the potential for the integrated Orion MPCV, SLS, and Ground Systems capabilities to support an earlier launch opportunity.

Question 4. SLS Acquisition and Development Approach: The initial configuration of the SLS includes components that are heritage from the Space Shuttle and Ares programs, such as the shuttle main engines and the 5-segment booster. Please provide a description of NASA's acquisition strategy going forward for the SLS program with regard to competition for major components to ensure maximum efficiency for the program? What efficiencies is NASA expecting to gain from its experience on Ares and Shuttle? To what extent is NASA factoring these efficiencies in to its cost estimating for SLS?

Answer. NASA has been aggressive in the development of the SLS, having announced the basic architecture of the system on September 14, 2011, followed by the release of several synopses in September, October, and December, designed to support the development of different components of the system, including:

- SLS Stages Acquisition (posted 9–28–11)
- SLS Core Stage Engines (posted 9–28–11)
- SLS Advanced Development NASA Research Announcement (NRA) (posted 3–20–12)
- SLS Advanced Booster Engineering Demonstration and/or Risk Reduction NASA Research Announcement (NRA)(posted 2–9–12)

As directed in the NASA Authorization Act of 2010, the Agency acquisition strategy is to utilize Ares I and Shuttle contracts to the extent practicable, leveraging the existing Design, Development, Test and Evaluation (DDT&E) activities and hardware. In many cases, the DDT&E efforts directly support the SLS system development thus reducing the development time. Contract changes have been approved to support the 5-segment boosters, SLS engines and development of the core and upper stages by modifying the scope of existing contracts. NASA has taken an aggressive stance on reducing costs at NASA Centers and at prime contractor locations. The number of requirements to develop the SLS launch vehicle has been reduced, providing a reduction in development and future operating costs as compared to the Ares and Shuttle programs. In an effort to reduce fixed costs, the SLS Program has worked diligently with industry partners to reduce overhead and right-size design, manufacturing and testing efforts. Finally, the SLS Program has released two competitive solicitations to reduce risk and increase future competition on the SLS Program; the Advanced Engineering Demonstration and/or Risk Reduction NASA Research Announcement (NRA) and the SLS Advanced Development NRA.

Question 5. SLS and Orion/MPCV Funding Profile: In the Fiscal Year 2013 budget proposal, the requested funding for Orion/MPCV and SLS are flat from 2014 through 2017. This draws into question how the budget is phased over these years with respect to the work that needs to be accomplished and what a typical development funding profile looks like. The FY 2013 budget request also indicates at least a $250 million decrease in vehicle development funding from the prior combined levels for these two programs. How can we be sure this planned reduced budget will not negatively affect the first combined launch of the Orion/MPCV and core elements of the SLS in December 2017?

Answer. NASA has implemented an executable plan to develop the SLS and Orion MPCV systems to support the flight in 2017 and the first human flight in 2021. This plan was developed to meet those critical milestones within the assumed flat-line budget. This plan is based upon leveraging heritage hardware and developing new, efficient and cost-effective systems to enable an affordable and sustainable U.S.-developed human exploration capability. An independent cost assessment of the plan was conducted last year, and the results validated the credibility of the plan in the near term. As the development of the SLS, Orion MPCV and ground systems continue to progress, the Agency will continue to aggressively assess the technical, schedule, cost and risk of those systems to ensure a successful first test launch of the SLS/Orion MPCV system in 2017.

Question 6. Baseline Cost Estimates: GAO recently reported that NASA will not be able to provide a baseline life-cycle cost estimate for SLS and Orion/MPCV until February 2013 when it expects to have greater clarity of the issues surrounding integration of these two programs. What steps are NASA taking to ensure that the cost estimate for the project is realistic and phased appropriately to ensure success in meeting the direction for human spaceflight outlined in the 2010 NASA Authorization Act? Please explain the basis for confidence NASA has in moving forward with these development activities in the absence of a credible baseline cost and schedule estimate for this program?

Answer. As stated in the previous response, NASA has developed an executable plan for meeting the direction for human spaceflight outlined in the NASA Authorization Act of 2010. This plan has been validated by an independent assessment and has been deemed credible and serviceable in the near term. During the current Fiscal Year, a number of significant Agency and Program reviews have either been completed or will be completed that will provide more clarity and confidence in the plan. The Exploration Systems Development (ESD) portfolio successfully completed the cross-program systems requirements review in December, enabling the SLS, Orion MPCV and ground systems programs to continue moving forward with their individual requirements development, design definition and systems development. Each of the programs has major reviews either underway or planned for this summer. Once these program reviews are complete, ESD will conduct a cross-program systems definition review to ensure all of the programs are properly aligned from a technical, cost, schedule and risk perspective. Additionally, ESD is currently performing a detailed budget assessment based upon the President's FY 2013 budget request. This detailed assessment, in conjunction with the aforementioned reviews, will enhance the basis for confidence to continue the successful development of the Exploration architecture.

Question 7. International Partners: What is the current status of discussions with potential international partners for joint activity in pursuing long-term future explo-

ration goals, including, for example, such questions as using European elements in the service module portion of the Orion/MPCV crew exploration vehicle?

