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THE INTERNATIONAL SPACE STATION: A PLATFORM FOR RESEARCH, COLLABORATION, AND DISCOVERY

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED TWELFTH CONGRESS

SECOND SESSION

JULY 25, 2012

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED TWELFTH CONGRESS

SECOND SESSION

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CONTENTS

THE INTERNATIONAL SPACE STATION: A PLATFORM FOR RESEARCH, COLLABORATION, AND DISCOVERY

WEDNESDAY, JULY 25, 2012

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

The Committee met, pursuant to notice, at 10 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, everybody.

Thank you for coming.

Senator Hutchison and I wanted, along with Senator Boozman, who is our Ranking Member of this subcommittee—John, come on over here closer.

[Laughter.]

Senator NELSON. The three of us wanted to have this hearing today so that the American people know what is going on in space. That there is this extraordinary contraption that is about 240 miles above the Earth that is as large as from the end of one end zone of a football field to the other. That is 120 yards. And as wide as a football field.

And if you will just look at the NASA model there, you will see that that is certainly true. If you look at all the components there, you will see that part of it is Russian, of which the Soyuz docks there, which is the vehicle that comes and goes and most recently, since the Space Shuttle was retired a year ago, is the vehicle that we have delivering crew until we have the American rockets that are man-rated with all the redundancies and escape systems that are being developed as we speak.

But in addition, we have a number of different payloads that are delivering cargo, the most recent of which was the successful flight and successful delivery of cargo by one of the American commercial ventures, SpaceX. And as we speak, we have already rendezvoused a Japanese space module that is delivering cargo, and it will be docking within a matter of days.

There is also a crew on a Soyuz that has launched. And have they docked yet? Oh, it is the Progress module, which is a Russian module. It is in the vicinity of the Space Station, and they are working out the sequencing for the delivery of cargo from the Japanese module as well as the Russian Progress module.

So there are a number of these payloads that are going up. In the case of SpaceX, it also had the delivery coming down of experiments that were loaded onto the spacecraft that returned successfully to Earth.

Now, I want to toot the horn of Senator Hutchison, but I want her to hear me tooting her horn.

[Laughter.]

Senator NELSON. Senator Hutchison is responsible for the American laboratory module to be designated a National Laboratory. Our national labs are some of the great assets of this country. Los Alamos is just one, for example.

The International Space Station, the American module, is designated a National Laboratory. And part of what the three of us wanted today to do is to have this testimony from the people who best can tell us, including our American astronaut who just returned and who has spent in the course of three space flights over one year in orbit.

And Dr. Pettit is going to share with us a number of these experiments and real-life things that are beginning to happen, such as the vaccines that we have already mentioned in the last hearing that we had on the progress of the overall space program.

So, with that, I have other comments that I will make later on. Senator Hutchison, let me turn to you and then to Senator Boozman.

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

Senator HUTCHISON. OK. I just wanted to open—I just wanted to open today's hearing because we have lost a space pioneer. Sally Ride did so much to promote space, and even though she tried to get out of the spotlight, she just attracted so much attention because she was interesting, she was committed to physics and science, and she was committed to getting girls to start taking the STEM courses.

And when I wrote a book in 2004, I did chapters on the women pioneers in different fields. So I did education, politics, government, sports, and aviation. And then I interviewed women who were still breaking barriers in the same fields.

So my aviation chapter was Amelia Earhart and Jackie Cochran. And my interview was Sally Ride. What could be more perfect than the first women to actually fly the long distances and prove women could be great pilots, and then the first woman in space?

And in my interview, I asked different questions about what was the most important trait for her success, and she said it was the ability to work with other people, which she found very helpful as the first woman astronaut. And I said, "Oh gosh, that is interesting. I would have thought you would have said perseverance." And she said, "Well, that is a close second."

And then I asked her what was her most helpful childhood memory, and she said, "You know, it is funny. It was actually an issue in school, and I got discouraged by something. I don't remember what. But I came home and I was very down, and my father basically said, 'Well, you have just got to reach for the stars.' "

She said, "That is ridiculous to think about right now," and she said, "but it did happen." So I think we all owe her a great debt of gratitude, and I just wanted to start this hearing by recognizing how much she gave.

I want to thank both the Chairman and the Ranking Member of the Subcommittee for being here because Senator Nelson and I have done so much to keep the emphasis and the importance of NASA in the forefront. I am a budget cutter. I am a person that wants to set the top line of a budget, but then it is so important that we set the priorities for what goes in that budget.

And Senator Nelson and I, and many others, have tried to assure that we don't eat our seed corn, that we continue research, that we continue to reach for the stars, to go beyond where we are now. And NASA is the agency that can do that.

And there have been people who have tried to abolish NASA, frankly. And I think that going forward, I will be certainly very comfortable with the ranking member, John Boozman, who has done a great job of learning the issues and where we are. And he has hit the ground running, and I am so appreciative for Senator Boozman and his interest.

Let me say that establishing our part of the Space Station as an American national laboratory was a great accomplishment in that it opened the Space Station for research from outside entities. And it can be private companies. It can be universities. It can be opened to anyone who is going to do research that can only be done in space. And we all know you can only do certain experiments in space because of the microgravity conditions, and you can't duplicate that on Earth.

So finding out what is out there is so important for our future. And we have seen what exploring space has done for us and national security, being able to put satellites up there and do satellite surveillance, satellite-guided missiles has helped our national security so much.

But now we have this laboratory, and one of the issues of this hearing is going to be what we are doing there and certainly are we going to extend it further than 2020, or is 2020 its life and what are we going to do to fully utilize it?

I was at Johnson Space Center a few months ago, and I saw the hits detected on the Alpha Magnetic Spectrometer. One of the almost-casualties of the budget cutting without establishing priorities was that we were told that there wouldn't be room for the Alpha Magnetic Spectrometer to be taken into space by a former NASA Administrator, and many of us fought back.

And Dr. Sam Ting fought back, the Nobel Laureate at MIT, who felt that we had to have that up there to detect the cosmic rays and try to determine if there is dark matter and what it is and what effect it might have on the expansion of the universe. And I am sitting in the Johnson Space Center, looking at the hits on the Alpha Magnetic Spectrometer, and it is so far 18 billion hits of cosmic rays. More than even Sam Ting thought we would get in this timespan.

And so, this is a very basic science that we are doing there that could lead to any number of things in the determination of what the universe is, and also if there is dark energy, is it something that can be harnessed? No telling.

And as Dr. Ting so aptly points out, almost all of the major research that we have done since we went to NASA and set NASA up, everything that we went into to research was for a purpose that is not what we got, but what we got was even more important. And that is why continuing the priority of NASA and space exploration is so important for us and our European partners, for our own quality of life and capabilities to expand.

So, Mr. Chairman, thank you very much for holding this hearing. I did request this hearing because I want to know what we are doing up there.

And so, I am looking forward to hearing from all of you, from your different perspectives. But I do hope that as I am going out the exit door that we are able to excite the American people, as we have in the past, on what the future is, and I thank you all for being here.

Senator NELSON. Senator Boozman?

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

Senator BOOZMAN. Thank you very much, Mr. Chairman.

And I have a very eloquent statement that I would like to put in the record in the interest of time, with your permission.

But I appreciate Senator Hutchison mentioning Sally Ride. I have got three daughters that are all grown now and have done well and very independent. But looking back, it is individuals like this, the example that you truly can do anything that you want as a female now, that has certainly not always been the case. And so, again, we so appreciate her example in so many different ways.

I want to thank you two, Senator Nelson and Senator Hutchison, for really championing this for so many years. Senator Hutchison mentioned the ability to get along as something that was so important, and certainly you two have modeled that in working together so closely, creating a very bipartisan group not only here, but also—and it is difficult—working with our House colleagues such that we have this bipartisan bicameral situation, which truly is unique.

There is not very many situations like this. So I do appreciate your all's leadership so very much.

I am going to be running in and out. I have got a markup in EPW, and so in a little bit, I have got to sneak out in just a second. In fact, Senator Boxer and Senator Inhofe will grab me by the throat if I don't get over there in a minute.

It is a unique committee. We are going to be voting on the Great Apes Act, and then you have also the Safe Chemicals Act. So there is a little something for everybody over there. But we do appreciate you all being here, and we certainly appreciate your efforts.

Thank you.

Senator NELSON. Sally Ride flew twice. She flew in 1983 and 1984. And I will never forget that launch the first time, she being the first American woman in space. There was a chorus that went up, "Ride, Sally Ride." And I think she captured the spirit of America in her participation in the space program.

She was a Ph.D. in electrical engineering. And after she left NASA, she never stopped working in order to inspire the next generation of explorers.

Now since the subject today is the Space Station, this thing started when a Navy SEAL, Bill Shepherd, opened the hatch on November 2, 2000, and he floated from a cramped capsule into the Space Station. And thus, he began as the commander of Expedition 1, and the International Space Station has been continuously occupied ever since.

The Act that Kay Bailey was mentioning a while ago extended the ISS operations until 2020. It authorized that. But once you hear about what is going on today on the Space Station, I think it is very shortsighted to think that this thing is going to be cutoff in 2020. But that the research will continue on this extraordinary facility, of which it has a pressurized volume as large as a Boeing 747. That is how big it is internally.

And then, once we are at the end of the design life of it in low-Earth orbit, some 240 miles up, circling the globe every hour and a half, what is the likely future for it? Perhaps to boost it further, maybe to the Lagrangian point between the Earth and the Moon, which is the point that the Earth's gravity stops and the Moon's gravity starts. Or possibly that Lagrangian point on the other side of the Moon.

And maybe as a future base, parts of it—not necessarily the whole thing, but maybe parts of it—could be used in that situation then as a way station if we decide in our future exploration that we want to go to and from the Moon's surface again. These are the possibilities.

And so, today, we are very fortunate to have a very distinguished panel of witnesses to talk about the accomplishments. Bill Gerstenmaier is NASA's Associate Administrator for Human Exploration and Operations. We look forward to continuing the discussion that we started last month about the commercial space operations to and from the Space Station and the scientific discoveries that we talked about last time.

We also have Thomas Reiter. He is from the European Space Agency, one of our partners. This is the International Space Station. And he is one of two Space Station astronauts with us today on this panel. He spent over 5 months on the ISS, and he is the European Space Agency's Director of Human Space Flight and Operations. And he is going to share ESA's perspective on operations and research aboard the ISS.

From the Center for Advancement of Science in Space, we have James Royston, and he serves as the Interim Executive Director. CASIS is a nonprofit organization working with NASA to manage a significant portion of the ISS research. And he will touch on how CASIS will help us get the most out of our Nation's investment in the Space Station.

And then we have Dr. Donald Pettit, who just returned on July 1. This last time he was on the station was 193 days. He has flown in space three times, as I mentioned earlier, and he has lived aboard the station twice. His creativity and his technical wizardry make him an outstanding example of what the human element brings to research and discovery.

So I am going to take the privilege of the chair, and I have already consulted with Senator Hutchison.

Dr. Pettit, we are going to start with you. We would like to hear from you.

Welcome home.

STATEMENT OF DONALD R. PETTIT, ASTRONAUT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. PETTIT. Thank you, Senator.

It is an honor to be here and to be able to tell stories of what it is like to be in space. There are 7 billion people that live on this planet. There are 6 people currently that can call space their home, and it is an incredible privilege to be part of the 6 people that are currently living off of this planet.

And with that privilege comes a responsibility when you return to tell stories about what it means to explore. And this is pretty much universal to any explorer that comes back in whatever period of exploration that they belong to. They tell stories. They talk about the meaning of the exploration. They talk about why we explore, and they incite ideas and thoughts in people who don't have the opportunity to go off and do that exploration themselves.

And this hinges on frontiers. Space is very much a frontier. We have frontiers all around Earth. They could be under the stage of a microscope. It could be through the eyepiece of a telescope, bottom of the ocean, in the Arctic and Antarctic regions. There are frontiers that surround us.

Space happens to be one of many frontiers we can explore. It happens to be the frontier where I am spending my career exploring. And in this frontier, your Earth-honed intuition does not apply. Things don't work the way that you think they should. The answers are not in the back of the book.

And this makes a place that is rich in discovery. And I think that is one reason why we go to these frontiers. And when we go to these frontiers, we can see things that you never imagine because nature has an imagination that is greater than what human beings have. And the only way we will know what is there is by virtue of going and seeing for ourselves what happens to be in this frontier, and from that, it can enrich our minds and tickle our imaginations.

And initially, these observations enrich your society, and eventually, you will make technology and other discoveries, other advances that will enhance the standard of living and enhance the arts, enhance theater, film, literature. It will embed itself into your society. And I think you can conclude that exploration in these frontiers is a metric for how viable your particular country happens to be.

I am happy to be here and answer any questions that you have.

Thank you.

Senator NELSON. We will get into that.

Mr. Gerstenmaier?

STATEMENT OF WILLIAM H. GERSTENMAIER, ASSOCIATE ADMINISTRATOR, HUMAN EXPLORATION AND OPERATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. GERSTENMAIER. Thank you very much.

The title for this hearing, "The International Space Station: A Platform for Research, Collaboration, and Discovery," I believe is extremely fitting. Through the discussion today, I hope we will all gain a deeper understanding of the amazing facility in space that we have created.

I also hope we gain through concrete examples an understanding of what is happening every day onboard the International Space Station. We are not simply talking about enabling research. We are really doing research every day onboard the Space Station.

The station is an amazing international research facility. The ISS major assembly is complete, and we are beginning to see significant research activity. Research was done during the assembly phase, but now we are focusing on the research itself.

Today, the focus on research, and we are trying to find ways to make it easier for the researchers to get their experiments to ISS. We are also trying to get the word out about the research facilities that are in place onboard the Space Station.

You know, there are fluid experiment racks, combustion racks, glove boxes, Earth observation facilities, material processing facilities, a vacuum interface, ample power and data interfaces, to name a few of the major facilities that are onboard the Space Station. There is also a crew available to perform the research and interact with the experiments.

This is a tremendous research capability, and it is present in a high-vacuum and low-gravity environment of low-Earth orbit. A facility like this has never existed for use by researchers throughout time or throughout the world.

ISS can enable technology development, understanding of the human system performance in microgravity, and enable both fundamental and applied research. ISS also offers a unique capability for commercial companies to test the advantages of microgravity research to their industry.

Commercial companies can experiment at very low cost to determine if there is a competitive advantage for them over other companies that do not take advantage of space-based research. ISS could enable development of a new economy based on space-based research.

Today, we are seeing a real increase in the research on ISS. As I discussed earlier, there are combustion experiments aimed at understanding the fundamentals of combustion. This may allow better and more efficient combuster designs. The Alpha Magnetic Spectrometer that was discussed earlier is looking for dark matter, and that may ultimately help us understand the very beginnings of the universe.

There are fluids experiments. And as we sit here today and you mentioned, the HTV, the Japanese cargo vehicle, is approaching the Space Station for docking on Friday with a large number of research experiments.

The Japanese cargo vehicle is carrying a system to deploy microsatellites from the Space Station. It is carrying a remote Earth observation camera system to monitor disaster areas on the Earth. It is carrying an aquatic habitat that will monitor the development of fish in microgravity. It is carrying a next generation of software-defined radios, where the radio can support multiple frequencies by just simply changing the software inside the radio.

And last, it is carrying two Lenovo YouTube Spacelab student science experiments to the Space Station. These students came to Washington, and their experiments were selected to fly on the ISS by a team of judges that included Stephen Hawking.

They did this activity through the Internet. They participated with many folks here, and the exciting thing was they got to meet with Sunita Williams, who is presently onboard the Space Station. So, Sunita, who they actually interfaced with and talked to, will now be performing their experiments onboard Space Station this fall.

So it is amazing that these students were here in Washington in the spring. Their experiments are flying to station here this summer, and their experiments will be performed on Space Station in the fall. This is direct evidence that the Space Station team can provide research opportunities in a very timely manner for folks out in the research community.

Again, this is an amazing time for space-based research. ISS is showing that it is an amazing research facility. ISS can inspire students and engineers to think differently, as Don talked about. And we will continue to make it easier for research to get to ISS and be performed there.

We are showing that ISS is an amazing research capability for this nation and the world. We cannot predict what results will come from the ISS and long-duration space-based research, but we can and we are making this facility available to a talented research community.

True advances come from discovery, and ISS is a platform for discovery. I look forward to your questions.

[The prepared statement of Mr. Gerstenmaier follows:]

PREPARED STATEMENT OF WILLIAM H. GERSTENMAIER, ASSOCIATE ADMINISTRATOR, HUMAN EXPLORATION AND OPERATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and Members of the Committee, thank you for the opportunity to appear before you today to discuss how we are using and benefitting from the International Space Station (ISS). The ISS, created and maintained by an international partnership with Canada, Europe, Japan, and Russia, represents an unparalleled capability for human space-based research that cannot be pursued on Earth, as well as a platform for the development of exploration technologies. It provides a research and development (R&D) opportunity that allows us to investigate biological and physical processes in a very different environment than that obtainable on Earth. Observing from, and experimenting in, the environment of ISS gives us a chance to learn about our world and biological and physical processes from a very different frame of reference. We have been using the unique "reference point" of the ISS to advance Science, Technology, Engineering, and Mathematics (STEM) efforts as well.

The ISS is also an international research facility. The three major science laboratories aboard the ISS—the U.S. *Destiny,* European *Columbus,* and Japanese *Kibo* facilities—as well as external testbeds and observatory sites, enable astronauts to conduct a wide variety of experiments in the unique, microgravity and ultra-vacuum environment of low Earth orbit (LEO). The ISS supports research across a diverse array of disciplines, including high-energy particle physics, Earth remote sensing and geophysics experiments, molecular and cellular biotechnology experiments, human physiology research (including bone and muscle research), radiation research, plant and cultivation experiments, combustion research, fluid research, materials science experiments, and biological investigations. It is also a place to conduct technology demonstrations and development efforts. R&D conducted aboard the ISS holds the promise of next-generation technologies, not only those directly related to NASA's exploration efforts, but also those with numerous terrestrial applications, as well. The ISS will provide these opportunities to scientists, engineers, and technologists through at least 2020.

Beyond being a feat of unparalleled engineering and construction, as well as international collaboration, the ISS is a place to learn how to live and work in space over a long period of time and foster new markets for commercial products and services. The ISS will be critical to NASA's future missions of exploration beyond LEO, and the ISS offers many unique benefits to the citizens of the United States and the world.

As stated in my testimony before this Committee last month, the success of our industry partners in providing commercial cargo and crew endeavors is critical to ensuring the effective utilization of the ISS. U.S. commercial cargo resupply capability will ensure the continued operation of the ISS and the full utilization of its formidable research facilities as a U.S. National Laboratory. American commercial crew transportation and rescue services will enable the United States to fly our astronauts to and from Station, end our sole reliance on foreign governments, and provide needed redundancy in the system. Partnering with the commercial space industry to provide access to LEO is enabling the Agency to increasingly focus on developing systems for sending astronauts on missions of exploration into deep space, while promoting the development of an economy in LEO.

The ISS will continue to meet NASA's mission objective to prepare for the next steps in human space exploration. The ISS is NASA's only long-duration flight analog for future human deep space missions, and, as such, it provides an invaluable laboratory for research with direct application to the exploration requirements that address human risks associated with deep space missions. It is the only space-based multinational research and technology testbed available to identify and quantify risks to human health and performance, identify and validate potential risk mitigation techniques, and develop countermeasures for future human exploration.

Benefits to Humanity and Growth in ISS Utilization

Almost as soon as the ISS was habitable, researchers began using it to study the impact of microgravity and other space effects. In the physical and biological sciences arena, the ISS is using microgravity conditions to understand the effect of the microgravity environment on microbial systems, fluid physics, combustion science and materials processing, as well as environmental control and fire safety technologies. The ISS also provides a test-bed for studying, developing, and testing new technologies for use in future exploration missions. Although each space station partner has distinct agency goals for station research, each partner collectively shares a unified goal to extend the resulting knowledge for the betterment of humanity. There are already demonstrated benefits in the areas of human health, telemedicine, education and Earth observations from space. Vaccine development research, station-generated images that assist with disaster relief and farming, and education programs that inspire future scientists, engineers and space explorers highlight just some of the many examples of research that can benefit humanity.

ISS crews are conducting 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. Many investigations conducted aboard ISS will have direct application to terrestrial medicine. 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 transition from the ISS assembly and spares pre-positioning phase is now allowing NASA to focus directly on increasing the utilization of ISS laboratories, testbeds and observatory sites. Through the conclusion of ISS Expedition 28 in October 2011, approximately 1,250 research investigations were performed that involved 1,309 principal investigators (PIs) from 63 countries around the world. Of these, U.S. PIs under NASA sponsorship conducted 475 investigations (38 percent of the total). Expeditions 29 to 32, which cover the period from October 2011–September 2012, included 259 total investigations. In other words, approximately 20 percent as many investigations were performed in these two post-assembly Expeditions as had been achieved in the prior 28 Expeditions combined. An impressive range of scientific research, technology demonstrations and educational outreach is underway.

In the area of scientific research, recent highlights include:

- The Monitor of All-sky X-ray Image (MAXI) instrument, a highly sensitive X-ray slit camera externally-mounted for monitoring more than 1,000 X-ray sources in space, including black holes and neutron stars, made the first observation, along with the Swift spacecraft, of a relativistic X-ray burst from a super-massive black hole destroying a star and creating a jet of X-rays. The research teams co-published their results in *Nature,* 476: 421–424 August 2011.
- The Alpha Magnetic Spectrometer (AMS) cosmic-ray particle physics experiment was installed and began science operations on May 19, 2011. AMS has recorded to date the passage of over 13 billion cosmic ray particle events originating from elsewhere in our Milky Way galaxy. The U.S. Department-of-Energy-sponsored collaboration across North America, Europe, and Asia is actively analyzing these cosmic-ray particle data for potential new physics and astronomy discoveries. The AMS Payload Operations Control Center is located at CERN, in Switzerland, which conveniently allows coordination with the ground-based Large Hadron Collider high-energy particle accelerator research activity.
- Flame tests conducted by Principal Investigator Marshall B. Long, Ph.D. of Yale University in Connecticut during the Structure and Liftoff In Combustion Experiment (SLICE) yielded stable lifted flames that can be simpler to numerically model. SLICE investigates the nature of flames under microgravity conditions and the results could lead to improvements in technologies that aim to reduce pollution emissions and improve burning efficiency for a wide variety of industries.
- Fluid physics experiments conducted by Portland State University in Oregon have led to a greater understanding of capillary flow phenomena and subsequent production of open-source code for modeling the behavior of fluids in space.
- Research on self-ordering systems (published in *Nature,* 478: 225–228 October 13, 2011), demonstrates mechanisms relevant to self-replication in primitive chemical environments. Colloidal systems for studying the behavior of self-assembling materials for photonic technologies are being used by Proctor and Gamble to develop more stable, concentrated products.
- Flight research conducted in the field of vaccine development for bacterial pathogens, such as salmonella and methicillin-resistant staphylococcus aureus (MRSA), has been completed for the first target drug candidate. This work was sponsored by a private firm, Astrogenetix, in cooperation with a leading scientist from the Veterans Administration (VA). The team is at the stage where additional funding is required to conduct ground-based pre-clinical trials prior to submitting an application for an investigational new drug (IND) with the Food and Drug Administration. Both the firm and VA are pursuing further funding to advance to the next stage.
- Space Act Agreements were signed with the Arizona State University Bio-Design Institute to conduct experiments initially focusing on the development of vaccines.

In the area of technology development and demonstration, recent highlights include:

- The same technology that went into building the Canadarm2 and Dextre (the Canadian robots that assembled, service, and maintain the ISS) was adapted to produce the world's first robot capable of performing brain surgery—neuroArm™—on a patient while the patient undergoes magnetic resonance imaging. This technology has since been licensed to a private, publicly-traded medical device manufacturer who will produce a two-armed version that allows surgeons to see three-dimensional images, "feel" tissue, and apply pressure during neurosurgical operations.
- The Robotic Refueling Mission (RRM) began operations March 7–9, 2012, and continued operations from June 19–22, 2012, marking an important milestone in satellite-servicing technology. RRM is designed to demonstrate technologies, tools, and techniques needed to robotically service and refuel satellites in orbit that were not designed for on-orbit servicing. During the gas fittings removal task, robot tele-operators at Johnson Space Center directed Dextre to retrieve tools and go through the tasks required to cut safety wires and remove representative fittings located on the RRM module on board ISS. These fittings are used on many spacecraft for filling fluids and gases prior to launch. Future RRM operations will demonstrate robotic satellite refueling, including opening fill valves, transferring fluid, and other servicing tasks.

- Robonaut 2 (R2) was launched to ISS on February 24, 2011. This dexterous humanoid robot was developed in partnership with General Motors. It is designed to duplicate the manipulation capabilities of a human so that it can handle tools and assist astronauts in performing tasks in space, or help workers build cars on the assembly line. Like Dextre, R2 will be tele-operated from the ground, and it will test a different way to grip and manipulate objects with its human-like, five-digit hands.
- The Multi-User System for Earth Sensing (MUSES) platform started development to provide a commercially managed platform for Earth observation instruments. The platform provides high accuracy pointing capabilities. It can hold up to four separate instruments at once including visible, near infrared, and hyperspectral instruments. Instruments can be changed out robotically as new technologies and new instruments are developed.

In the area of educational outreach, recent highlights include:

- Literally thousands of two-minute video submissions were received in areas of physics or biology from more than 80 countries for the first YouTube Space Lab global contest sponsored by YouTube, Lenovo Computers, and Space Adventures, Inc. in cooperation with NASA, the European Space Agency, and the Japan Aerospace Exploration Agency . This educational project challenges 14–18-year-olds to design a science experiment that can be performed in space. The top two experiments will be conducted on ISS.
- The Program also conducts experiments that involve student participation. One example is the Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) facility. SPHERES are three bowling-ball sized spherical satellites that are used inside the Station to test telerobotics operations in addition to spacecraft formation flight, autonomous rendezvous and docking maneuvers. NASA, along with the Defense Advanced Research Projects Agency with implementation by the Massachusetts Institute of Technology, have co-sponsored three "Zero Robotics SPHERES Challenge" competitions for high school and middle school students from the U.S. and abroad. The competitions challenge students to write software code, which is uploaded to the robots on ISS, and the SPHERES satellites then execute the instructions, such as formation flight and close proximity operations. Student finalists were able to watch their flight program live on NASA–TV.
- Astronauts aboard ISS participate in educational downlinks with schools, and engage in communicating with people around the world using "ham" radio.

A National Laboratory in Orbit

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 solid strides in its effort to engage other organizations in the ISS program. Subsequently, 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, NASA issued a cooperative agreement notice on February 14, 2011, and on August 31, 2011, the Agency 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. The CASIS organization is 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 R&D portfolio based on U.S. national needs for basic and applied research; 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 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 transition of the National Laboratory management function to CASIS is progressing. Earlier this year, NASA, with the help of the Office of Science and Technology Policy, put out a request for candidates for the permanent board that will guide CASIS' efforts in this groundbreaking enterprise. NASA is working with CASIS' interim Board of Directors to identify and evaluate a diverse group of outstanding individuals for that board, and the Agency is also in the process of transitioning existing National Laboratory agreement holders to CASIS.

To help facilitate U.S. National Laboratory opportunities aboard Station, on June 26, 2012, CASIS launched its first solicitation for proposals. Through this solicitation, CASIS aims to enable next-generation research in the area of protein crystallization and life science breakthroughs. The current request for proposals calls for crystallography investigations—studies using three-dimensional structures of protein molecules.

NASA's National Laboratory partners can use the unique microgravity environment of space and the advanced research facilities aboard Station to enable investigations that may give them the edge in the global competition to develop valuable, high technology products and services. Furthermore, the demand for access to the ISS will support the providers of commercial crew and cargo systems. Both of these aspects of the U.S. segment of ISS as a National Laboratory will help establish and demonstrate the market for research in LEO beyond the requirements of NASA.

International Partnership Progress

The ISS Multilateral Coordination Board (MCB) and Heads-of-Agency (HOA) met in Quebec City, Canada, February 28 and March 1, 2012, to discuss future plans for the ISS, progress on utilization, and potential contributions to future human exploration missions. The International Partners reported progress on identifying potential technology demonstrations that could be conducted on the ISS. These demonstrations correlate closely with the recent report issued by the National Research Council, Aeronautics and Space Engineering Board on NASA Space Technologies and Priorities.

In addition, the MCB and HOA released two documents related to ISS utilization:

- *"ISS Utilization Statistics,"* Fall 2011 (inaugural issue), which documents the number and thematic areas of research being conducted by each partner.
- *"ISS Benefits for Humanity,"* which launches a new international web portal describing achievements of the ISS partnership in the areas of human health, Earth observation and disaster response, and education.

Copies of both documents are available at: *http://www.nasa.gov/mission_pages/station/research/index.html*

Conclusion

We have many challenges and opportunities ahead as we continue to sustain and productively utilize the ISS. These include training the next generation of scientists, engineers, and technologists for greater challenges as human presence is extended further into the solar system. This mission pull drives us to develop innovative solutions that benefit humans on the Earth today. We have two extraordinary assets that have never before existed in the history of human space exploration—an experienced international partnership encompassing Canada, Europe, Japan, Russia, and the U.S., and a permanently crewed, full-service space station in low-Earth orbit. Our ability to continue working together as a global team, while making the best applied use of our assets, will pace the future progress of space exploration and expansion of benefits on Earth.

Great nations explore in order to advance. Throughout history, nations have progressed and benefited from exploration. Exploration drives technological breakthroughs and scientific discoveries that benefit society; without exploration, the cycle of innovation and advancement is broken. This innovation is well documented in the U.S. patent record. In the past 30 years, the U.S. Patent and Trademark Office has granted over 818 microgravity-related patents, and in the past decade over 587 further applications have been filed. The same holds true for Space Station, where 1,722 patents have been granted and 1,107 applications are pending, and for the Space Shuttle, where 2,384 patents have been granted and 1,285 applications remain pending. These 7,903 patent actions are historic evidence of the promise for the future.

The ISS has now entered its intensive research phase, and this phase will continue through at least 2020. Station will continue to meet NASA's mission objective to prepare for the next steps in human space exploration—steps which will take astronauts beyond LEO to destinations such as near-Earth asteroids, and eventually, Mars. The ISS is NASA's only long-duration flight analog for future human deep space missions, and it provides an invaluable laboratory for research with direct application to the exploration requirements that address human risks associated with deep space missions. It is the only space-based multinational research and technology test-bed available to identify and quantify risks to human health and performance, identify and validate potential risk mitigation techniques, and develop countermeasures for future human exploration.

The ISS Partnership has transformed exploration from an effort for the advancement of individual nations, to an endeavor committed to the advancement of humankind. Closer to home, NASA's National Laboratory partners can use the unique microgravity environment of space and the advanced research facilities aboard Station to enable investigations that may give them the edge in the global competition to develop valuable, high technology products and services. Furthermore, the demand for access to the ISS will support the providers of commercial crew and cargo systems. Both of these aspects of the U.S. segment of ISS as a National Laboratory will help establish and demonstrate the market for research in LEO beyond the requirements of NASA.

NASA appreciates this Committee's ongoing support of the ISS as we work together to support this amazing facility that yields remarkable results and benefits for the world.

Mr. Chairman, I would be happy to respond to any question you or the other Members of the Committee may have.

Senator NELSON. Thank you, Mr. Gerstenmaier.

Mr. Reiter?

STATEMENT OF THOMAS REITER, DIRECTOR, HUMAN SPACEFLIGHT AND OPERATIONS, EUROPEAN SPACE AGENCY

Mr. REITER. Dear Mr. Chairman, dear members of the Committee——

Senator NELSON. Don't worry about those bells.

Mr. REITER. OK.

Senator NELSON. That is what is going on over on the floor of the Senate.

Mr. REITER. All right. It is also great opportunity and honor for me to testify before you today and present the European Space Agency's role and capabilities on ISS.

The successful utilization of ISS is of highest priority for the European Space Agency and for the European ISS partners. ISS is a unique platform for scientific research and technology development.

It is in full recognition of the extraordinary utilization opportunities of the ISS that Europe decided to engage as a full and very active partner in this unparalleled international cooperation together with the United States, with Russia, with Japan, and Canada. Europe, working through the European Space Agency, developed and operates two key elements: the Columbus laboratory, which you see here in the front side on the left, and the Automated Transfer Vehicle.

Columbus is a multi-function laboratory, which is shared with NASA and the other partners, and it is equipped with 10 interchangeable payload racks containing an advanced number of research instruments.

The second key element, the ATV, Automated Transfer Vehicle, which is able to deliver more than 7 metric tons of cargo to the ISS. One of these vehicles is currently docked to the International Space Station until mid of September, and two more of these vehicles about to come next year and in 2014.

Apart from cargo delivery, ATV is providing fuel for maintaining attitude control and giving boost to the station and also gas, water, and other supply articles.

Apart from Columbus and the ATV, Europe has also contributed to other elements, equipment, and design skills. For example, the DMS–R, the data management system, which has been a key part in the station's "brain," so to say. Two of three nodes that link station components, a dome-like structure with panoramic windows called the cupola, allowing astronauts to operate the station Robotic Manipulator System and other equipment.

And inside U.S. Destiny research module, various laboratory equipment like the material science rack and freezer units.

Europe also provides members of the ISS crew. Since 2001, 18 European astronauts have lived and worked onboard ISS. And one of my colleagues from Europe, Dutch astronaut Andre Kuipers, just returned a few days ago, together with Don Pettit, from a half year work onboard the station.

Europe's participation in the ISS program means that throughout ESA's member states, thousands of Europe's scientists and engineers at hundreds of universities and high-technology companies are working on the frontier of 21st century science and engineering. ESA has implemented a broad portfolio of research activities, covering fundamental science, applied research, as well as human exploration preparation and technology development.