Answer. NASA has continued to build and strengthen international partnerships to meet the greater challenges of human exploration including future long duration missions. In addition to the on-going research being conducted on the International Space Station (ISS) among the ISS partnership, discussions are underway to explore how the ISS can be most effectively used as a testbed for long duration missions. In parallel, the International Space Exploration Coordination Group (ISECG) space agencies are coordinating an international effort to define technically feasible, programmatically implementable, and sustainable exploration pathways beyond low-Earth orbit (LEO). As a result, significant progress has been made and there is now a consensus among NASA and the participating ISECG agencies that the next steps for human exploration include sending humans beyond LEO to destinations such as near-Earth asteroids, the Moon, and eventually Mars. In preparation, it is important to maximize the use of the ISS as a unique space-based research and technology testbed. Specific international cooperation with NASA in its beyond-LEO exploration architecture will be defined as NASA's human space exploration strategic planning and analysis advance, and specific near-term opportunities for the SLS and Orion MPCV, as well as technology demonstrations, will be explored as these programs develop.

Commercial Crew Development

Question 8. Commercial Market Potential: Please provide details regarding who, other than the U.S. or other government, can be expected to buy crew launch capacity from the commercial carriers you are currently paying to design commercial human crew launch capacity? Is this market big enough for multiple commercial crew companies? Please provide specific projections justifying your conclusions and a detailed basis for those estimates.

Answer. On April 27, 2011, NASA submitted to Congress, "Commercial Market Assessment for Crew and Cargo Systems Pursuant to Section 403 of the NASA Authorization Act of 2010 (P.L. 111–267)". This report assessed the market for commercial crew and cargo services, ranging from space tourism to research and development to national interests. Over time, the commercial markets identified in this report hold the strong promise of significantly more customers, more flights, and potentially lower prices to the U.S. Government.

Question 9. Prioritization of funding: As noted previously, NASA's proposed FY 2013 budget includes a significant reduction in vehicle development funding for the combined Orion/MPCV and Space Launch System, while also proposing a $423 million increase in funding for commercial crew development, well above the amount authorized for FY 2013. Both programs have been given equal priority in the agreements between the Congress and the Administration reached last year. Please explain this decision to decrease Orion/MPCV and SLS vehicle development to levels even below what had been presented for the Independent Cost Assessment conducted mid-year in 2011, coupled with the dramatic requested increase in funding for the commercial crew program.

Answer. Please see responses to questions 1 and 3 vis. SLS and Orion MPCV. During the FY 2013 budget development process, NASA strove to strike the right balance among all our human spaceflight capabilities. The $830 million requested for the Commercial Crew Program was believed to be the amount necessary in FY 2013 to achieve safe, reliable, cost effective ISS crew transportation capability by 2017. As the primary means to U.S. access to the ISS, NASA wanted to take all steps necessary to provide assured crew access to the ISS and to eliminate our sole reliance on foreign systems.

Question 10. Commercial Crew Acquisition Strategy: NASA's budget documents indicate that in the transition from the Space Act Agreement phase to a certification phase for Commercial Crew development, NASA will have to "accommodate redesign as necessary to ensure compliance with agency requirements". What is NASA doing to minimize the potential for having to significantly redesign commercial partners' crew systems to ensure they meet agency requirements? Does NASA have an estimate as to how much it might cost to ensure compliance? Do the savings presented by using a space act agreement outweigh the lack of insight and oversight provided by a space act agreement?

Answer. NASA plans to use a Federal Acquisition Regulation (FAR)-based contract for certification of commercial systems prior to flying crew on these systems. NASA intends to structure the certification phase following the Commercial Crew Integrated Capability (CCiCAP) effort to permit the Agency to fully evaluate the proposed systems and accommodate any necessary redesign to ensure compliance with NASA safety, performance, and mission success requirements. The provider(s)

awarded a certification contract will not only be required to meet the NASA requirements in order to fly NASA personnel, but they will also have to show verified compliance of how the design and hardware will meet these requirements. Thus, there will be no reduction in the safety expectations or requirements as a result of this change in acquisition strategy.

Delaying the use of FAR-based contracts will prevent NASA from mandating compliance with certification requirements during the next phase of SAAs. However, NASA will address this issue in several ways. First, NASA has released the baseline set of safety, performance, and mission success requirements to all of industry. NASA also has made these requirements available to all providers as reference under the CCiCAP effort. Although compliance with these requirements is optional for industry under a funded SAA, NASA anticipates that providers will use the NASA requirements to inform their development activities, thereby reducing the technical risk associated with the lack of NASA oversight under an SAA. Because NASA plans to have more than one company in the next phase of SAAs, we believe the competitive environment provides strong incentive for the companies to align with NASA's certification requirements in order to remain competitive in the future certification and services phases.

Third, NASA included an "Overall Safety Goal" in the CCiCAP Announcement for Proposals (see page 3 of the Announcement) which states:

> "Successful commercial human space flight demands the highest commitment to safety; therefore NASA has the goal of fostering a safety culture in the commercial space flight industry that ultimately will minimize the risks associated with human space flight to LEO. NASA's goal is for Participants to demonstrate safety processes that include strong inline checks and balances, healthy tension between responsible organizations, value-added independent assessments and appropriate data archival, which will increase Government confidence in the Participant's approach to safety."

As a result, NASA will have increased insight into the providers' approach to safety during CCiCAP as the providers meet their milestones associated with the CCiCAP agreements.

Question 11. Is NASA comfortable that the level of insight and oversight during this critical phase of development is sufficient to provide the government with information it needs to eventually certify a vehicle and ensure obtaining the best price possible when buying commercial crew services?