To date, ESA has performed more than 200 experiments onboard ISS. And since the deployment of the Columbus laboratory in February 2008, increasingly long duration experiments—at an average of 30 to 40 per year—have also been implemented.

Examples have already been given in the areas of human physiology and fundamental physics. Let me just give one additional example from the area of material sciences, which we have just concluded a project investigating processes for the development of new lightweight alloys. And these new lightweight alloys are now used for turbine blades in aircraft engines in an industry valued some 2 billion Euros over the next coming years.

Many of the fundamental and applied research projects conducted within the European Program for Life and Physical Sciences, called ELIPS, are creating a growing knowledge basis to improve production processes and to create new products, such as medical equipment, casting technologies, and other miniaturized sensors and devices.

Of course, the ISS also offers outstanding opportunities as test bed for Human Exploration preparation beyond low-Earth orbit. Apart from already ongoing or planned scientific and technological investigations, ESA supports challenging new ideas to pave the way for human exploration beyond low-Earth orbit. The joint implementation of these activities by the whole ISS partnership will allow rapid progress for the preparation of future human exploration missions.

The European Program for Life and Physical Sciences in Space involves some 1,500 scientists in almost 150 projects included in the research pool of ISS experiments.

Now besides the significance of the ISS for science, applications, and technology, its utilization opportunities and the astronauts working on the station are a strong inspiration for the young generations to consider a science, technology, engineering, and mathematics education. In this context, ESA carries out education activities on the ISS in close collaboration with our partners.

The continuous efforts of the ISS partners for the global promotion of the ISS accomplishments with dedicated publications of the ISS Program Science Forum and public events like the recent ISS Symposium, which took place in Berlin, highlight the value of the International Space Station and the strength of its international partnership in the public.

Now, in conclusion, the successful and optimal utilization of the ISS is important to the European Space Agency in order to demonstrate to its member states the return of investment. ESA has already reaped considerable benefits from the scientific research, applications, technology demonstrations, and education activities performed on the International Space Station, and more are expected to be realized in the continuation of ISS utilization in the years to come.

I would, therefore, like to underline an extremely important dimension of this international partnership in the ISS program: the excellent and highly valued cooperation between ESA and NASA. Forging such an international partnership and working together as partners is often referred to as one of the biggest achievements of the ISS program.

It is the international partnership that brought the ISS and its unique utilization opportunities into existence, and we will also need an international partnership, probably even a wider one than the one for ISS, when aiming at the next steps for human exploration.

Sorry for extending a little bit the 5 minutes. Thank you very much, and I am ready to answer your questions.

[The prepared statement of Mr. Reiter follows:]

PREPARED STATEMENT OF THOMAS REITER, DIRECTOR, HUMAN SPACEFLIGHT AND OPERATIONS, EUROPEAN SPACE AGENCY

Mr. Chairman and Members of the Committee, thank you for the honour and the opportunity to testify before you today and present the European Space Agency's role and capabilities on ISS, in particular with respect to its utilisation for scientific research, applications, technology development and education purposes. The successful utilisation of the ISS is of highest priority for the European Space Agency and for the European ISS partners.

The European Space Agency's Role and Capabilities on ISS

The International Space Station (ISS) is a unique scientific and technology platform in space, which continuously allows researchers from all over the world to put their talents to work on innovative experiments that could not be done here on Earth. Weightlessness, as well as other properties of the space environment, are influencing a huge variety of physical, chemical and biological processes. Low-Earth orbit is therefore an ideal environment for research in a wide spectrum of disciplines, as well as an excellent area for preparing future human exploration of space. The domains for utilisation are many and diverse: from fundamental physics to human physiology, from new alloys to growth processes in plants, from astrophysics to demonstration of space technologies and services. It is in full recognition of the extraordinary utilisation opportunities of the ISS that Europe decided to engage as a full and very active partner in this unique and unparalleled international cooperation undertaking together with the United States, Russia, Japan and Canada.

Europe, working through ESA, developed and operates two key elements of the Station: the European Columbus laboratory and the Automated Transfer Vehicle (ATV).

The European Columbus laboratory is one of the key ISS research capabilities, which ESA shares with NASA. Equipped with 10 interchangeable payload racks, Columbus is a multi-function laboratory with an advanced suite of research instruments, namely for fluid physics, materials science and biology and especially for human research. On its four external platforms with different orientations it also provides unique external exposure and observation accommodation capabilities for unpressurized payloads.

Europe's second biggest contribution is the Automated Transfer Vehicle (ATV), a vast versatile cargo supply vessel lifted into orbit by the Ariane-5 launcher with full autonomous rendezvous and docking capabilities to ISS. The ATV carries up to 7 tonnes of cargo including provisions, scientific payloads and rocket propellant. Once docked, the craft can use its engines to boost the Station higher in its orbit, counteracting the drag from the Earth's atmosphere. After the first ATV, *Jules Verne* in 2008, *Johannes Kepler* was flown in 2011 and the third one, *Edoardo Amaldi* was launched to the ISS on 23 March 2012 and will still remain docked until the end of September. The fourth and fifth ATV's are already in preparation for launch in 2013 and 2014.

Apart from Columbus and the ATV, Europe's scientists and engineers are also contributing other elements, equipment and design skills across many elements of the ISS.

Among these elements, the DMS–R data management system, which has been a key part of the Station's 'brain' since its July 2000 launch aboard the Russian Zvezda Service Module.

Europe built also two of the three nodes that link Station components, as well as the Cupola—a dome-like structure that is the crew's panoramic window on space and a control room for astronauts operating the Station Robotic Manipulator Systems and other equipment.

In fact, European technology plays an important part in many Station sections. Inside the United States Destiny research module, for instance, Europe has mounted, among other equipment, a specialized material science rack and freezer units. The Japanese Experiment Module also hosts one of the three MELFI freezers, which ESA has developed for NASA, as the cold stowage sample preservation reservoir on ISS, which is jointly used by the whole ISS partnership in conjunction with NASA's smart cold transportation assets.

Europe also provides members of the ISS-crew. European astronauts have flown in space since 1983, and since 1998 the European Astronaut Centre in Cologne has concentrated on training men and women for future ISS missions. The first European to serve a tour of duty on the ISS, went on mission to the ISS in April 2001 on the Space Shuttle. Since then 18European astronauts have lived and worked on board the ISS as team members of fully integrated ISS crews.

The astronauts on the ISS will always be part of a much larger scientific team on Earth which is closely following the crew activities on ISS. The European user community is very active and therefore the corresponding ISS utilisation demand is very high. The current European research plan of selected flight experiments already lasts until 2017 and the next Announcements of Opportunity will be solicited in due time.

In fact the European mission control centres—the Columbus Control Centre (COL–CC) in Oberpfaffenhofen, Germany and the ATV Control Centre (ATV–CC) in Toulouse, France—direct onboard experiments and the European ATV missions, sharing Station command with the United States and Russia.

Nine European User Support and Operation Centres (USOCs) are based in national centres distributed throughout Europe. These centres are responsible for the use and implementation of European payloads on board the ISS and support the user community on the ground. The USOC activities also extend to investigations, which are done with European research equipment in ISS modules beyond Columbus.

Right now, Europe's participation in the ISS means that throughout ESA's Member States, thousands of Europe's best scientists and engineers at hundreds of universities and high-technology companies are working on the leading edge of 21st-Century science and engineering. And the European ISS team is fully embedded in the international ISS partnership, which allows to exploit many synergies and invaluable experiences.

Scientific and Technological Objectives and Accomplishments to Date

ESA—through its research programmes on board the ISS—has implemented a broad portfolio of research activities, in fundamental science, applied research as well as human exploration preparation and technology, addressing the following key research areas:

- Fundamental Physics
- Atmospheric and Environmental Research
- Materials Sciences
- Physics of Fluids and Combustion

- Astrobiology
- Cell, Developmental and Plant Biology
- Human Physiology and Performance
- Astrophysics
- Technology Testing

More than 200 experiments have been performed so far by ESA on board the ISS: short duration experiments before the assembly of the Columbus laboratory to the ISS, making use of Soyuz "Taxi-flights" under agreements with Russia, and since 2006 with NASA in the Destiny lab in the frame of the so-called "Early Utilisation Agreement" and also making use of Russian resources. Since the deployment of the Columbus laboratory in February 2008 increasingly long duration experiments—at an average of 30 to 40 per year—have also been implemented.

A very good example of the tangible benefits of the research on board ISS is the already successfully concluded IMPRESS project, a material sciences research project the results of which were actually instrumental to develop new light-weight alloys; these new light-weight alloys are now used for aircraft engines turbine blades, in an industry valued some 2 Billion Euro over the next 10 years. The space part of this research project has been performed with furnaces and electromagnetic levitation facilities on parabolic flights and short-duration Sounding Rocket missions. Now ESA's Material Science Laboratory (MSL), which is operated with NASA in the Destiny module under a bilateral cooperation agreement in the Materials Science Research Rack (MSRR–1), and soon also the unique Electro Magnetic Levitator (EML) in Columbus offer such capabilities for institutional and industrial users on board the Station. This will allow the optimum directional solidification of alloys in MSL and complementary container-less high-precision measurement of thermo-physical properties on a large variety of alloys which is essential for advanced casting processes and materials features.

Also the joint operation of the European developed ISS facilities Microgravity Science Glovebox (MSG), European Modular Cultivation System (EMCS), Pulmonary Function System (PFS) for a large suite of investigations with fluids, biology, human research and again the MELFI freezers for samples preservation are invaluable assets on ISS space for advanced experimentation by our increasingly demanding user communities.

Furthermore, many of the fundamental and applied research projects conducted within the European programme for Life and Physical Sciences in Space (ELIPS) create the growing knowledge basis for new products and improved processes, such as medical equipment, casting technologies, miniaturised sensors and devices.

In future an ensemble of high-precision atomic clocks (ACES) on ISS will demonstrate, in combination with the world best ground reference clocks, advancements in frequency and time measurements for navigation, improving navigational accuracy.

The ISS offers outstanding opportunities as test-bed for Human Exploration preparation beyond LEO. Apart from already on-going or planned scientific and technological investigations, ESA also fully supports the challenging ideas, which are under detailed elaboration by the International Expert Working Group (IEWG) teams under the leadership of NASA. The joint implementation of these activities by the whole ISS partnership will allow rapid progress and outstanding accomplishments on ISS for the preparation of future Human Exploration missions beyond LEO.

The European programme for Life and Physical Sciences in Space, ELIPS, involves some 1500 scientists in almost 150 projects included in the research pool of ISS experiments. ELIPS includes a large and diverse group of industrial users interested in application-oriented research and industrial R&D; industrial R&D is often implemented in combination with the objectives and expertise of institutional researchers from academia. Hence, the continued utilisation of ISS and Low-Earth Orbit creates economic opportunities that stimulates both the academic and industrial sector and is providing for a variety of socio-economic benefits on Earth. ESA is making every effort, in full coordination with ISS international partners and through dedicated Announcements of Opportunities, to attract the best ISS utilisation proposals, including those from international research teams beyond the borders of Europe. Corresponding to the diversified user needs, ESA is following an approach that enables utilisation opportunities across the entire spectrum of utilisation fields.

Besides the significance of the ISS for science, applications and technology demonstrations, the ISS, its utilisation opportunities and the astronauts working on the Station are a strong inspiration for the young generations to consider a Science, Technology, Engineering and Mathematics (STEM) education. In this context, ESA carries out education activities on the ISS in close collaboration with NASA.

The continuous efforts of NASA for the global promotion of the ISS accomplishments with dedicated publications of the ISS Programme Science Forum and public events like the recent ISS Symposium in Berlin highlight the value of the International Space Station and the strength of its international partnership to the public.

Optimisation of ISS Utilisation and Potential Improvements

In order to optimize the science yield of ISS, the establishment of an internationally coordinated ISS research plan and joint science opportunities' solicitations are sought. The optimisation of the ISS utilisation can be accomplished making use of the well-established international working groups in life and physical sciences (ISLSWG and IMSPG) and pooling research objectives and flight resources. ESA has currently identified more than 20 joint ISS experiments with NASA and in total more than 50 with all the ISS partners. The shared use of unique on-orbit research infrastructure is of high importance to allow optimum and efficient experimentation on ISS according to terrestrial laboratories standards, despite the additional spaceflight challenges. In general most of the ISS research originates from earthbound problems. Hence a very solid anticipated terrestrial research programme is instrumental for defining and reaching challenging utilisation objectives on ISS, which are also of major impact in terms of Earth benefits. This close link even applies to a lot of the research and technology objectives for Human Exploration preparation on ISS. A thorough preparation of ISS experiments on ground or short-duration precursor flight opportunities (drop towers, parabolic flights, sounding rockets) is of great scientific and technical importance.

Conclusions

The successful and optimal utilisation of the ISS is important to ESA; ESA has already reaped considerable benefits from the scientific research, applications, technology demonstrations and education activities performed on the International Space Station, and more are expected to be realised in the continuation of the ISS utilisation in the years to come.

To conclude, I would like to take this opportunity to underline a highly visible and highly important dimension of the international partnership in the ISS programme: the excellent and highly valued cooperation between ESA–NASA. The forging of such an international partnership and getting experience in working together as partners is often referred to as one of the biggest achievements of the ISS programme. It is the international partnership that brought the ISS and its unique utilisation opportunities into existence and fruition. We will also need an international partnership, probably even a wider one than for the ISS, when aiming at the next steps of human space exploration.

Mr. Chairman, I would be happy to respond to any question you or the other Members of the Committee may have.

Thank you.

Senator NELSON. This is the first time that we have had a representative of the European Space Agency in a decade testify in front of this committee. So, Mr. Reiter, we appreciate that very much.

How many days were you in space?

Mr. REITER. In total, 350. I flew to the Russian Space Station MIR in 1995 for 179 days, and the ISS in 2006 for 171 days. So 350.

Senator NELSON. Very good.

Mr. Royston, tell us about CASIS at the Kennedy Space Center, how you are preparing the experiments to go to the station.

STATEMENT OF JAMES D. ROYSTON, INTERIM EXECUTIVE DIRECTOR, CENTER FOR THE ADVANCEMENT OF SCIENCE IN SPACE

Mr. ROYSTON. All right. First, I would like to thank the Committee for the opportunity to speak here today. It is a real honor to sit here on this panel and in this room with those that envisioned, built, and recently spent time on the International Space Station.

To our elected officials, I want to thank you for your leadership, support, and ongoing commitment to this great national asset. I would especially like to thank Senator Hutchison for your outstanding service and commitment not only to the ISS, but also to manned space flight. Your leadership and dedication is why we are here today, and you will definitely be missed.

I would also like to thank Senator Nelson from my home State of Florida for all your past, present, and future leadership in space. And I must acknowledge the junior Senator also from my great state of Florida, Senator Rubio.

As you are aware, CASIS was formed in response to the direction provided by this committee regarding independent management of the National Lab. The CASIS mission has one overarching goal, and that is to maximize the use of the National Lab. And by doing so, we need to give our taxpayers the return on investment they deserve.

This is a challenging task. To achieve this goal, CASIS must stimulate and open new markets and introduce new users to this unparalleled asset. We must help all Americans understand why we go there and how it benefits them, and we must fully utilize what I believe is the best teaching tool ever created to inspire our next generation of scientists, mathematicians, and engineers.

In our short existence, CASIS has made great strides in spreading the word about the potential of the National Lab while building a solid foundation that will guarantee the future success of this organization. In line with the original vision in our proposal, our staff has worked urgently to partner with industry, academia, and others to ensure that CASIS can be responsive to the needs of potential users and to maximize utilization.

Our world-class panel of scientists has identified initial avenues of promising research after poring over more than 135 projects flown in space to date. We have conducted extensive outreach activities, meeting with over 160 companies and organizations from coast to coast to convince them of the benefits of doing research and developing products in space.

This ongoing effort also provides us with valuable information on how industry views space and the barriers to doing business on the National Lab. We have issued our first funded solicitation for research, with many more to follow. We have taken steps to enhance the capabilities of the National Lab from an external research platform to new software enhancements. We have assembled an expanding list of hardware and integration experts to assist researchers in getting their projects to space.

We have worked with NASA to increase the efficiencies and speed by which we can get projects from just an idea into orbit. We have become an enabler of the new commercial space flight industry, and we will build their backlog that will drive the flight rates.

We have enticed new players from nontraditional markets to develop their consumer goods on the National Lab. We have attracted more than 30 unsolicited project proposals, which are currently going through our evaluation process. We are working with Fortune 100 companies and brand-new startups that see space as truly a new, emerging market.

We have created product endorsements capable of bringing the awareness and the wonder of the ISS into people's living rooms. And we have established an education program that soon will be capable of reaching hundreds of thousands of school children in a very short period of time.

Most importantly, we have met our key milestones that were laid out for us in our performance plan. And as we transition from our standup phase to our operational phase, I am excited to tell you that the permanent Board of Directors, including some of America's brightest minds from business and science will soon be announced.

I firmly believe that this Board, along with our new Executive Director, will exceed the expectations envisioned by this committee and also by others.

In closing, I believe this is our defining moment. The outpost is in place. The railroads have been built. History will look back at this moment as a time when industry and government came together as true pioneers, and companies invested their own money to ferry cargo and humans back and forth from this great outpost.