Answer. NASA is comfortable with the level of insight and oversight currently planned for the CCiCAP development phase. In addition, our partners have a complete list of the NASA safety and performance requirements to which their crew transportation systems will be certified. The next phase of the plan calls for crew transportation system certification activities to be conducted using a FAR based acquisition.

Question 12. Impact of Funding Levels Less than Requested: Please describe the impact on the commercial crew program should Congress decide to continue funding the program at or near the level appropriated for FY 2012. Provide anticipated impacts for each of several potential funding levels in $100M increments less than the requested amount, to an amount equal to the FY 2012 appropriations level. Include in those projections the impacts on anticipated time-frame for achieving the first commercial crew flight to the International Space Station, and what specific steps the program would need to take to adjust to these respective funding levels.

Answer. NASA has not performed an assessment of impacts of lower than requested funding levels in FY 2013. During the FY 2013 budget development process, NASA strove to strike the right balance among our human exploration capabilities. Based on the many needs in FY 2013, the Agency submitted a request for $830M for FY 2013 for the Commercial Crew Program. This amount was believed to be the amount necessary in FY 2013 to achieve safe, reliable, cost effective crew transportation capability likely by 2017 (although earlier availability of services is not precluded).

Question 13. Commercial Space Regulations: Eventually, commercial space flight activity may be regulated, at least in part, by the FAA. As you know, there is currently a moratorium on FAA issuing such regulations. To what extent is NASA planning to facilitate or participate with FAA in the preparations leading to formulation of commercial space regulations?

Answer. Both NASA and the Federal Aviation Administration (FAA) envision a state where the FAA licenses commercial human spaceflights provided by a robust industry, from which NASA and the private sector can purchase transportation services. The FAA has already developed processes and procedures for licensing and

regulating commercial space activities to protect the safety of the public. NASA and FAA have complementary and interdependent interests in ensuring that commercially-developed human-rated systems and vehicles for low-Earth orbit are effective and safe. Both agencies seek to avoid conflicts between their requirements or duplicating each other's roles. NASA and FAA will be working together to ensure that commercial providers are subject to a coordinated and complementary set of requirements and regulations when providing services to NASA.

ISS National Laboratory

Question 14. Non-NASA Research: As you know, the Congress has designated the U.S. Segment (including bartered assets in partner-provided facilities) of the International Space Station as a National Laboratory. It has essentially divided that segment into two halves, operationally, and required the establishment of a Cooperative Agreement with an independent entity, organized specifically for the purposes of managing non-NASA research in the fifty percent of the U.S. segment allocated to it by law. As you know, this activity has been slow in getting put in place. Can you bring the Committee up to date on the progress in getting research up and running in the non-NASA portion of the National Laboratory?

Answer. CASIS has made significant progress in establishing its research program. It has appointed an Interim Chief Scientist, Dr. Timothy Yeatman, who has extensive experience in biomedical research and in industry, and an Interim Scientific Collegium. The interim Scientific Collegium members include:

- Leroy Hood, M.D., Ph.D. • President/Co-founder Institute for Systems Biology • Member, National Academy of Science, National Academy of Engineering, Institute of Medicine and National Inventors Hall of Fame (Also invented the DNA sequencer/synthesizer) • Founder of 14 companies including Amgen, Applied Bio systems and Integrated Diagnostic
- Walter Chazin, Ph.D. • Professor, Biochemistry and Physics Vanderbilt University • Director, Center for Structural Biology and Ingram Professor of Cancer Research • Instrumental in the development of structural biology and molecular biophysics (involves complementary application of different structural approaches including spectroscopy, scattering, crystallography and microscopy) • Research focused on multi-protein complexes, 3–D structures and characterization of binding interfaces/interactions
- Arnold Levine, Ph.D. • Professor, Institute of Advanced Study, Princeton University • Professor, Department of Biochemistry, Robert Wood Johnson Medical School • Former President and CEO of Rockefeller University • Recipient of American Cancer Society Medal of Honor • Co-Discoverer of p53 tumor suppressor gene
- Torben Orntoft, Ph.D. • Head, Department of Molecular Medicine, Aarhus University, Denmark. • CEO of AROS Applied Biochemistry • Member, European Academy of Cancer Sciences • Member, Scientific Advisory Board, Novo Nordisk • Research focused on identification of molecular biomarkers for use in disease classification and prediction
- Jeffrey Trent, Ph.D. • President, Translational Genomics Research Institute • Founding Scientific Director, Intramural Research for the Human Genome Research Institute, NIH • Member, multiple commercial company scientific advisory boards.

The Interim Scientific Collegium has reviewed past NASA-sponsored research in biology and biotechnology and has identified several areas of initial interest. The group has consulted with major pharmaceutical companies to determine market potential. CASIS has structured its first research solicitation, planned for release this June, around the findings of the Collegium.

Question 15. National Lab Designation: One of the driving factors in the National Laboratory designation—and especially in the requirement for an independent entity to manage half of the research conducted in the U.S. Segment was to ensure that research planned for the station would not be subject to changes in NASA research requirements and priorities. What are you doing to ensure that the independent entity with which you have a Cooperative Agreement actually remains independent and free from those kinds of changes in NASA priorities?

Answer. Under the cooperative agreement, CASIS is free to work with NASA whenever CASIS's objectives will benefit from access to NASA facilities or capabilities. However, NASA has no control or influence on the research directions chosen by CASIS. All of the NASA personnel responsible for communication with CASIS understand this principle. CASIS has not been asked to coordinate its research with

NASA, or to align its objectives with NASA priorities, other than to fully utilize the ISS by conducting significant, highly meritorious research.

Question 16. National Lab Research Processing: One purpose of the independent National Laboratory management role is to ensure equal opportunity for Principal Investigators to prepare and submit research proposals to, in effect, compete for access to the resources of the ISS National Laboratory. To enable the preparation of those research proposals, the underlying "rules" of the proposal and selection processes must be published and available for information and understanding of the criteria that will serve as the bases for selection. Have these "rules," or guidelines and procedures been established, disseminated and explained by the Independent management entity? If not, what is the expectation of the availability of that information? What role has NASA played or will it expect to play in the development of those guidelines and procedures?

Answer. The cooperative agreement with CASIS requires that resource prioritization decisions be made ". . .using a fair, transparent, and impartial selection process that maximizes value of the ISS investment made by the Nation." The valuation framework that will be employed to determine the merit of competing projects is one of the third quarter deliverables identified in the 2012 Annual Program Plan.

Question 17. ISS Logistics and Supportability: What is the impact of the latest delay of the first mission of SpaceX's Falcon 9 to the ISS on the utilization of ISS given that initial planned milestones have been delayed and GAO reported as late as November 2011 that SpaceX was scheduled to fly 3 fully operational resupply missions to the ISS in 2012? At what point, without augmentation from planned commercial cargo delivery capability, will the ISS begin to experience shortfalls in the necessary supplies to support ISS crew and science? Please provide a timeline for such potential shortfalls and details regarding NASA and its partners' contingency response should they be experienced.

Answer. On May 22, 2012, SpaceX launched its second COTS demonstration flight, and three days later, the Dragon spacecraft was berthed to the ISS. The mission, which accomplished the remaining COTS demonstration goals for SpaceX, was brought to a successful conclusion on May 31, with the deorbiting and splashdown of the Dragon capsule. NASA expects Orbital to complete the on-orbit COTS demonstration to ISS this year.

NASA anticipated a delay in CRS resupply services and has adequately provisioned the ISS with maintenance, operational and utilization support cargo to sustain a delay into 2013. NASA is currently working with SpaceX and Orbital to complete the first CRS flight in FY 2012 and four additional flights in FY 2013. NASA is also working with its International Partners to prioritize utilization cargo over other cargo if necessary to meet our utilization goals. Given that the ISS is continually being resupplied by the Partner vehicles, Progress, ATV and HTV, and that the CRS missions are expected to begin in the summer/fall time-frame of this year, NASA does not expect shortfalls in utilization.

James Webb Space Telescope (JWST)

Question 18. JWST Funding Impact on Other Programs: We have agreed on the importance of moving forward with the JWST program. However, with a constrained to-line funding level for NASA, the replan for the JWST project has meant that tough decisions had to be made at the expense of other projects and activities in the 2015 through 2018 time frame. Can you outline what projects and activities in NASA's portfolio were terminated or scaled back to accommodate the JWST project's lifecycle cost increase? Additionally, what other constraints is the agency dealing with due to the JWST delay, such as test facility access, and how is the agency addressing these issues to minimize the impact on other ongoing projects?

Answer. NASA's FY 2013 budget request identifies four key priorities to be funded in this constrained fiscal environment: ISS sustainment and utilization using commercial crew and cargo services; Space Launch System and Orion Multi-Purpose Crew Vehicle; JWST; and new technologies. In view of these four key priorities for NASA (not just JWST) and of our constrained fiscal environment, we will not be moving forward with the 2016 and 2018 ExoMars missions that we had been studying with the European Space Agency. Instead, NASA is developing a new, integrated strategy for Mars missions to ensure that the next steps for Mars exploration will support science, as well as longer-term human exploration goals, and take advantage of advanced space technology developments. NASA will complete this integrated plan, including the framework for a mission to take advantage of the 2018 or 2020 launch opportunities, no later than this summer. In addition, NASA is slowing the ramp-up of some current science projects and delaying the start of some future ones, such as slowing the rate of solicitation for new competed missions, in the

notional outyear budget projection in the FY 2013 Budget. Finally, NASA will be unable to initiate development of the highest priority new large mission recommended by the NRC's 2010 Astrophysics decadal survey—the Wide-Field Infra-Red Survey Telescope (WFIRST) until JWST development is largely complete. With regard to test facility access, NASA is actively managing the movement of JWST, the Magnetospheric Multiscale (MMS) mission, and the Global Precipitation Measurement (GPM) mission through the available facilities given their overlapping schedules, and we have resolved the schedule conflicts in a manner that removes the pressure of requiring multiple missions to have perfectly timed entrance and exit from difficult testing periods. In so doing, we have minimized the risks to all three missions. It is important to note that this situation was not driven solely by the delay in JWST development, as MMS and GPM have also had internal schedule challenges.

Miscellaneous Issues

Question 19. Astronaut Selection: NASA recently reported a record number of astronaut applications even though the size of the astronaut office is less than half the previous number of positions before the end of the Space Shuttle program. What do you believe is driving that? Can you provide for the record a summary of the stated reasons given by the applicants for this high level of interest?