It is our moment, and working together, we can open this new frontier to all Americans for the benefit of all humankind.

Thank you. And I look forward to your questions.

[The prepared statement of Mr. Royston follows:]

PREPARED STATEMENT OF JAMES D. ROYSTON, INTERIM EXECUTIVE DIRECTOR, CENTER FOR THE ADVANCEMENT OF SCIENCE IN SPACE

Introduction

Good morning. It's a privilege to be here before you this morning and I want to thank the Committee for this opportunity to update the American people about the performance and accomplishments of the Center for the Advancement of Science in Space, better known as CASIS, and its role as the manager of the International Space Station National Laboratory (ISS NL).

The entire CASIS organization is working diligently to establish procedures for outreach, business development, operations, education and fundraising that will ensure we successfully enable companies, academic researchers, students and Federal agencies to conduct research and development on board Station. These efforts will produce breakthroughs in science, technology, materials and pharmaceutical drugs which will provide American taxpayers with a positive return on their investment while benefitting all humanity.

Because of its unique mission and mandate, CASIS has greater flexibility and can conduct activities far different than NASA. As Congress intended, CASIS' status as an independent and non-profit organization allows for the development of partnerships, funding sources, endorsements, and other opportunities that NASA cannot pursue. CASIS can raise money, advertise, and innovate in ways that open new opportunities for ISS utilization.

The CASIS staff shares the Committee's sense of urgency with regards to maximizing use of the ISS NL. In the following testimony, I will discuss how CASIS is developing and pursuing innovative, forward-leaning, and broad strategies to attract a wide-range of users to ISS NL.

Foundation and Organizational Structure

During its standup phase, CASIS has developed an organizational structure faithful to our proposal, Cooperative Agreement with NASA, and original Reference Model, but one which is also responsive to the practicalities of implementation and the realities of the marketplace.

We currently have 27 full-time employees. Staff members bring with them an array of skills and extensive experience with NASA and the aerospace industry, R&D, venture capital, media, commercialization, management, and operations. Our staff has worked with urgency to establish CASIS' essential functions: business development, marketing, education, and operations. We have worked and partnered with industry, academia and others to ensure that the CASIS organization can be responsive to the needs of potential users of the ISS NL. We have conducted extensive outreach activities. All work undertaken thus far has been in an effort to move the organization forward in an efficient, timely and practical manner in step with efforts to establish a permanent Board of Directors and executive leadership. We are confident that the steps taken so far to identify initial research pathways while raising awareness and developing partnerships satisfy our mandate and will be approved by a permanent Board of Directors.

The Board of Directors selection process began several months ago when the Interim Board contracted with a well-respected executive search firm, Korn/Ferry International, to conduct an independent, verifiable search for qualified candidates. Stakeholders, including the leadership of this Committee and its House counterpart, NASA, and other science-focused Federal agencies, had the opportunity to submit names of Board candidates. Through a series of evaluations, interviews, and down-selects, the Interim Board has identified the first group of permanent Board of Directors candidates, all of whom represent the best American minds in the fields of scientific research and management from academia, government, and industry. An announcement of the first set of Board members will be made shortly, with the remaining 15-member Board finalized soon thereafter. As envisioned by Congress and the ISS NL Reference Model, the permanent Board will be made up of world-class scientists and leaders who will provide CASIS with guidance, expertise, and credibility. They will serve as ambassadors for CASIS and the ISS NL, reaching new users and supporters through their various networks. Additionally, the initial permanent Board members will appoint the permanent Executive Director.

While awaiting the appointment of a permanent board, CASIS has taken steps to establish a path toward effective utilization in line with Congressional intent, our Cooperative Agreement with NASA, and other guiding documents. This includes the appointment early this year of a world-class Interim Chief Scientist and an Interim Science Collegium comprised of renowned experts to review past life sciences research conducted in space in order to identify initial research pathways. Their effort resulted in our first solicitation for research in the area of protein crystallization. This is a well-established area of interest for researchers, but in need of a more systematic approach than has been taken in the past. The validity of the collegium's approach is supported by a recent National Academy of Sciences' study highlighting the importance of studying crystal growth without gravitational bias. Protein crystallization in microgravity can validate its scientific worth and unlock the potential for countless discoveries.

State of Valuation and Prioritization Process

CASIS' valuation model has been developed in order to best respond to the specific needs of the ISS NL as well as to meet the requirements of our charter. Designed to be a transparent process, it incorporates standard business model elements with regards to project evaluation and prioritization and has evolved into a robust methodology, taking into account scientific merit, economic value, readiness, and operational feasibility.

An interim process was used on multiple test cases, starting with an operational review to gauge the feasibility of proposals. The Interim Chief Scientist and his team reviewed projects for scientific merit and impact. The Chief Economist and his team then assessed projects for value and potential return to the U.S. taxpayer. Our compliance team scrutinized the legal implications and challenges. Final decisions were made by the Interim Executive Director with Interim Board approval.

Once a permanent Board of Directors is in place and selects a permanent Executive Director, the final CASIS Evaluation and Prioritization Framework will be used on solicited and unsolicited proposals. Under the final methodology, the interim process expands to include the evaluation of projects by the scientific collegium and outside industry experts who will score and help prioritize projects using a standardized set of metrics for the scientific and economic reviews. These metrics will be posted publicly on the CASIS website. Taking into account the scoring results, the CASIS science and economic teams will deliver the final recommendations to the Executive Director, Chief Scientist and Chief Economist, who will then make the final award and funding decisions. The methodology is designed to adapt to new and ever-changing market demands. The Framework in its entirety is spelled out in Appendix iii.

Outreach Efforts

The vast majority of Americans, including business leaders and leading scientific researchers, simply do not know that the ISS NL exists and is open to them for research. To fully realize the potential of the ISS NL, there must be aggressive outreach and education activities to raise awareness of Station and its capabilities. This has become a top priority for CASIS. Over the last 11 months, we have set out to establish and develop relationships with new and previous researchers, commercial entities, entrepreneurs, financial partners, philanthropic organizations, educators, students, and citizen scientists. Since March, CASIS staff has met representatives from over 165 organizations from coast to coast to inform them about the numerous opportunities to use the ISS NL.

In addition, CASIS has supported the *Destination Station* outreach programs by participating with NASA on several research panels, Twitter Town Halls, University presentations, and informational exhibit booths.

Last month, CASIS, in conjunction with the American Astronautical Society (AAS), was a co-sponsor and active participant in the First Annual ISS Research and Development Conference conducted in Denver, CO. During this conference, CASIS also successfully produced and coordinated the first-ever Implementation Partner Tradeshow, which included over 20 implementation partners exhibiting their capabilities. This provided a cutting-edge venue for the over 400 attendees, who could be potential users of the ISS National Lab, to collaborate with established payload implementation and integration partners, allowing them the opportunity to gain an understanding of the capabilities available to ensure the success of science missions.

Over the last six months, CASIS has reached out to hardware providers, flight and integration specialists and others to create a consolidated directory of implementation partners to assist ISS NL users to efficiently and effectively get their research into space. The ever-expanding resource is the first of its kind and is available in hard copy or as a PDF via the CASIS website. It provides technical and contact information useful for ISS NL users and currently lists more than 35 specialized companies and organizations The objective is to match users with integration and hardware partners and in doing so stimulate new investigators and researchers by making it easier and more cost-effective for to prepare their research for flight.

In June, CASIS announced the creation of the "Space Is In It" seal which the organization will bestow upon companies that successfully develop commercial products based on research and development, testing or use on the ISS NL. Through the "Space Is In It" endorsement, CASIS positions Station in the forefront of the general public's understanding of our space program. This seal adds marketing value to the ISS and allows non-traditional users the opportunity to understand the benefits of science in space. The goal of the seal is to connect Station and the ISS NL research with consumers, fix ISS awareness more strongly in people's minds and in pop culture, and to entice U.S. companies to look more carefully at the value of developing and researching products on Station. Last month, CASIS announced it would award the "Space Is In It" seal to any products developed by COBRA PUMA Golf from investigations on the ISS NL, after the golf manufacturer declared its intention to conduct materials research on Station with the hopes of creating revolutionary sporting goods for consumers.

Education Initiatives

While the overlying mission of CASIS is to effectively and fully utilize the ISS, educating the future engineers and technical professionals of tomorrow about Station and careers in space are paramount to maximizing our Nation's investment. The CASIS Education Program seeks to use the research CASIS brokers on Station as a springboard to increase STEM literacy for all students from Kindergarten to higher education; excite students about STEM careers; support teachers in improving STEM education; and promote the ISS as a STEM learning platform..

CASIS will work with commercial and academic National Lab users to develop curricula around their payloads in cases where it makes sense for educational purposes. This aspect of our education mission holds great potential for raising awareness about the ISS, supporting teachers, and teaching students about the practical uses of space-based research. This will be an on-going focus for CASIS staff. CASIS will also play a key role in ISS advocacy by developing curricula to excite younger children about Station science in general.

In June, CASIS has signed an agreement with the Student Spaceflight Experiments Program (SSEP), spearheaded by the National Center for Earth and Space Education (NCESSC), to sponsor student science projects on Station. In 2013, SSEP could reach thousands of students and hundreds of communities nationwide. CASIS will work with NCESSC to enhance the program to expand its outreach.

In another example of the innovative, multi-layer deals CASIS can make, the organization this year established a partnership with the PGA of America. By leveraging PGA's immense network of players, professionals, fans and sponsors, CASIS can bring attention and relevance to both Station and the space program by reaching a whole new audience of children, educators, companies, and decision makers. The first prong of this strategic cooperation constituted a pilot PGA STEM Enrichment Camp in June at the PGA Center for Golf and Learning. Over five days, in classroom settings and on a golf course, underprivileged children received instruction in more than just golf; they learned science, math, and engineering and about the ISS and the kinds of research that could take place there. They learned about the physics of golf and how the same principles are used by engineers and astronauts every day. The event was so successful that the PGA is considering rolling out the program nationally, initially expanding the program to 50 sites next year, then to 250 the following year and up to 750 in its third year. This pilot program is model that can be adapted and used by other established organizations to reach the maximum number of students in the shortest period of time.

Other initiatives that CASIS has put into motion with regard to educational endeavors include 'Story Time From Space', in which a well-known science children's author will write a series of books designed to create awareness about Station, which will be read by astronauts in front of video cameras on the ISS NL, exciting young readers about the world in space., . The videos will posted on the CASIS website and social media platforms. 'Story Time From Space' will reach a previously underserved demographic and connect literacy with STEM concepts. CASIS is working to finalize this deal by the end of the year.

Operations

The CASIS Operations Director was hired in 2011, and project management staff positions were filled beginning in January of this year. It is completely staffed, with six members. All team members have extensive project management and flight hardware experience from time at space centers, the aerospace industry, and the transportation sector. Operations staff members are responsible for working with their clients from project conception to completion. They will use their knowledge and skills to develop, integrate, and operate projects in order to accomplish the goals of users and to ensure alignment with the CASIS mission.

The operations directorate has assumed responsibility for all National Lab projects and payloads scheduled by NASA for current and future ISS Expedition increments. This includes all research, planning and sponsorship efforts. In particular, CASIS has sponsored research plan updates, assisted with the development of science missions, and assembled the entire ISS NL research plan for September 2013–March 2014, which has been approved by NASA. CASIS Operations is also managing flight opportunities in September 2012–September 2013 for unsolicited projects and the upcoming series of RFPs promoting the utilization of existing ISS facilities in earth observation and microgravity science.

With regards to fulfilling future increments as required by our Cooperative Agreement, we are ahead of schedule. CASIS has identified and developed payloads that will be flown on Increment 37/38, well ahead of the Increment 39/40 time-frame set in our Annual Performance Plan (APP). During Increment 37/38, we are working towards flying 5 to 6 payloads consisting of unsolicited projects that are currently being vetted through our evaluation process. Additionally, we plan to deliver the Windows on Earth software at the end of this year during Increment 35/36. These missions will serve to validate CASIS' processes and capabilities, as required by the APP.

The operations division has also worked with NASA to transition all National Lab projects to CASIS, with the exception of two due to extenuating circumstances. As part of this effort, CASIS adopted the commitments of the existing Space Act Agreements and entered into new Memorandums of Agreement with existing National Lab partners to ensure a continuation of project support and other commitments within CASIS's ability to support.

Under a MOA signed with Bioserve, CASIS has tasked the company with developing a commercial rodent research model in cooperation with NASA Ames and Professor Ted Batemen, a leader in the field of space-based rodent research. Our goal of flying a proof-of-concept mission in the Fall 2013 cuts in half the time it would normally take to develop and deploy such a concept. Along with establishing ground and on-orbit processes, this initiative will include the demonstration of on-orbit analysis capability, which has never been available to researchers before. Pursuant to this case, we will fly an off-the shelf bone density scanner, which is being hardened for use in space, to develop new means for future osteoporosis research.

The importance of developing a long-term, robust animal research platform cannot be underestimated; it was deemed important by a recent decadal survey as well as the CASIS interim science collegium as key to utilization and maximization of return on investment. The brand new opportunities for research this initiative will provide are essential to developing new business for the National Lab; several pharmaceutical companies have expressed serious interest and a willingness to use the ISS NL, and are eagerly awaiting the successful accomplishment of milestones. This project will also benefit NASA, in that it will be able to utilize this innovative method and hardware for exploration focused research.

Moving forward, this effort will greatly expand the ability of NASA and commercial users to conduct life sciences research in ways that have never been done before. This will enable ISS NL users to move from limited fundamental research to applied research, product development, and ultimately, commercial realization.

Another example of the successful transition of projects from NASA to CASIS is the MOA with NanoRacks. Through this agreement, CASIS has reserved space on the first commercial platform available for researchers outside the ISS in the extreme environments of space. CASIS will be issuing a formal solicitation for proposals to use this one-of-a-kind platform for anything from earth observation to materials research and biological sciences.

This opportunity enables NanoRacks, the provider of sophisticated shoe-box sized space research hardware, to begin design and fabrication of the external platform pallet and be ready for flight in early 2013—almost a year ahead of schedule. By enabling NanoRacks to extend their "NanoLabs" outside Station, CASIS is helping to bring a whole new generation of researchers to the ISS. The deal also fulfills part of the CASIS mission to enhance capabilities of the ISS NL.

Challenges

As a new organization, CASIS recognizes the inherent obstacles encountered in standing up a new and unique entity. Similar operations typically encounter growing pains. CASIS management must endeavor to maintain independence from NASA, while creating a new way of doing business on the ISS NL. In such circumstances it is not uncommon to see management changes and executive turnover. CASIS was no exception in this regard.

In February 2012, Dr. Jeanne Becker, the CASIS Executive Director, announced her resignation citing the pressures that she felt at the head of the organization. New management stepped in to get the organization on track and to keep it moving forward. Since Dr. Becker's resignation, CASIS has been developing the initiatives started under Dr. Becker and executing our mandate.

As we have sought to implement the Cooperative Agreement, we have encountered several challenges. As with any engineering project or standup business, there were many issues that Congress, NASA, CASIS and our guiding documents failed to anticipate or address prior to implementation. Given the fact that this concept is brand new and that our mission is to develop and establish innovative ways to promote the ISS NL, challenges were expected.

CASIS is currently working with NASA regarding the handling of Intellectual Property and Data Rights, the resolution of which is essential to securing commitments from commercial users. CASIS continues to work with NASA to find resolutions to these and other critical questions, while understanding our role to establish new pathways and maintain independence from NASA.

How to best capture unsolicited proposals is an area that is continuing to evolve.

Because unsolicited proposals will by their very nature address topics CASIS might not be pursuing through a formal solicitation process, we set out to develop a fair, streamlined process that aligns with overall goals and organizational structure. As with the formal solicitation review process, this method takes into account market realities, resources, and scientific merit. Several unsolicited proposals are currently moving through the pipeline as test cases for CASIS procedures and criteria.

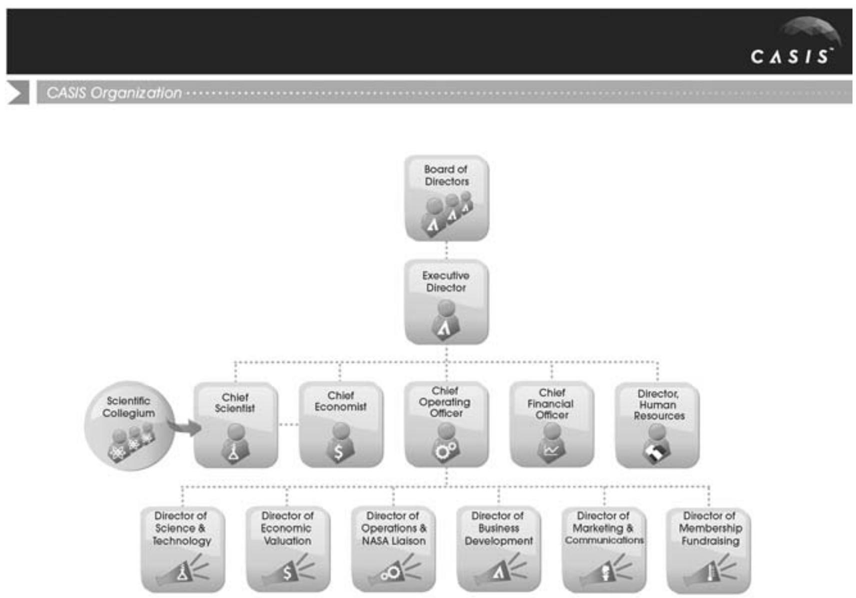
Through significant promotion and outreach efforts, CASIS has and will continue to receive many unsolicited proposals from academic and commercial investigators hoping to utilize the ISS NL. Many have their own funds and are only seeking CASIS' support with transportation, payload integration and/or hardware/experiment design. This unsolicited interest has driven the CASIS Valuation and Prioritization Framework to evolve so that we do not disenfranchise potential users of the ISS NL. History has shown that people have unique and powerful ideas, and CASIS has created a process that will capture, evaluate and prioritize all unsolicited commercial and academic proposals to conduct science on the ISS NL.