Answer. Being an astronaut is an aspiration many people have their entire lives, and this response indicates that many thousands would love to be a part of our continuing human spaceflight program as part of the Astronaut Corps.

Since we do not have a survey mechanism as part of the application process, there is no way for us to know for certain why so many people applied this year. We feel the dramatic increase in applicants for this application window is likely due to any combination of factors—including the high-visibility of NASA in the news as we transitioned from the space shuttle to International Space Station and a redesigned USA JOBS application process.

The agency executed a comprehensive communications campaign to ensure the public knew about this opportunity. The public affairs team not only utilized traditional communications techniques and mainstream media, but also capitalized on social media channels (such as Twitter, YouTube, Facebook and blogs) to raise awareness of this job opportunity. The agency also encouraged employees and astronauts to share information via their own personal and professional networks and at speaking events and appearances, created Public Service Announcements (PSA's) that were made available online for radio and television use, and reached out to all branches of the U.S. military to ensure they had information they could share with their members.

Question 20. Mars Exploration Program: This Budget has raised concerns in the planetary science and international space community about the reductions in planned Mars Exploration programs. Can you address those concerns, and explain how you intend to reaffirm the country's interest in these programs—and our reliability as an international partner in future joint cooperative missions?

Answer. The NASA Administrator has directed the Associate Administrator for the Science Mission Directorate to lead Mars program reformulation activities working with the Associate Administrator for Human Exploration and Operations Directorate, the NASA Chief Technologist, and the NASA Chief Scientist. In support of this reformulation, NASA has established a Mars Program Planning Group (MPPG), to develop options for a program-level architecture for robotic exploration of Mars that is consistent with the President's challenge of sending humans to orbit Mars in the decade of the 2030s, responsive to the primary scientific goals of the 2011 NRC Decadal Survey for Planetary Science, and consistent with the President's FY 2013 budget request. The MPPG is expected to identify potential investigations and options in sufficient detail for NASA to be able to select and initiate high pay-off mission(s) beginning with the 2018 launch opportunity, and to facilitate NASA's decision-making process for a reformulated Mars Exploration Program. In concert with the Mars Exploration Program the MPPG will communicate with customers, stakeholders and partners to ensure a collaborative and responsive set of investigations and options, This process will inform NASA's development of its FY 2014 budget submission.

We plan to actively engage ESA and the Canadian Space Agency in the next few weeks, seeking their input and engagement with the Mars Program's reformulation as early as practicable. We also intend to engage the broader international community in May through the established International Mars Exploration Working Group (IMEWG), an ad hoc organization of Space Agencies that was formed in 1993 to facilitate coordination among the world's Mars-faring nations.

NASA has a long history of very successful cooperation with nations around the world, and a part of that history has from time to time included some decisions by NASA and some by our international partners to re-phase or re-design or even terminate planned cooperative activities. Our partners are very aware that in all instances our cooperation is based on the availability of appropriated funds, just as we are aware that their participation has similar funding constraints. Consistent with the National Space Policy and the Space Act, NASA will continue to pursue international cooperation in support of its activities and mutual objectives. Currently, NASA has over 500 active agreements with over 100 countries and anticipates that international cooperation will remain a cornerstone of all of its future activities.

Question 21. Alternative Mars Exploration Planning Activities: During the hearing you said, regarding Mars Exploration program future planning, "However, we are now developing a new integrated strategy for Mars missions to ensure that the next steps to Mars exploration will support the science objectives that were laid out in ExoMars, the priorities established by the National Research Council's decadal survey on planetary science, and also support our human exploration." Please provide your timetable and details on how you are developing this new integrated strategy. Lessons Learned: Historically, many NASA projects have experienced cost increases and schedule delays, whereas the GRAIL and Juno projects both launched on schedule and are currently within budget. What practices or procedures allowed these projects to meet their baseline? To what extent are lessons from those programs applicable—and being applied—to a broader array of NASA program activities?

Answer. As noted above, NASA has established a senior leadership team focused on reformulating the Mars program and has set up a Mars Program Planning Group (MPPG). The MPPG will develop options for a program-level architecture for robotic exploration of Mars that is consistent with the President's challenge of sending humans to orbit Mars in the decade of the 2030s, responsive to the primary scientific goals of the 2011 NRC Decadal Survey for Planetary Science, and consistent with the President's FY 2013 budget request. The MPPG will provide NASA with progress reports in April, June, and August. These reports will provide senior NASA leadership with decision-making opportunities to steer the MPPG in investigation and architecture options, and the Mars Exploration Program in associated budget development, culminating in a presentation of options in August. We anticipate that NASA will be able to brief the relevant Congressional Committees on progress periodically through the summer, and will be able to provide more detailed briefings on a proposed mission architecture after the release of the President's FY 2014 budget request in early 2013.