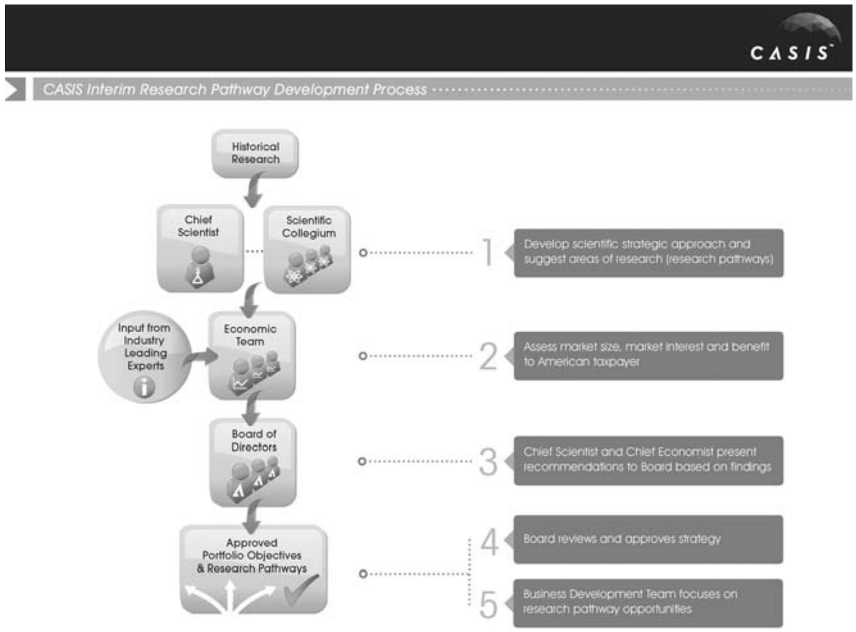
Conclusion

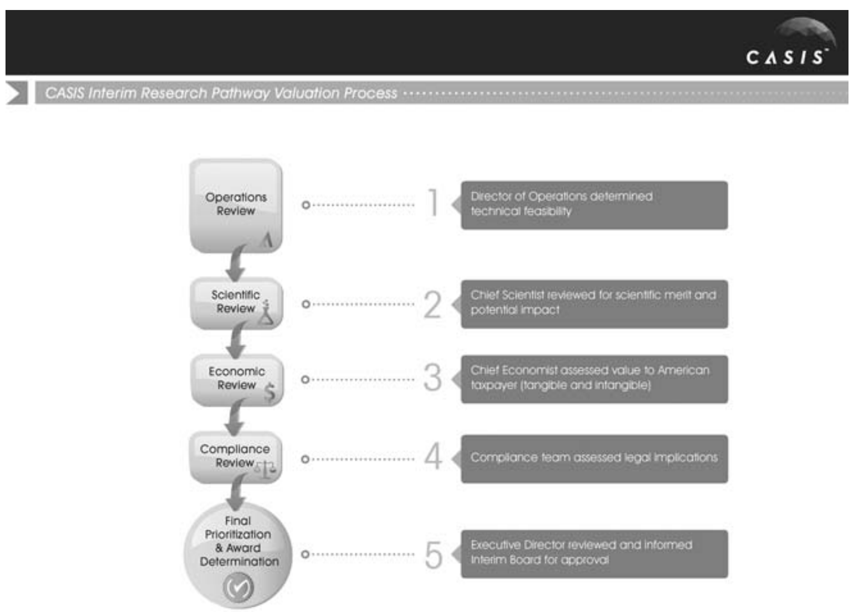
Over the past 11 months, CASIS has seen its share of negative press, in particular, with the resignation of our Executive Director. Since that time-frame however, CASIS has continued to move forward, effectively promoting the ISS NL aggressively and passionately. Through any struggles that might have been perceived, CASIS has continued to meet or surpass all milestones established for the organization during its first year.

CASIS is now moving from its standup phase to become a fully-operational organization. From our first RFP to announcing partnerships with non-traditional users, CASIS has been making tremendous strides towards maximizing the use of the ISS NL. Our staff continues to engage potential users of Station, developing and evolving our processes which will further identify research opportunities, and with our new Board of Directors nearly in place, the future for CASIS and the ISS NL is unquestionably bright.

The entire CASIS team believes Station is the next emerging market and we plan to promote the world's greatest engineering achievement as a mechanism to create beyond what was previously thought possible. Time is quickly passing, and CASIS will continue to be aggressive in our efforts to bring users on board Station, creating breakthroughs that will benefit humankind




CASIS
CASIS Interim Research Pathway Development Process
Historical Research
Chief Scientist
Scientific Collegium
Input from Industry Leading Experts
Economic Team
Board of Directors
Approved Portfolio Objectives & Research Pathways
1
Develop scientific strategic approach and suggest areas of research (research pathways)
2
Assess market size, market interest and benefit to American taxpayer
3
Chief Scientist and Chief Economist present recommendations to Board based on findings
4
Board reviews and approves strategy
5
Business Development Team focuses on research pathway opportunities


CASIS
CASIS Interim Research Pathway Valuation Process
Operations Review
Scientific Review
Economic Review
Compliance Review
Final Prioritization & Award Determination
1
Director of Operations determined technical feasibility
2
Chief Scientist reviewed for scientific merit and potential impact
3
Chief Economist assessed value to American taxpayer (tangible and intangible)
4
Compliance team assessed legal implications
5
Executive Director reviewed and informed Interim Board for approval

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CASIS Valuation and Prioritization Framework

Proposals to utilize the ISS National Lab ("NL") fall into two categories: **Solicited and Unsolicited.** Solicited proposals are responses to CASIS RFP releases driven by portfolio objectives and research pathways approved by the CASIS Board of Directors ("BOD"). Unsolicited proposals are a result of promotion of the ISS NL and focused CASIS outreach led by the CASIS Business Development ("BD") team. These outreach efforts allow both academic and commercial investigators to realize that CASIS can facilitate access to the microgravity environment provided by the ISS NL.

Solicited Proposal Valuation and Prioritization Process:

1. Chief Scientist ("CS") and the Science Collegium ("SC") will first develop overall portfolio objectives (basic research vs. applied research) and suggest research pathways (biosciences vs. materials science vs. earth observation, etc.). The SC will consist of various academic and commercial experts in their respective fields.

2. The CASIS Economic team reviews the portfolio objectives and research pathways identified by the CS and SC. The Economic team may utilize relationships with industry-leading external consultants depending on the industry (e.g. McKinsey & Co., Bain & Co., Boston Consulting Group, etc.) to recommend changes to the portfolio objectives and/or research pathways if appropriate. Some key areas of consideration include (i) market size, (ii) time to translation of benefits to American taxpayers, (iii) potential customer feedback, and (iv) scientific merit as determined by the SC.

3. Chief Economist ("CE") and CS sign off on research pathways and portfolio objectives. It is the responsibility of the CE and CS to present research and portfolio objectives to the CASIS Board of Directors ("BOD"). The BOD will then either approve or disapprove these objectives and pathways. In addition, the BOD may suggest changes to render pathways consistent with the CASIS mission.

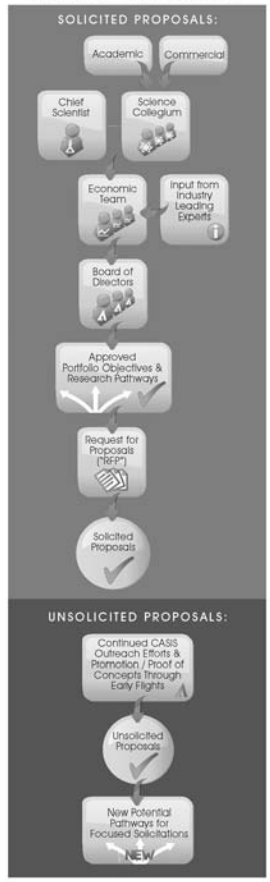
4. Upon BOD approval, execution takes place through the CASIS Business Development ("BD") team. BD develops a tactical execution plan for each defined vertical market segment, using the Board members as well as the economic team, scientific team, communications team, and external consultants to help stimulate demand. The execution plan may include attending industry conferences, communicating directly to industry associations, potential commercial customers and key researchers in a given field, and releasing focused solicitations.

CASIS will use funds to:

- (i) offer grants through solicitations,
- (ii) match investigator funding and
- (iii) create enhancements to current ISS NL capacity and ground capabilities.

1

STIMULATING DEMAND

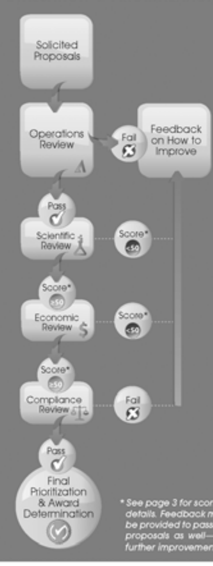


CASIS

5. After receiving proposals that aim to achieve the established portfolio objectives and research pathways, CASIS will utilize a valuation and prioritization framework for grading each individual proposal. The valuation and prioritization process for solicited proposals will include five steps:

- **a.** Expedited review by the CASIS Operations team to determine technical feasibility of the proposed project and the achievability of the estimated budget and timeline
- **b.** Evaluation by the Scientific Project Selection Panel ("PSP"), an external panel of subject matter experts, to score the proposal for scientific merit and potential commercial/social impact
- **c.** A two-pronged economic evaluation process by the Economic PSP, managed by the CASIS economic team, to score potential commercial and intangible value
- **d.** Review by the CASIS Compliance team of regulatory and legal risks
- **e.** A final prioritization and award determination by the CASIS Executive Director ("ED"), CE and CS on the basis of recommendations from the PSPs and CASIS staff, as appropriate

SOLICITED PROPOSAL EVALUATION & PRIORITIZATION:



* See page 3 for scoring details. Feedback may be provided to passing proposals as well—for further improvement.

Further details on each step of the process are:

OPERATIONS: Technical feasibility of proposals is performed to ensure the viability and readiness for flight. The review is performed by the CASIS Operations team, which will consult as needed with NASA and outside technical experts to determine overall feasibility. This review is an unscored, pass–fail initial screening; however, CASIS may consider an interview with the investigator(s) to clarify technical elements of the proposal as well as the proposed budget and schedule in order to make its determination. Specifically, the technical feasibility review considers the following elements:

Logistics: Proposed resources including implementation partner support, facility needs for ground testing and flight operations support, use of ISS crew for research support, power and data requirements, weight and any known hazards

Hardware: Availability, limitations, appropriate planned use, alternatively the costs and feasibility of proposed new hardware development

Projected Budget and Timeframe: Preflight development and testing considerations, time to flight and time to completion

Hazards: Procedures, situations and materials that could potentially be hazardous and a plan to mitigate any identified issues

Questions: Follow-up questions for the investigator(s), including as appropriate—

- Revised methods/analyses, and how results will be collected, analyzed and interpreted
- Awareness of potential barriers and ideas about alternative approaches

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The Operations team will organize its comments into an Operations Appendix to the proposal. The Appendix will provide crucial input for prioritization (e.g., time frame and budget) and will identify logistical challenges in the proposals in areas where new-to-space investigators will potentially be deficient. This function serves to support the new space investigator so that appropriate considerations are made in their proposals, as well as to prevent experienced space investigators from scoring higher in the later rounds of review (thereby supporting the CASIS goal to attract new users).

Only proposals that demonstrate operational feasibility will pass this round of review and advance to scientific evaluation. The decision of the Operations review is final and not subject to appeal.

SCIENTIFIC EVALUATION: Using the scoring rubric below, an external panel of subject matter experts in the RFP target field, assembled by CASIS, will evaluate proposals which passed the Operations review. Their evaluation will consider both the original proposal and any additional information provided in the Operations Appendix.

SCORE	DESCRIPTIVE FEATURES	POTENTIAL FOR SELECTION
90–100	**EXCELLENT:** A thorough, comprehensive and compelling proposal of exceptional merit that fully responds to the objectives of the RFP, as documented by several major strengths; no major weaknesses and only very minor weaknesses, if any.	Top priority for selection.
80–89	**VERY GOOD:** A competent proposal of high merit that fully responds to the objectives of the RFP, as documented by one or more major strengths and no major weaknesses; strengths substantially outweigh any minor weaknesses.	Second priority for selection, barring issues of funding availability or programmatic priorities.
70–79	**GOOD:** A competent proposal that represents a credible response to the RFP, as documented by no major weaknesses; strengths and weaknesses on the whole are in balance, but strengths somewhat outweigh weaknesses.	May be selected as funds permit according to programmatic priorities.
50–69	**FAIR:** A proposal that nominally responds to the RFP, in which one or more major weaknesses, in combination with any minor weaknesses, clearly outbalance any strengths.	May be selected after revisions as funds permit according to programmatic priorities.
0–49	**POOR:** A proposal with several major weaknesses or weaknesses that constitute fatal flaws.	Not selectable regardless of programmatic priorities or availability of funds.

Minor weakness: an easily addressable weakness that does not substantially lessen merit/impact.
Major weakness: a weakness that severely limits merit/impact.

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0-49	50-69	70-79	80-89	90–100

FAIL

PASS

Reviewers will score the following categories on a 0-100 scale and will average individual scores to produce an overall merit/impact score:

- **Significance** - DESCRIPTORS/CRITERIA: If successful, the results will have rapid scientific, commercial and humanitarian impact and significant scientific, commercial and humanitarian potential. The results could yield a new line of space research with strong scientific, commercial and humanitarian potential or build on prior successful research produced on the International Space Station. If successful, the results will advance the leading edge of the field. Negative results will have significant impact within the research area. If successful, the results will influence broad fields of study. The research builds on a foundation of existing space or ground research to bring the pathway closer to commercial application.
- **Investigators** - DESCRIPTORS/CRITERIA: The investigator(s) has the financial stability to complete a project. The investigator(s) has documented success in the field of study (as demonstrated by strong publication record, commercial success, patents or technology implementation resulting from R&D). The investigator(s) has a strong publication record or demonstrated success in R&D (as measured by commercial success, patents or technology implementation resulting from scientific research). If the applicant is a new investigator(s), or one in the early stages of an independent career, the investigator(s) has appropriate experience and training or has partnered with a qualified coinvestigator. If the project is collaborative (e.g., multiple institutions or coinvestigators), the investigators have complementary and integrated expertise; their leadership approach, governance and organizational structure are appropriate for the project.
- **Innovation** - DESCRIPTORS/CRITERIA: The project is innovative with respect to multidisciplinary integration and novelty of topic or approach. The project's results, if successful, will challenge current research or commercial practice paradigms. The project's concepts, approaches, instrumentation or interventions are new to more than one field of research. The project improves or suggests a new application of theoretical concepts or approaches.
- **Approach** - DESCRIPTORS/CRITERIA: The scientific merit of the proposal is sound. The proposed project fits the CASIS mission, satisfying the overall objective of the RFP and both the short- and long-term objectives of CASIS. The proposal explains the hypotheses or the required elements of the proposed technology demonstration, including well-defined ground controls. The project requires the space environment for advancement with respect to time and/or capability. The project's potential problems, alternative strategies and benchmarks for success are presented (may refer to Operations Appendix).
- **Environment** - DESCRIPTORS/CRITERIA: The investigator(s) has access to crucial ground technology and experience necessary for preflight work and ground controls. The proposal contains compelling and well-developed preliminary work. The project will benefit from the space environment. The investigator(s) has demonstrated understanding of how data collection, analysis and interpretation must be approached on the basis of the unique conditions of the space environment (may refer to Operations Appendix).

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ECONOMIC EVALUATION: The Economic Evaluation process will be twofold, with each branch of the process (Commercial and Intangibles) using a 0–100 scale and the same scoring rubric as the Scientific Evaluation process. The weighting of the intangible score in the final combined score will range from 0 to 50%, depending on what part of the research pathway the proposal affects (higher weighting for affecting later points in the pathway closer to commercial product application).

Similar to the Scientific Evaluation process, CASIS will assemble an external panel of subject matter experts to evaluate the proposals. These experts will most likely come from industry-leading consulting firms including McKinsey & Co., Bain & Co., Boston Consulting Group, etc.

Reviewers will evaluate commercial letters of support during this stage, which may impact multiple scoring categories.

COMMERCIAL EVALUATION:

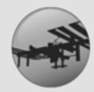
Reviewers will score the following categories:

- **Management and Key Employees** - DESCRIPTORS/CRITERIA: The current management team is qualified to and can execute the project. The team has prior successful experience working together. The team or PI has prior experience in similar capacities (however, cannot fault for lack of space experience) and has demonstrated high likelihood of future success in the field of interest. The project lists necessary, relevant and qualified key collaborators.
- **Market(s) and Competition** - DESCRIPTORS/CRITERIA: The current size and forecast growth rate of the relevant market(s) is noted and addressed, and these data support potential market impact of successful results. The proposal addresses both barriers to entry and market competition. The team can either commercialize products or partner with companies with established commercial success. A customer base exists for potential products (i.e., new innovation vs. advancing something existing or solving a problem).
- **Products/Services and Technologies** - DESCRIPTORS/CRITERIA: The products/services/key technologies that will benefit from successful results are clearly defined, feasible and unique. The resulting product/service will provide specific and significant benefits to the U.S. economy or population. Customers will easily understand the benefits/products resulting from successful results. Product/service development plan, timing and costs are feasible and realistic. Technology risk assessment, if applicable, has been performed and/or is not likely to pose a problem. Patents, trade secrets or copyright protection, if available for the products/technologies/services, will increase likelihood of market impact and commercial success.
- **Business and Operating Plan** - DESCRIPTORS/CRITERIA: The proposal coherently states project mission, strategy and implementation. The competitive environment and CASIS objectives are clearly understood. Required resources (e.g., human, capital) are described and understood. The description of commercial application is adequate, and the forecast results are reasonable. Contingency plans are in place and reasonable.
- **Customers and Suppliers** - DESCRIPTORS/CRITERIA: Customer opinion about the field/market/competition is favorable to market entry and success. Key suppliers are stable and reliable/high quality. Single-source components or technologies are unlikely or are acceptable where applicable. Investigators are aware of companies interested in commercializing the product(s) resulting from the research.

INTANGIBLES EVALUATION:

Reviewers will evaluate three key categories:

- **Greater Good to Society** - DESCRIPTORS/CRITERIA: The overall potential for impact on the U.S. society is of significant value. The project advances discovery and understanding while promoting teaching, training and learning. The proposed project broadens the participation of underrepresented groups. The project increases throughput of the supply chain—innovations affecting humans, animals, plants, climate and resources now or in the future (e.g., fewer deaths, fewer sicknesses, healthier livestock, a more abundant food supply, the protection of endangered plant or animal species, reduced pollution, improved ground energy efficiency). Project success will beget future projects of intangible or tangible value. The project addresses an important problem or a critical barrier to progress in the field.



- **U.S. Leadership in Space** - DESCRIPTORS/CRITERIA: The success of the project will change the concepts, methods, technologies, treatments, services or interventions that drive the relevant field. Potential exists for significant international impact. The project advances the CASIS mission to balance a diverse portfolio of research disciplines and stages. The project enhances awareness among potential International Space Station constituency groups regarding the advantages of performing science in space (i.e., it will promote interest in using the National Lab). The project shows how space station technology contributes to products and services revenue and related tax revenue from profits (i.e., it demonstrates value to the public).

- **Economic and Human Capital Development** - DESCRIPTORS/CRITERIA: The benefits of the proposed project to society include job and wealth creation, as well as improved quality of life, knowledge, skill sets and sustainability. The project bridges basic science with industrial R&D applications. Project success will enhance the infrastructure for space-based research and education (e.g., facilities, instrumentation, networks and partnerships). The results will be disseminated broadly to enhance scientific and technological understanding, enabling developments in science by allowing researchers to build on each other's work and providing content for educational curricula.

REGULATORY REVIEW: After the economic evaluation, the CASIS Compliance team will review meritorious projects, providing notes regarding potential problems for the following areas: data integrity, risk liability, ethics and research integrity, regulatory compliance and conflicts of interest.

PRIORITIZATION AND AWARD DETERMINATION: The ED, CE and CS will perform the final prioritization and award determination, initiating discussions with members of the Project Selection Panels and CASIS management-level staff as necessary.

The ED, CE and CS will meet and review the eligible projects, relative to the entire NL research portfolio, on the basis of scientific merit, scientific value, economic value, technology advancement and educational value. They will consider estimated cost and timeline alongside scores and comments from all review steps.

The ED, CE and CS will analyze the Operations Appendix to proposals to ensure sufficient facility capacity and on-board resources in the given increment. Based on the facility and resource requirements known at the time of prioritization, they will categorize and organize payloads accordingly, consulting CASIS Operations staff as necessary for clarification. If all eligible projects fall within the available CASIS resources and facility capacity, then prioritization, for this purpose, would not be necessary. If unforeseen changes to available resources occur, CASIS will reprioritize the payloads.

All projects must meet minimum eligibility requirements such as readiness for an increment, secured funding (including CASIS grant funding) and an agreement with an implementation partner. Prioritized proposals with sufficient funding will advance to the CASIS Operations team for preflight activity and project management. CASIS Operations staff will participate in NASA research processes to support established strategic and tactical planning.

For projects without sufficient funding to advance to Operations, CASIS will assist with finding potential funding sources including reaching out to the investor community.

Lower priority proposers will be notified that their project needs improvement with feedback on its weaknesses, and they will be invited to re-submit at a later date and/or post an advertisement seeking financial or research support on the CASIS Innovative Marketplace Exchange Forum.

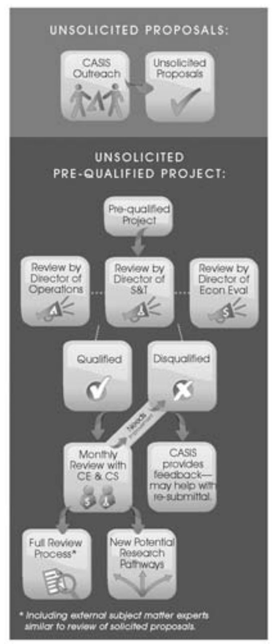
Unsolicited Proposal Valuation and Prioritization Process

Through promotion of the research opportunities available on the ISS NL, CASIS has and will continue to receive many unsolicited proposals from investigators hoping to utilize the ISS NL and are asking what it would take to get there. This unsolicited interest has caused the CASIS approach to evolve so that we do not disenfranchise potential users of the station. History has shown that people have unique and powerful ideas, and

> CASIS has created a process that will capture, evaluate and prioritize all unsolicited commercial and academic proposals to conduct science on the ISS NL.

Upon receipt, all unsolicited proposals or leads will be forwarded to the Business Development ("BD") team. If a full proposal is delivered to CASIS (rather than a verbal description), the proposal will then be logged into the CASIS database as a "pre-qualified" project. The BD team will alert the Director of Operations, Director of Science and Technology, and Director of Economic Evaluation of all new projects that require a review for qualification. Upon notice, the respective directors and their teams will, in parallel, evaluate each proposal to see if (a) it has potential to fly and warrants further investigation or (b) it has obvious deficiencies and does not warrant further investigation. For those that are disqualified, feedback is provided to proposers on potential enhancements that might improve their chances of moving forward.

All qualified unsolicited opportunities will be discussed in a monthly review with the CS and CE. During this monthly review, the CS and CE will receive a flash report of qualified proposals, and each project's details and merits will be discussed. The CS and CE will provide feedback on specific projects. Additionally during this monthly review, the CS and CE may identify and develop new research pathway opportunities for BOD consideration.



Specific projects the CS and CE identify as qualified opportunities fall into the same review process as proposals that are submitted through traditional solicitations, including (i) an Operations Evaluation, (ii) Scientific Evaluation with external review panel, (iii) Economic Evaluation with external review panel, and (iv) the final selection panel consisting of the ED, CS, and CE.

All unsolicited projects must meet minimum eligibility requirements such as (i) readiness for an increment, (ii) secured funding (including CASIS grant funding), and (iii) an agreement with an implementation partner. Prioritized proposals with sufficient funding will advance to the CASIS Operations team for preflight activity and project management. CASIS Operations staff will participate in NASA research processes to support established strategic and tactical planning.

For qualified projects that lack the necessary funding for advancement, CASIS will assist in creating relationships with the investor community for potential financial partnerships.

Lower priority proposers will be notified that their project needs improvement with specific feedback on weaknesses, and they will be invited to re-submit at a later date and/or post an ad on the CASIS innovative marketplace exchange forum.

Senator NELSON. Thank you so much.

I am going to turn first to Senator Hutchison, and I would like, in the course of the discussion, if you all would bring out what is going on on the development of the vaccines, an up-to-date report.

Senator Hutchison?

Senator HUTCHISON. First of all, Mr. Royston, thank you for the report. Because we are anxiously awaiting the appointment of the board so that we can see the CASIS get up and go and really start showing results. And I think the board membership will be crucial, and I am encouraged that you are saying it will be leading scientists, as well as people in business.

Dr. Pettit, I would like to ask you, if you identified any areas—and of course, Mr. Reiter, I would like for you to jump in as well on this area where the ability to perform valuable research aboard the Space Station could be improved. Are there any specific suggestions on what we could add or what more would be effective on the Space Station for the basic research?

Dr. PETTIT. Senator, currently, I believe the rate-limiting resource for doing scientific research on Space Station is the availability of crew time. We have an amazing infrastructure that is currently just getting going with the commercialization of space, for bringing supplies to Space Station, where we have more scientific apparatus on Space Station, more equipment waiting to be used, more science experiments in the queue than we have crew time in the USOS segment with three crew members that we could spend working on this.

And currently, crew members are working about 13 to 14 hours a day. And out of that, we can get about 6.5 hours of mission programmatic work done.

And you may wonder why we work 13, 14 hours a day, we only get 6.5 hours of program work done. That is because we are in a frontier, a harsh frontier, and we spend 13, 14 hours a day just to keep the machinery going and keep it possible for human beings to be there. And you will find this is commensurate with other frontiers that are harsh on the surface of Earth.

If you go to Antarctica, which I had the opportunity to go and participate in the Antarctic search for meteorite expeditions that is jointly funded by National Science Foundation and NASA, we were looking for meteorites on the glaciers maybe 200 miles from the South Pole, living in Scott tents, which have changed very little from the design that Scott used when he did his expeditions.

We would spend 13 to 14 hours a day working in this Antarctic environment to enable about 6 hours of actually mission work gathering meteorites. And we would spend time working on our snowmobiles. We would spend time just trying to chip at the ice so we could make water, drying your gear, all these—shoveling snow so your tents wouldn't get buried by the sastrugi. And we would work 13, 14 hours a day just to enable the 6 hours of on-the-mission work.

I think if you look at deep sea, people living in the deep sea doing work, saturated conditions on platforms, it is difficult to put human beings in a harsh environment and have them work more than about 6 hours of on-the-mission work.

And so, what we find in Space Station is commensurate with what we find on Earth in these harsh environments, and you reach a limit with a crew of three of how many hours can you work and still keep your mind, still keep your wits, and still get enough sleep so that you can respond to contingency situations? And so, currently, our ability to do the engineering and organization to get scientific equipment up and the ideas behind the science experiments, there is no shortage of that. It is crew time.

Senator HUTCHISON. So we need to get seven people in that station. That is good.

Mr. Reiter, did you have anything to add?

Mr. REITER. Yes, thank you, Senator Hutchison.

I believe considering the fact that we have almost just transitioned from a buildup phase of the ISS to a quasi steady-state operation, it is a little bit early maybe to really say if we already are utilizing the station in an optimum way.

Don has just mentioned we have given parameters, assets. Crew time is one of them. Up and download and scientific facilities that have been mentioned. And I think the next years will show where there are further areas of improvement.

Now from a programmatic point of view, I can imagine that, for example, in the coordination, in the international coordination of research subjects, there is space for optimizing the processes. And in fact, ESA has currently identified more than 20 joint experiments together with NASA and in total more than 50 with all the ISS other partners, and the shared use of this unique orbit research infrastructure and the assets is of high importance and will help us to see where there is area for optimization.

In addition, I have to say, of course, looking at the internal processes, there are certainly areas where I will look into the future. For example, one of the remarks I am receiving from the scientific community in Europe is that the turnaround time maybe can be improved.

This is motivated by comparing it to the time of the Spacelab, which was flying a couple of years ago onboard the Shuttle. And I will look into the possibility if we can indeed decrease the time from the moment where the scientists are proposing their experiments until they hold the results in their hands.

Also I think in a structural way we are using multiuser facilities, big facilities in the various modules, and I will see if this is the right balance with these huge multiuser facilities, compared to small experimental hardware which is dedicated to single experiments. If we can optimize that in order to improve or to increase the scientific outcome, but that will need some time of this steady-state operation that we have just entered.

Senator HUTCHISON. Thank you very much.

I will have another round, but let us let everybody go.

Senator NELSON. OK.

Senator HUTCHISON. And I like your virus issue. You need to cover that.

Senator NELSON. Yes. As a matter of fact, I want to ask you about that. But I just want to point out that since we were talking about Sally Ride, that the American astronaut on the station now, Sunita Williams, will become the second female commander of the

Space Station crew, coming this September. The first female Space Station commander was Peggy Whitson, who is presently the Chief Head of the Astronaut Office.

So, again, we see these women pioneering. I thought it was also in the number of comments that had been made to the press about Sally that one of the most interesting was from the first female commander of the Space Shuttle, Eileen Collins. So, with that backdrop, we proceed.

Would you all—before I turn to Senator Rubio, would you all share with us, whoever, about the advances on the vaccines?

Mr. GERSTENMAIER. I can do that a little bit. We have learned that almost all bacteria and viruses in space mutate into a large, different gene strain. And we have flown salmonella several times on the Shuttle.

Senator HUTCHISON. I couldn't quite understand. Did you say large and different?

Mr. GERSTENMAIER. Yes. Different, and they mutate——

Senator HUTCHISON. They mutate? OK.

Mr. GERSTENMAIER.—to various strengths of the various bacteria and viruses. So, for example, salmonella, you fly it up and you get back a whole variety of different salmonella than you would typically see here on the ground. Some are stronger, some are weaker.

Then what we have been able to do or what the investigators have been able to do is they return these samples to the ground. They then learn which genes turn on the strength of the salmonella, which genes potentially turn it off. Then they can genetically engineer a strain of salmonella that is strong enough to give the human an immune reaction, but not strong enough to actually give you the disease, and that is the basis of the vaccine.

So they have done enough trials on orbit that this looks very promising. The same thing can occur for viruses. So flu, you could potentially engineer a flu vaccine ahead of time with a very quick turnaround.

Again, it is still conceptual, and we don't understand why bacteria and viruses perform this way in space. The company is close to taking this into FDA trials. We have done almost enough work to go complete that activity and take it into trials. I believe they would still like to fly a few more samples to space to get some more material back and then maybe do a little more research before they prepare the final package that goes to FDA.

We are still discussing with them exactly how they are going to work that out in the future. But this is one very promising area where we don't know exactly the reason that this occurs in space. But if you give it to a creative industry, they are able to take this phenomena and then apply it in a way that is tremendously beneficial to us here on the Earth.

So I think this area of research in virus and vaccines has a lot of interest to us. Arizona State is also looking very hard at trying to understand why this occurs. So they are looking at it from kind of the pure research side. What is unique about the properties of microgravity that causes these viruses and bacteria to behave in this unique way? So very promising.

Senator HUTCHISON. That is going to be essential because you can't manufacture enough up there to bring back very easily. So that is really going to make a difference if they can figure out what that cause is.

Mr. GERSTENMAIER. And the advantage is once you understand which genes are turned on and turned off, then you can manufacture this vaccine on the Earth. So it no longer requires you to go to space.

So you just use space to essentially spark your creativity about which genes are effective in making the virus stronger or weaker, and then that can be used on the ground then to actually generate the vaccine.

Senator NELSON. What about the vaccine for the raging bacteria MRSA?

Mr. GERSTENMAIER. It does the same exact phenomena as the others, and we believe a similar strategy can be developed for the MRSA, the resistant bacteria that is a tremendous problem to us in hospitals. So, again, we are working with some companies to go take a look at that as well.

Senator HUTCHISON. Could I just pursue this for one second and ask you if you have got vaccines, and can it also apply to cancers? And can you grow cancer cells and look at a mutation and determine if there is a vaccine or an antidote for that?

Mr. GERSTENMAIER. It is not as clear in the cancer case, but we have some researchers that proposed some investigations along the cancer line. But what we have done is we have flown a variety of both bacteria and viruses to space to confirm that it is there.

We have not done enough research in the cancer area to understand if there is a connection in there. We could get some of the actual researchers to come, give you some information specifically.

[The information requested follows:]

Clarification on vaccine development in space

The increased pathogenicity in microgravity comes from changes in gene expression (which genes turn off and on), but there is no mutation involved—microorganisms have the same genes before, during, and after flight. There is no connection between bacterial virulence and cancer.