Lessons Learned: NASA's experience with managing the development of challenging, one-of-a-kind science missions has led to several lessons identified and applied to all new programs. These lessons have resulted in updates to NASA's formal procedural requirements documents for management of all NASA-developed spaceflight programs and projects. Specific steps NASA has taken include:

- Establishment of joint cost and schedule confidence level (JCL)-based life cycle cost budgeting that improves the understanding of the complexities and risks associated with a development result in more accurate estimates of cost and schedule as evidenced by the recent performance of Juno and GRAIL;
- Requirement that projects implement Earned Value Management (EVM) systems to weigh technical progress against expenditure of funds on a monthly basis provide early indicators of issues;
- Extended duration Phase B definition and preliminary design to allow for technology maturation and through system engineering to better characterize the risks to be retired during development and identify unique integration and test needs;
- Use of a formal acquisition strategy process before and during Phase A to define program management structure and Center and contractor roles in a way that best fit the project under consideration;
- Strong independent reviews at key points in the development to verify that the project is making progress per its plan and to offer additional insights based on the independent review teams experience; and,
- Regular reviews with senior NASA management to assure that project concerns are addressed quickly to avoid cost and schedule implications.

Question 22. (Launch Vehicle Access): GAO recently reported that 9 major projects experienced issues with launch vehicles, including increasing costs and availability of launch vehicles. Additionally, GAO also made a recommendation in its duplica-

tion mandate report on the need for increased coordination between NASA, DOD and NRO on the acquisition of launch vehicles. Is NASA actively addressing this issue, given the impact that this issue could have on the cost of current projects? How does NASA plan to pursue coordination with DOD and NRO to increase efficiency in the acquisition of launch vehicles?

Answer. Yes—NASA is actively addressing both issues identified by the GAO. The first part of your inquiry is from the GAO's March 2012 report, "*NASA: Assessments of Selected Large-Scale Projects.*" The GAO identified 20 programs and projects with space launch related aspects in this report. As you note, the GAO identified nine of those projects as having "launch issues." In NASA's view, six of the nine missions do not have launch issues of note since they have either already successfully launched (GRAIL & NPP); or have launch service contracts in place and are on track for launch (LADEE, MAVEN & TDRS); or are in the early stages of development (SPP). NASA agrees there are three medium-class missions with launch issues to resolve (ICESat-2, SMAP & OCO–2). ICESat-2 identified in the GAO report that launch service cost was its challenge, thus the NASA Launch Services Program (LSP) is working with the project to identify and develop launch alternatives to meet their needs in time for a CY2016 launch. SMAP and OCO–2 identified in the GAO report that launch vehicle availability was their issue. NASA's LSP recently terminated the Taurus XL launch service task order (LSTO) for OCO–2 due to the Orbital Science Corporation's inability to determine the root cause for the previous two Taurus XL launch failures. On February 3, 2012, NASA LSP released a Request for Launch Service Proposal to industry to begin the competitive process to provide a commercial launch service for SMAP and a new commercial launch service for OCO–2. Awards are expected in the July 2012 timeframe.

The second part of your inquiry is from the GAO's February 2012 report, "*2012 Annual Report: Opportunities to Reduce Duplication, Overlap and Fragmentation, Achieve Savings, and Enhance Revenue.*" Section 23 of this report deals with "*Space Launch Contract Costs*" and has as its premise that "*Increased collaboration between the Department of Defense and National Aeronautics and Space Administration could reduce launch contracting duplication.*" This section of the GAO report is written specifically on the procurement of Evolved Expendable Launch Vehicles (EELVs) which are "intermediate" and "heavy" class launch vehicles provided by United Launch Alliance (ULA). NASA, together with the Air Force and NRO are already actively addressing the issue of increased coordination and we provide the following as evidence. First, the NASA Administrator meets with the Secretary of the Air Force and the Director of the NRO quarterly to discuss and coordinate activities on multiple topics of mutual interest. The formal commitment to continue our coordination efforts was put in place via a Letter of Intent that was signed by the three Agency heads in October 2010. A Memorandum of Understanding (MOU) on Evolved Expendable Launch Vehicles (EELVs) was signed by the three Agency heads in March 2011 and formalized what had been a long-standing informal process of coordination between the NASA Launch Services Program Manager and her counterparts within the Air Force and NRO. This MOU established a "*Government Expendable Launch Vehicle (ELV) Executive Board as a forum for interagency communication of acquisition, certification, and programmatic ELV launch issues.*" This forum meets on a quarterly basis and is "*the mechanism to implement the block buy strategy, baseline and modify EELV launch requirements, and enable resolution of EELV programmatic issues to provide clear direction to launch providers.*" The additional signing of the *Coordinated Strategy for New Entrant Launch Vehicle Certification* in October 2011 is further evidence of our close work together for launch service acquisition. As NASA identifies its launch vehicle needs through our competitive process, and if those identified needs includes EELVs, those acquisition plans will be coordinated with the Air Force and the NRO in order to maximize the U.S. Government's buying power.

Question 23. Education Program Reductions: The proposed Education budget is down approximately 30 percent. How will NASA further our scientific advancement and contribute to our economic and technological viability and competitiveness if it is unable or unwilling to invest in educating our Nation on the advantages and benefits of Science, Technology, Engineering and Mathematics? What steps are you taking to ensure NASA can continue to make an important contribution in this area?

Answer. NASA brings many assets to support the Administration's emphasis on science, technology, engineering and mathematics (STEM) education beyond funding. Our people, platforms like the International Space Station, and our facilities across the Nation all contribute to strengthening STEM education. Though funding is being reduced in alignment with the Administration's priority on focusing limited funds, NASA remains committed to advancing high quality STEM education using NASA's unique capabilities, and to leveraging our contributions with Federal and

other partners as they tackle the STEM challenges we face. NASA will align its funding on the priority STEM issues identified by the National Science Technology Council (NSTC) Committee on STEM Education through grants, cooperative agreements, internships, fellowships and other hands-on experiences for learners, educators and institutions.

The FY 2013 request is $100.0M, a $38.4M or 28 percent decrease from the FY 2012 request ($138.4M) and the FY 2012 Effective Planning Level ($138.4M). The FY 2013 request includes:

- $24.0M for Space Grant, a nationwide network of colleges, universities, and other organizations that provide NASA space-related opportunities to students, educators, and the public.
- $9.0M for EPSCoR, which provides competitive research opportunities to institutions in targeted states.
- $30.0M for MUREP, which provides competitive NASA research and study opportunities to students of underserved and underrepresented groups and competitive opportunities to enhance the research and technology capabilities of Minority Institutions.
- $37.0M for STEM Education and Accountability projects, which provide competitive opportunities, foster innovative education efforts at NASA Centers and through grantees, and formal evaluation activities.

To offset some of the impacts, NASA is increasing its emphasis on strategic partnerships. The Agency currently has an open partnership announcement available at *http://www.nasa.gov/offices/education/about/NASA_Seeks_Collaborators.html.* NASA seeks unfunded collaborations with organizations to enhance its ability to achieve its strategic goals, outcomes, and objectives as they relate to education and as articulated in the 2011 NASA Strategic Plan. This Announcement requests information from creative organizations with wide-ranging areas of expertise interested in collaborating with NASA in reaching new or broader audiences across a national scale.

Question 24. Construction, Environmental Compliance and Restoration: During these times of belt tightening, please elaborate on the justification for what new and necessary construction or restoration NASA is funding with the proposed increase of 27 percent in this line of funding from FY 2012?

Answer. The 27 percent increase in Construction and Environmental Compliance and Restoration (CECR) is primarily a result of continuing program requirements which were initially identified in December 2011 in NASA's FY 2012 Initial Operating Plan, as well as requirements for the environmental clean-up effort at NASA's Santa Susana Field Laboratory site in California.

The majority of these program requirements are for Space Launch Systems (SLS) and 21st Century Space Launch Complex. Exploration did not have FY 2012 Construction of Facilities in the President's Budget as these emerging programs did not exist early in the FY 2012 budgetary process. For example, SLS was not a program until May 2011. These funding increases from FY 2012 to FY 2013 are normal and expected as the program ramps up and the requirements become more defined.

These construction projects are for manufacturing of the actual SLS flight hardware at Michoud Assembly Facility, modification of test stands for structural testing of the new SLS flight hardware at Marshall Space Flight Center, as well as, modifying launch and integration facilities at Kennedy Space Center for the new programs. While SLS is using as much of the existing infrastructure as is feasible, modifications for the new flight hardware are still required.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO NEIL DEGRASSE TYSON, PH.D.

Question 1. The long-term goal for our human space program is Mars. There have also been arguments for near term destinations such as the Moon, an asteroid, or perhaps an area in deep space on the far side of the Moon called "L2." What are your thoughts on the need for NASA to balance achievable, near term destinations with longer term goals?

Answer. An important question whose answer often gets mired in the pet destinations of those making the arguments. When the interstate highway system was proposed, the goals was never to just connect New York with LA. The goal was to connect as many places as there are to as many places as we could think of. Commerce, tourism, security, would all be enhanced by this. So too would our future in space. If we create a suite of launch vehicles, with variable launch capability, then needs

at any one moment will determine the destination. Science on Mars? That's one configuration. Tourist jaunts to the near side of the Moon? That's another. Military needs to secure cislunar space? That's another. Mining on the far side of the moon or on an asteroid? That's yet another launch configuration. With this setup, the entire solar system transforms to become our backyard. And as long as frontiers are being crossed in these efforts, innovation follows like day follows night. You don't sequence our steps in space, you do it all.

Question 2. What do you think are some of the most compelling destinations for NASA to target?

Answer. Mars (life). Mars Moons (monitor mars). Lunar Poles (frozen water repository). Metallic asteroids (Mineral rich). Asteroids with orbits that cross that of Earth (we don't want to go extinct, do we?). Earth-Sun L2 (telescope haven). Far Side of the moon (great for radio telescopes and other work that requires radio-silence from Earth). Cislunar space (the new high ground). All destinations—(tourists will pay to go anywhere).

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. TOM UDALL TO
NEIL DEGRASSE TYSON, PH.D.

Question. You spoke eloquently about the importance of inspiring our nation to dream and seek adventure through advancement in STEM fields.

Programs such as Nova scienceNOW engage students' interest and show them the role that science plays in their own communities. New Mexico is home to strong educational initiatives such as NASA's "Launch and Learn" program, and my state is proud to have many students that excel in STEM at a national level. But our country can do much more to support STEM education.

Through your experience working with today's youth, could you share any lessons learned that could help us better prepare tomorrow's scientists?

Answer. The problem is not the undereducated youth of today. It's the rampant science illiteracy of adults who control resources and opportunity and governments. An enlightened adult population (which outnumbers kids by a factor of five) would feel compelled to bring forth major science and technology initiatives in the country that could not help but get noticed by the next generation. In this way, the very act of engaging in frontier discovery becomes the force required to excite the next generation. On that level, you don't need government funded STEM education programs. The motivation would be drawn from the innovation flywheel set into motion by NASA and other agencies of discovery.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. KAY BAILEY HUTCHISON TO
NEIL DEGRASSE TYSON, PH.D.