Arizona State University (ASU) assisted with the discovery on pathogenicity changes in space, but is not participating in on-orbit Salmonella or MRSA vaccine development. ASU may do some additional spaceflight studies in the future to see if they can improve a vaccine for pneumonia that is in clinical trials.

Astrogenetix has not applied for Investigational New Drug Approval from the Food and Drug Administration (FDA). Additional flight work may be required before they apply—and this could be years away—depending upon what the company believes is required to ensure a positive finding from the FDA.

Senator HUTCHISON. Yes, because I know they have done breast cancer cell growth in space. And if they could do the same for that, that would be a medical breakthrough of phenomenal proportions.

Well, thank you.

Senator NELSON. Mr. Royston, what is CASIS doing to manage this kind of research?

Mr. ROYSTON. Good question, Senator.

I think with this—and Mr. Gerstenmaier did a good job of explaining what some of the areas are being looked at and what has been done. One of the things that I see CASIS really providing a real baseline to is with our, as you will see soon, the Board that is coming on, let alone our scientific collegia that is made up of some of the brightest minds out there in biotechnology, materials technology, but especially in the bio areas, that we can take and baseline all this work.

Because as a nonprofit, we are not trying to get new research money and we are not trying to be somewhat biased within our research. We need to be able to gather that, put it together, and that is what we have started doing so that we can then pass that on to researchers that are looking at areas of either antigenicity, muscle wasting, or osteoporosis.

But we will have gathered that up and put real facts around the science and be able to say this is the baseline by which you can build on.

Senator NELSON. Senator Rubio, before I turn to you, this prompts another question I have got to ask the two of you that have been in space for so long. What we are finding in the annual physical exams is bone loss. What has been your experience with this since, I would assume, that the bone loss would be directly proportional to the amount of days in space?

Dr. PETTIT. Senator, bone loss is something that we are starting to get a handle on, and we have an empirical remedy. I won't call it a solution, an empirical remedy that if you exercise in the right way, and in some respects a 6-month trip to Space Station is like spending 6 months in health camp in terms of the amount of exercise that we do. We found that this keeps the bone density at bay.

It doesn't prevent it, but it keeps it in a manageable category. And again, we don't know why. It is an empirical remedy. We are working on what the fundamental cause of this is.

And I liken this state to where scurvy was around 1750 when some British surgeon found out that if you suck on citrus, you keep scurvy at bay. They didn't know why. It took another 150 years before we even discovered vitamins and the idea that small amounts of organic compounds are essential in maintaining human health and then the fundamental cause of scurvy through lack of Vitamin C.

It is the combination of, first, an empirical solution, which allows the seaman to go out and not get this disease and eventually coupled with the basic understanding, and it is a basic understanding that allows all the people that stay on the continent that don't go on these voyages to benefit from this information, which is literally pried from the souls of those who explore.

And this is what we are doing right now with the bone density loss. We don't know why. We need to continue the effort so that we understand fundamentally what is going on because we have got this gravity knob, which we can now tweak and experiment on human beings as well as other creatures. And this allows us to dissect out new pearls from the human physiology. And we have got this empirical solution that will allow us to continue to explore space, but we need to understand the fundamentals, and that is what will bring the benefit to everybody that stayed firmly planted on this planet.

Senator NELSON. Of course, osteoporosis is a real problem here on Earth.

Senator Rubio?

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

Senator RUBIO. Thank you.

It is actually along the lines of what you have already been asking. So I will just continue it. You know, one of the things that we face a challenge with today when you talk to the everyday man or woman on the street is, well, why are we spending all this money at this time in our history on these things when we have so many other needs?

And I think one of the answers to the question is what you have been talking about today, is all these innovations that are only possible in that setting. So we have talked about vaccines. You talked about bone loss, another. What other kinds of—and I think this is for the whole panel—what other kinds of advances, whether it is for commercial and consumer application or health applications, what other kinds of exciting things are happening up there in that setting that justify these expenditures which allows us to get people excited about space travel internationally, but also domestically?

Dr. PETTIT. I will punch the button on the microphone again.

If you look at fire, fire and its either discovery or learning how to tame fire is what literally brought us out of the cave and allows us to have our civilization in terms of what we know now. Fire gives us our electricity. Fire allows us to have vehicles, airplanes, and cars and machines. It literally turn the wheels of our civilization.

Fire has—and from a scientific point of view, we don't call it fire. We call it combustion. It has a strong gravitational factor to looking at what is going on in combustion, and we learn empirically that heat rises, right? We learn that from fire. Fire goes up.

Space Station now offers us the ability to dissect deeper down into what the processes are in combustion that literally turn the wheels of our society by looking at it in an environment free from gravity, free from the gravitational driven convection. And this allows us to look at things and figure out what is going on at a level that you could never see without taking it to space.

And one experiment that I worked on on Space Station this last mission was looking at solid air combustion and looking at it under lower convection, lower differential velocities between the air and the fuel that was being burned than what is possible on Earth because of the convection.

And what we found is that things are more flammable than what we thought. That here on Earth if you lower the convection to a certain point, the flame goes out. But in microgravity environment, we found that the combustion will continue at a state of lower convection than what we can actually go to here on Earth.

And what the effect of that will be in terms of turning our wheels in our civilization, I don't know. but it is one small, little step, incremental step in learning more about how this combustion process works.

Mr. ROYSTON. Well, Senator, I will just add that when we look at it again as trying to develop new pathways and develop new kinds of markets, if you will, for certain things, we kind of look at it in, I would say, almost four areas. We talked about life science.

And in life science, I think there are just a vast number of things that we can do in life science.

We talked about muscle wasting, osteoporosis, and tissue generation. Diagnostics, I think, are really going to bloom in that area.

Then we move over into material science. I think there are some very unique things that we will see in the future in the areas of material science. Nano alignments, crystallization, different things that we can do by taking that gravity factor out.

And then we move over into physical science and some others. But one thing that sometimes gets forgotten, and I look at it almost as kind of a satellite guy, we have constructed basically the largest, most powerful spacecraft up there ever imagined. So with that sitting up there, we can do some really amazing things in Earth observation.

We can put new instruments up there almost immediately, and we are working on some of those now with companies. This is a vehicle that passes almost all land mass every few days, and it is great platform to do Earth observation.

So there is a plethora of things that are really there, and I think it is for us to kind of compartmentalize them, put them out, and then get out to those industries that can really utilize them.

Mr. REITER. Senator Rubio, I had last Saturday a 2-hour interview on a Saturday morning radio show where I got a lot of phone calls that I had to answer that were exactly related to the question that you were just asking. Why are we spending so much money for that?

And as Don just did, I think there is a lot of justification. Living in a world without gravity allows us to look into processes that help us to understand how life is functioning, and into a lot of physical process and that, in turn, creates certainly tangible benefits for society.

However, in that I would like to add here, if we only look at those direct tangible benefits, I think we leave out an important aspect, and that is the fact that gaining knowledge, gaining insight into the surrounding is a benefit by itself, even if it is not immediately connected to, let us say, a utilization here on ground.

The aspect of exploration which Don described is one of these examples. If we fascinate our young people to get engaged in these STEM topics, I think that is also a benefit, which is maybe not directly tangible as maybe creating new materials or new drugs or vaccines that help us to fight diseases. But I think we always need to have the view on these overall benefits, the tangible and not the tangible ones.

And last, not least, I think the cooperation, the international cooperation, as I also stated before, is an important aspect of space flight. Working together in space is a very valuable asset.

Thank you.

Mr. GERSTENMAIER. Just add quickly, any physical phenomena that we have that has a little g in it, the gravity vector, when you take it to space and you remove that gravity, you get a different insight into that physical phenomena. And then that allows researchers and companies to potentially exploit that benefit like we have been discussing here in new ways we can't imagine.

But it is tough to predict exactly where those breakthroughs are and exactly how they are going to pay back. But if they start, you could potentially start a whole new industry that never existed before.

The other thing it does, I think, to Thomas's point, the intangible benefits, one thing is the creativity aspect. If you look at these student experiments that are flying up on the Japanese vehicle, the one student's experiment was to take a jumping spider and fly it into space.

And this spider knows how to jump from one spot to another based on the gravity that affects the spider. So he knows exactly how to jump on his prey. What will happen in zero gravity where he no longer has that gravity?

Will this spider now learn and adapt to jump in a different direction as the humans do after a while? When they first get on space, they see these guys bump around. But then after a couple of days, they are honed in on the zero g phenomena, and they can float pretty effortlessly. Will the spider do that?

But what was interesting is this student in his own creativity, he imagined what this would be like, and he thought about a physical phenomena, a physical insect, and said, well, how will that perform?

And that creativity and that ingenuity and that excitement in this student is just an amazing thing going forward. So how do you quantify that as being worthwhile?

Senator RUBIO. What did the spider do?

Mr. GERSTENMAIER. We don't know.

Senator RUBIO. Oh, OK.

[Laughter.]

Mr. GERSTENMAIER. Spider news this fall, when he actually—Sunita will do the experiment. But that is the point. It is this inquisitive nature that really brings out the best in us and can really compel a nation to be exceptional.

Senator RUBIO. Let us know about the spider when that happens. Now I am dying to know.

Mr. GERSTENMAIER. Will do.

Senator RUBIO. Thank you. Thank you. Those are great answers.

Senator NELSON. Senator Boozman?

Senator BOOZMAN. Thank you, Mr. Chairman.

Mr. Gerstenmaier, one of the things that comes up a little bit, we have lost American access to the Space Station using our Space Shuttle orbiters. I guess the question is have we lost a significant barter/able asset that perhaps will diminish the amount of research that we will be able to accomplish in the next 8 or 10 years?

And from where we stand today, will our research be increasing? Our capacity, will it be increasing or decreasing as time goes by?

Mr. GERSTENMAIER. I think, as we have discussed earlier, from a cargo standpoint, we have a pretty good ability to get cargo to Space Station. And we have the HTV, the Japanese cargo vehicle, which is on its way to station. We have the ATV, which is from the European Space Agency, currently attached.

We saw the SpaceX demonstration this year. They are going to schedule to fly again possibly this fall in the October timeframe. Then Orbital is working on their cargo vehicle. Its demonstration flight should be probably by the end of this year, probably in the December timeframe.

So we see we have a pretty robust with multiple vehicles that can carry cargo to station. That is important from a researcher to make sure that their research experiments get to space and get to Space Station.

On the crew side, we have the Soyuz vehicle. We would like to get a redundant capability for that as soon as we can. That is the basis of our U.S. commercial crew transportation activity. We need to bring that online as soon as we can to have a redundant way of getting crew to space.

I am not concerned about the Russians' ability to do that. It is just our environment is very tough. You know, when we had the Columbia tragedy, the Soyuz was able to back up our transportation and was able to keep this continuous crew string that Senator Nelson talked about possible onboard Space Station. So we were able to use that Soyuz vehicle during that time.

Right now, we are essentially single string, with one way to get crew to orbit, the Russian Soyuz. We would like to get our U.S. crew transportation system online as soon as we can, and we are working that as fast as we can. Hopefully, by 2015, 2016 timeframe.

Senator BOOZMAN. Very good. Thank you.

Let me ask you guys, and again, whoever would like to comment. But as a scientist and then just as a citizen, we have talked about the spider. We have talked about bone loss. I am an optometrist, an eye doctor, and interested because I know there has been some visual things that have gone on.

But all of this research is going on up there and down here. I guess my question would be what excites you the most about specific areas that we are doing that you see the most potential in the future? If you had to pick a thing, what would it be?

Dr. PETTIT. I think one of the most exciting parts of going into a frontier are the pages of the book that don't have any writing on them yet because you don't even know enough to know should this be the exciting part? Should this be the significant part?

And certainly, you bring up the idea of these eye maladies where about 20 percent of the people living for long duration time on Space Station come back with these wrinkles on your retina, and there is a name. I think they call them choroidal folds, these technical names. You know how engineers and scientists, they like to talk tech.

But what they really are, are wrinkles on your retina. And depending on where they go, they can impact your vision. And we currently haven't a clue as to why they form. There are certain mechanisms for these wrinkles forming with people on the ground that have to do with elevated intracranial pressure, again, another term for just saying the pressure in your brain.

And we have just learned that these wrinkles can form on station crew members that have low to normal intracranial pressure. So thoughts on why these things form, we haven't a clue now.

And another thing that makes this really fascinating is that they are predominantly in the right eye. So why is it just the right eye. Sometimes the left eye, but mostly the right eye. And it is like a

Sherlock Holmes story. These are little nuggets. These are little clues scattered about which tell us something about the human physiology.

And again, the pages of this particular chapter have not even been written because we are currently in the process of writing them. The answers are clearly not in the back of the book. And when you go into a frontier, it doesn't get any better than this.

Senator BOOZMAN. Mr. Royston?

Mr. ROYSTON. Yes, Senator. I would add to that one of our challenges is, and I think all of us in this room agree, is time, right? So we are looking at how we can get success as fast as possible.

So, one, it continues to show everybody that we need to keep this great outpost going. We need to continue the research. But for us and for my organization, one of the things we try to kind of bubble up to the top are those things that we think can have the earliest impacts.

And we mentioned osteoporosis, and one of the things there is it is a good example of a known. We know there is bone loss in space. So in order to test osteoporotic drugs, you need bone loss.

And typically, to get that, you have to test older patients that have other problems, have other things. Where if we are able to go into space and I have an animal model there that is still in good health, but their bone loss goes down by 80 percent, that is an unbelievable test bed to be able to look at drugs and rapidly do either first-fail scenarios or be able to determine what is going to work and what isn't.

Now, as we talked about with either virulents or some of the other things, I think it is taking the knowns that we have, with protein crystal growth being another one. We know that we can grow better proteins. We can do better crystallization because we have taken the vector out, that gravity vector, as Bill mentioned. But our goal is to really look at the knowns that we have up there in parallel with the unknowns.

So we are trying to use what we know is current capability and things that are going to work with the fundamental science of why is it happening, and what is it doing? So from our perspective, it is a balancing act. We want to get moving on the things we know will make a good research test bed and development, but also don't forget the fundamental science and the whys that are happening.

Senator BOOZMAN. Yes. I think it really important in the sense that one of the things that you all have to do a good job as components of the agency is being able to relate what the positive things that are going on. And certainly, we as members that are very supportive, the Committee, have to do a good job of being able to relate to the public. The fact that we are spending a lot of money, but this is the—these are the very positive side effects that we are getting as a result of that.

So thank you, Mr. Chairman.

Senator HUTCHISON. Mr. Chairman?

Senator NELSON. Senator Hutchison, of course.

Senator HUTCHISON. Can I ask one quick question? Because I have got to go, but I wanted to ask Mr. Gerstenmaier a two-pronged question. Number one, is there the possibility of extending the life safely of the Space Station beyond 2020? And if so, is it being considered?

And the second part of the question is, I am fascinated by this NASA picture on the Earth observation issues that have been mentioned by several of our astronauts and researchers, and the importance of being able to see the Earth for river plumes, for flood depth, for earthquakes or rather volcanoes that we don't feel yet, but you can see it from space, managing fisheries, oil spills. All those things.

Can we put an orbiting satellite up with cameras that could do what the Space Station does? Or are we in need of having another capability to do these observations?

Mr. GERSTENMAIER. I will try to do both of these, and then these guys can fill in a little bit. The first one, beyond 2020, we are looking technically to make sure that there is not any problems with extending Space Station. So we are looking at physical system seals, rotary joints, those kind of things, major components.

What is the life-limiting factor for Space Station? And we are doing that with our partners, taking a look at that. And we think we can, from a physical standpoint, station can be operable probably to 2028. We are still looking at structural life and other things. So we have done those investigations.

I think it is important to us at this point to really focus on, as these guys have discussed earlier, of utilizing station and showing some benefit and return back. And if we can do that in the next couple years, then I think the discussion about do we continue beyond 2020 becomes a little bit of an easier discussion.

So at this kind of juncture of where we are transitioning from, from assembly to research, I think we need to get a little bit more of this research under our belts and to make the systems proven a little bit that we can then sell those to our governments and folks to move forward to extend station.

To the other question about Earth observation, I think station is a tremendous platform to do technology development. So if you have potentially a new sensor that it is maybe not mature enough to actually put on a dedicated satellite, you could fly it very easily to station, mount it on station, get some quick results from it, and determine that, hey, this is really a good device to go use.

And then after you determine that, then you could go put it on a dedicated satellite. We have done that with a couple. We have the ISRV, which is essentially a telescope that will be set in the window observation facility. It is on HTV. It will look for disaster areas. It is part of the severe network, where you can call up for a disaster. You can get location information.

There is also, I think, the HICO-RAIDS experiment, which may have been the pictures you were showing to me there.

Senator HUTCHISON. It is.

Mr. GERSTENMAIER. Yes, that is a hyperspectral spectrometer that was developed by the Naval Research Laboratory. That was a very quick demonstration to see what could be done onboard Space Station with a quick device to get up and see what kind of information they could get out of it.

It has actually operated for much longer than they anticipated, but it is a good test bed for those quick kind of tests to make sure that the equipment or the device you want to fly is really the right device to fly.

Senator HUTCHISON. Thank you very much.