Question 1. NASA Long-term Outlook. Dr. Tyson, in your latest book, Space Chronicles, you include a very insightful description of the political challenges facing NASA and the U.S. space program. One of the challenges you mention is the difficulty for the President. . .any President. . .to gain support for implementation of a goal that may not be reached until many years after he or she leaves office. Unfortunately the pursuit of space exploration beyond earth orbit is unavoidably a long-term undertaking. Can you provide us your thoughts on how such a long-term goal can be achieved? And what role do you see the Congress playing in that?

Answer. You have challenges creating sustained funding any time the urge to fund one project or another issues forth from the portfolio of interest from one member of congress or another. This leaves the survival of the initiative up to the political winds of the moment, and especially whether the district of one Member stands to benefit directly compared with other districts. So people need to recognize the fundamental value to the Nation's economy that the fostering of an innovation nation can bring. When this happens, the decision to fund NASA is simply one of return on investment for the Nation and not one of whose district benefits directly from a flow of monies to it. I foresee the day when the electorate learns of this need and compels their representatives to fulfill this mission statement. Only then would the goals transcend partisan politics and possibly even politics itself. If this does not happen, America will continue to fade, while it applies feeble band-aids to problems thought to be solvable by funded programs that target them. It's hard to teach people how a culture can shift in attitude and goals and mission statements. Most people never have the occasion to think about the culture in which they are embedded. An innovation nation is just the force necessary to shift that culture to one that em-

braces the fruits of STEM fields. And you get an innovation nation practically for free with a fully funded NASA.

Question 2. International Space Station. You have made the comment that you don't want to "boldly go where hundreds have gone before," referring to low-Earth orbit, instead, you suggest expanding the space frontier into "real" exploration. I can agree with that sentiment. However, I also believe we have a responsibility to ensure the maximum utilization, especially in the near term, of the International Space Station. To date over 40 million students from all over the world have had direct educational interaction with the crew members and research aboard the ISS. Do you agree that the ISS has great value in helping to stimulate what you refer to as a "science-focused" society?

Answer. I think the ISS as a designated National Laboratory was an excellent idea from the beginning. Any active presence in advancing a space frontier would be unthinkable without a permanent orbiting space station. Just don't expect the ISS to trigger a cultural shift in American innovation. And that's what we're after here. The cultural shift itself, brought about by advancing space frontiers, is what triggers interest in STEM fields like nothing else. The day we return to the Moon, or go on to Mars and asteroids and Lagrangian points with astronauts, the ISS will be long forgotten in the educational pipeline—as it should be—leaving it to serve the pure zero-G science interests that so much political capital of recent years has been invested to preserve.

Question 3. Technological Innovation. You have spoken and written about the need to continue development of new technologies that will take us further into space exploration, and the risks we take if we cease exploration with current technologies and wait for those new technologies to "arrive", so to speak. Can you describe for us some of these risks and challenges, and perhaps talk about how to strike a balance, if that is what it requires, in times of shrinking budgets?

Answer. In a free market capitalist democracy there is always money to invest when the return on investment is manifest. In this context, I do not fear shrinking budgets. Nor should anyone. The future economic health of the country is at stake. As for balancing risk and reward, the rewards are not solely the business that gets conducted in space (tourism, resource mining, military high ground, etc.), it's the effect of those granted patents have on Earth-borne problems and it's the effect that the advancing frontier has on "everyone's" vision of America's future. It's the broader outlook that will transform society, in which you no longer need programs to convince people—adults or kids—that it's good to embrace STEM fields. The metrics of success will not need to be the actual space achievements. The metrics of success will be how we as a nation learned to seek out and advance the frontier, and came to recognize that our future economic security and wealth depended on it.

Question 4. Historical Moment of Significance. In your book, you described John F. Kennedy's call for putting a man on the moon as really "a battle cry against communism." Lacking a "race" to the Moon or Mars, similar new "sputnik moments" sparking calls for new and innovative science, technology and research, have not been seen, or at least not broadly acknowledged. What do you believe will be the next real "Sputnik moment," or has it happened, and just not been recognized?

Answer. The nation is in the middle of a Sputnik moment and does not realize it because our culture has not successfully connected the dots between our investments in space and the overall health of our economy. Until that connection is made, we will continue to fade on the world stage.

Question 5. NASA Economic Contribution. What aspects of the NASA's activities do you think have the greatest promise to help in the economic recovery of America?

Answer. The cultural influence that a healthy NASA has on the country is its biggest force—powerful enough to create an innovation nation. As headlined flow like rivers from the frontier of space the urge to want to enter STEM field in the educational pipeline will be high without the need of a targeted program to enable it. This movement will not be about spinoffs. It will simply feed the urge to invent and innovate in the first place.

Question 6. Government Role. You have made the point that, historically, it has been a role of governments to fund the great explorations of the past. Can you discuss your view of where the threshold is or should be between government support and a purely private sector-supported level of exploration? Or is that a matter of distinguishing between true, leading edge exploration versus utilization and routine operations?

Answer. There can be no capital market valuation of the space frontier. Too expensive. Too dangerous. Unknown risks. If billionaires choose to do it, it will be a vanity project and not a business model. Private enterprise comes later, after the government advances the frontier, routines are established, patents are granted, and risks are assessed.

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