Dr. PETTIT. If I could add a couple of words? Oftentimes, it takes a human being in the loop to figure out what it is you really want to measure in the first place. And for example, you could put a satellite platform in orbit, and you know that you shouldn't look at the direct reflection of the sun off the ocean—that is called sun glint—because it could burn out your detector.

Now you put an astronaut on orbit, and sometimes they don't have the kind of common sense that you would think they should have. And we will go ahead and look at the sun glint off the ocean because, wow, it is neat. And then all of a sudden, you could see some structure off the surface of the ocean. Because of the way the lighting is coming directly from the sun, you can see things that nobody knew was there before because, of course, you don't take a detector on a satellite and let it look at a direct reflection from the sun.

And once you make that discovery, then you could optimize a satellite platform for making that observation. And it could collect more data, possibly better data than what the human being could have made in the first place. But it takes a human being somewhere in the loop to realize that you can look outside of where your initial design was made by people on the ground who have never been in space.

Senator HUTCHISON. So important. That is so important because we do have people who say, oh, we can do all of this so much more efficiently with no people, and just machines. But that is one very good testimonial.

Dr. PETTIT. One thing to say about that. In space, there is no issue with machines, robots, and human beings working together. We work together hand and end effector in space, no issues.

Where I find the conflict really occurs is here on the Earth. So, in space, astronauts love robots because it allows us——

Senator HUTCHISON. And in that 4 square miles in Washington, D.C.

[Laughter.]

Dr. PETTIT. Yes.

Senator HUTCHISON. Thank you very much.

Mr. REITER. Senator, if I may add just a short comment also? From the European point of view, we have launched an announcement of opportunity exactly in this regime last year, asking in the Earth observation community if there is, indeed, some interest to use ISS as a platform for Earth observation.

And we received, indeed, a lot of replies, more than 80, if I remember correctly. And all very valuable replies, which were in support of using the ISS for Earth observation.

And in fact, we have on the Columbus module, we have a sensor installed, a sensor that receives the identification signals from ships. And that is the classic application where you design the sensor, optimize it, and then bring it in future on satellites in an optimized way.

And I think that is a good example how, indeed, the International Space Station, in addition to the examples that Bill and Don just gave, can be used in the area of observation.

Senator HUTCHISON. Thank you very much. Thank you, Mr. Chairman.

Senator NELSON. As you have to leave, Senator Hutchison, I am going to follow up asking about some things on cancer that you raised, and we will get that information to you.

Years ago, in the very beginning of the protein crystal growth, which CASIS, Mr. Royston, is now directing a number of those experiments. Originally, and when I participated in this experiment, it was actually proposed by the Comprehensive Cancer Center at the University of Alabama at Birmingham.

And that over the years has morphed into the protein crystallography center. And I would be curious from that very first experiment of which we had some dramatic results.

You take away the influence of gravity in growing protein crystals. They grew much larger and, at first blush, much more pure. The idea by the cancer center at UAB was, well, if you can then back on Earth determine the molecular structure of the protein, you could manipulate it to then do what you wanted with regard to cancer research.

Now this protein crystallography has been going on for years, and you are directing some of it right now, Mr. Royston. What has happened since January 1986 on this?

Mr. ROYSTON. And Senator, by no means am I an expert in this area. So I will—I will do my best to convey from the science team, and some of the people that flew with you and worked with you have still been involved. I think it is an area, if we had more biotech representation here, we would hear that it is still an ongoing methodology by which a lot of drugs are looked at.

Again, I think in the past, if we looked at the work there, it was somewhat sporadic. There were different types of equipment that were being looked at, being used. The Japanese have continued over the years to continue that research.

What our goal is, and we have just put a solicitation out, is to really look at the different methods, look at the different hardware that can be used. NASA has a project that is going on and we are partnering with to be able to, I don't want to say once and for all, but really look at this objectively, to be able to look at different ways to crystallize proteins and the methods by which we can look at them eventually on orbit, but also bring them back down in a way that we can get them into the right equipment areas or the right labs that can then look at them and use them for what they are for.

But I think we have heard it clearly, talking to large pharma, bio-tech companies. They are very interested in this. I think finally now that we have station, everything is built, where we have a solid platform up there, good transportation capability back and forth, I think we will see protein crystallization is one of the areas that will grow on orbit, no doubt.

Senator NELSON. Mr. Gerstenmaier, we worry about space debris and, from time to time, have to worry about lifting the orbit of the station in order to avoid space debris. Tell us about that.

Mr. GERSTENMAIER. We have some shielding on the outside of station that protects us from fairly small particles. Then there are the large objects that we can track, we can determine that they may come close to Space Station. We have a box that when we determine they will come inside that box, we actually can do a maneuver and maneuver Space Station to avoid a collision with those larger objects.

And then there is another class in between that we really can't track yet, and they are actually larger than our shields. And we are at risk from those objects. We have protected the station as best we could. It has the best protection system of any spacecraft we have flown on the outside.

We are continuing to improve that. We have made changes to both the Soyuz and the Progress vehicle. There will be a Russian EVA in August to actually add some more shielding to the Russian segment, which will help with debris protection.

We also put onboard recently software. It used to take us about 3 days to get ready to do a debris avoidance maneuver. That software now is resident onboard, and we should be able to do a maneuver much quicker. We are working with our Russian colleagues to actually get the details of how we could do that.

So, therefore, we could get identified from our tracking assets that there is an object that is going to come very close to station, and we should be able to maneuver in a very short period of time. So we are actively trying to improve the debris protection on station, both from a physical be able to move it standpoint and also improve the shielding onboard station.

Senator NELSON. And I can't help but point out that debris is getting to be a problem in space, and the Chinese really added to the debris. When they did their ASAT test, it added tens of thousands of particles at sufficiently high altitude that it is going to take a long time for gravity to pull those items back to Earth.

And of course, that is what we and the other space-faring nations have to worry about, and we try to track these, as Mr. Gerstenmaier said.

Mr. Royston, let me ask you what is CASIS doing to reduce the time it takes to identify and fund research opportunities and get those experiments up to the station?

Mr. ROYSTON. That is a great question, Senator. As you know, and I think everybody in this room knows, businesses and the marketplace moves at the speed of light today. So if we go to them and say that, well, 4 years from now we think we can get you on orbit, and we might be able to do some good stuff, it is not going to work.

So one thing, I definitely want to acknowledge the effort that has been on Bill's side, on the NASA side in the Payloads Office, to transition from their construction phase and now into their operational phase. And our organization works with the Payloads Office on a day-to-day basis on how we can streamline those—get more efficiency, streamline the processes and procedures by which to do that.

And then the other thing is CASIS; what we want to be able to go out into industry and talk about with potential customers is the fact that we handle all of that for you, that we can be the organization which allows you to think of the National Lab as just another lab. It is a lab like going from here in Washington down to Raleigh to do some experiments.

You don't have to worry about rockets and all kinds of different paperwork and science advisory panels and everything else. We are there to do that for you, and I think we are making real progress in that. And I think that is really our key, again, to attracting some of the big market that we want to bring into the National Lab, is to show them that it isn't painful to get up there.

It might be 300 miles away, and it might be vertical, but it is not a big deal. It is a great laboratory. There is great opportunity, and we will hold your hand and get you there painlessly.

Senator NELSON. Since we were talking about bone density loss, why don't you tell us about you are getting ready to fly a bone density scanner, and how does that play into the future osteoporosis research?

Mr. ROYSTON. Well, we are not quite ready to fly it yet. We are doing a study right now with reards to what are the best designs to be able to put a small bone scanner up there. So if we look at osteoporosis research, for instance, and we have an animal model that we are going to look at and be able to experiment with. One of our concerns, and I think we know it, as far as transportation—and we are coming online with other options—is down mass. How can we get things back to Earth?

And I think what the real focus in the short term needs to be is how we can do things on orbit and get the data that we need. That is a perfect example of why we need to have a small bone scanner up there. So we are watching the effects of the osteoporosis drugs on a day-to-day basis without being able to bring specimens back or being able to do that.

And I think that is really key not only as a bone scanner, but other equipment, whether it is the crystallography, Senator, as you mentioned, that we could do some determination or some review of the data or the crystals on orbit without waiting for the time it takes to get them back down to Earth.

Dr. PETTIT. And Senator, I would like to add that it is important to be able to collect more data points, particularly on human physiology, than preflight and post flight because there is a lot that happens in between, and we have no data. And we are working on improving that.

This bone scanner would allow us one more way to poke and pummel astronauts on orbit to extract more nuggets of information from their physiology. And we are also working on getting advanced eye diagnostics on orbit, too, again to try to crack this problem of what is happening? What is causing the wrinkles in the eyes? When do they form?

Do they form right away, or do they form toward the end of your mission? We don't know. And the only way we are going to find out the history of what happens when you get on orbit is to have these advanced diagnostic techniques that have been packaged from big laboratories and big centers on Earth somehow shrunk down, somehow that can work in the confines of this orbital frontier.

And then we can use these instruments to collect data from the astronauts on orbit, and one side benefit to this is every time we can an advanced piece of equipment, medical diagnostics that we can use on Space Station, there shows up numerous places on Earth where this same technology can be applied to remote places that will help diagnose and correct ailments for people that never leave the planet.

Senator NELSON. You know, we have come a long way. Mr. Gerstenmaier, remember when we flew John Glenn 50 years ago? We did not know what was going to happen to the human eyeball. And it has been rather extraordinary, our ability to experience space.

Final question for Dr. Pettit and Mr. Reiter. What do you think we can do to raise the awareness of this unique structure that is out there that the public does not have much awareness of?

Dr. PETTIT. One way is through education of our students because the students are the future of this country. And they have—they have the wherewithal to take us to the next phase, and we don't want them to forget about what it means to fly in space and do this exploration.

And when I talk to students, I like to ask, "How many of you would like to do my job?" And you would be amazed at how many want to do this. And I think you could say that there are more students that want to become an astronaut and fly in space than want to become President of the United States.

And I think that is a good thing because we need them, we need the students in science and engineering and technology, and they need to have a strong foundation of math in order to work in those fields. And what would break my heart would be to talk to students and say we no longer can fly in space. We don't do that anymore. And that, that would break my heart.

And we need to make sure that we can talk to the next generation and wind them up and point them in the right direction and let them carry the fire.

Senator NELSON. And I can pretty well tell you we will.

Mr. Reiter?

Mr. REITER. I can only support what Don has just mentioned. I think that these occasions where we directly tie in pupils from all over the world in experiments onboard the Space Station really show a remarkable effect. And Bill gave some experiments of the spider that is now on orbit, becoming the astrospider. And Don gave some experiments.

Andre Kuipers, who was in orbit together with Don, he had some dedicated school experiments where there was a direct link, a live link to the station, and that was then disseminated in the schools not only in the Netherlands, but I think across the world.

And there are beautiful examples. I just had beginning of the year the opportunity to attend an event which was dedicated to a U.S. experiment, SPHERES it is called, where you can bring developed software for little satellites that are flying with carbon dioxide cartridges, and you can let university students develop guidance, navigation, control algorithms, and that found a great interest all across the world.

So I think here also there is a fantastic opportunity to work together, and I think also in bringing these experiences into schoolbooks can steer the interest of our young generation in space, in exploration, and steer this what is I believe in our genes to be curious, to see what is beyond the horizon.

Thank you.

Senator NELSON. Thank you.

Senator Boozman?

Senator BOOZMAN. No questions.

Senator NELSON. Gentlemen, thank you. A most informative session.

Thank you, and the meeting is adjourned.

[Whereupon, at 11:40 a.m., the hearing was adjourned.]

APPENDIX

PREPARED STATEMENT OF HON. JOHN D. ROCKEFELLER IV,
U.S. SENATOR FROM WEST VIRGINIA

Assembly of the International Space Station was completed last year. It took five space agencies from around the world to build it. While this by itself is quite an achievement, our attention has shifted from the construction phase to maximizing the scientific return on this investment. At its core, the space station is a laboratory and a classroom—a scientific and educational asset available not only to NASA, but to all Americans and the international community for research, discovery, and education. We have already seen important discoveries and progress from research conducted on the space station—such as studies of treatments for debilitating diseases like osteoporosis, creation of new materials that the automotive and aerospace industries are interested in using, development of vaccines that may one day prevent deadly infections, and fundamental studies of the nature of our universe.

The availability of half of the U.S. portion of the station for national lab managed research opens up the microgravity environment to private companies to test and develop new products and services for use on Earth. A constant American presence on the space station also presents a unique opportunity to inspire our children's interest in science, technology, engineering, and mathematics—the so-called STEM fields. We know how critically important STEM skills are for jobs of the twenty-first century, whether it is in advanced manufacturing, pharmaceuticals development, new computing technologies, or designing the next generation of spacecraft.

Astronauts on the space station reach students around the world. Elementary school children can talk to and interact with astronauts via communication links through NASA, asking questions and watching the astronauts conduct experiments live 220 miles above the Earth. Just a few months ago here in Washington, D.C., I met with the student finalists from the YouTube Space Lab Challenge, an international contest for high school students to design an in-space science experiment. More than 2000 project ideas were submitted from students in more than 80 countries. Experiments from the two winning teams—one from Michigan and one from Egypt—lifted off for the space station just last Friday on board a Japanese robotic cargo spacecraft that is scheduled to berth with the space station this Friday. The students' experiments will be conducted by a NASA astronaut onboard the station. This is an unparalleled opportunity for these aspiring young scientists that I hope will encourage them and their peers to continue to pursue degrees and careers in science and engineering.

Our time with the International Space Station is limited and I want to see this nation look back on our investment as both a great achievement and a stepping stone toward our continued scientific leadership, both here on Earth and in space. I look forward to the testimony from our witnesses today and to their perspectives on how we make the most of this unique national asset.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. BILL NELSON TO
DONALD R. PETTIT

Maximizing ISS Utilization

Question. Now that construction of the space station is complete, the goal has shifted to getting the most out of the station's research capacity. What metrics would tell us we are doing a good job maximizing productivity of the station?

Answer. As Mr. Gerstenmaier reports in his answer to Senator Nelson's question, NASA tracks many metrics that show different dimensions of the productivity of the International Space Station (ISS). Monthly productivity metrics are collected on such metrics as numbers of investigations and investigators, science disciplines accommodated, facility occupancy, dedicated research crew time, numbers of countries involved, numbers of students reached, and numbers of scientific publications.

From my perspective as an ISS astronaut, I would offer the following for consideration on utilization metrics for the ISS, which could be the basis for future improvements in monitoring and defining ISS progress.

The International Space Station is a diverse laboratory in a harsh frontier environment where defining a single metric for success is difficult if not counterproductive. There are three distinct categories I believe are worthy of a metric to evaluate progress and each should be considered when it is appropriate to do so. One is for a mission covering a particular six person crew, another is for an annual review for the Space Station as a whole, and a third is for internal metrics developed as administrative/operational tools to aide in the allocation of crew time and resources.

For a particular mission covering a six month period where nine individuals rotate to maintain a six person crew, the metrics should be based on the following: crew health, vehicle health, and completing the required work. Crew health covers the safety and well being of the crew, including following prescribed countermeasures and maintaining professional positive attitudes towards crewmates and mission control. Vehicle health is a divided responsibility between mission control and crew. Repair and maintenance of systems and research apparatus is essential to sustaining an operating vehicle in a harsh environment where logistic for spare parts and limited crew time can complicate matters. Vigilance by both crew and mission control is required to extend the useable life for vehicle thus creating an efficient safe environment where the mission work can be completed. The crew is part of a large international team that includes their crewmates as well as the control centers scattered over many countries. Being able to work together as a team is essential to mission success. Completing the required work is self-explanatory and includes completing the research objectives defined.

An annual review for the Space Station as a whole includes research accomplishments as well as the overall state of the vehicle health. Accomplishments include both advances in scientific research as well as engineering research (engineering research includes prototype spacecraft systems operating in space using Space Station as a test platform). This evaluation should use the time-tested practice of external review for proposed projects and peer review when the final papers are published (this is currently being done for research on Space Station). This review process will ensure high quality ideas, projects, and final technical publications are maintained. The overall state of the vehicle should be reviewed on an annual basis to track factors affecting the long-term health and lifetime of the stack.

Universities and National Laboratories (such as Los Alamos National Laboratory where I worked for 12 years) rely on similar peer review to maintain high quality research and use peer reviewed publications, citation indexes (how often a paper is cited by others working in the field), and patents as a part of the evaluation metric.

It is essential to realize that it takes years to bring research to fruition whether at universities, national laboratories, or now, Space Station. Patience must be exercised when evaluating the research returns on a new endeavor (Space Station was just completed and placed in a full operational state last year).

Internal metrics developed as administrative/operational tools are useful to aide in the allocation of crew time and resources. Such metrics, when taken out of context, may seem ill-fit; however, these were never intended as a means to evaluate over all Space Station performance. For example, consider maintenance and repair of a complex vehicle in a harsh environment (this applies to sail boats as well as to Space Station). If left unchecked, maintenance and repair could expand to take all available crew time. To ensure that a significant fraction will be available for mission research, an internal metric has been set to reserve about 1/3 of mission related crew work hours for research. This metric, as an internal administrative tool, has caused critical review of all maintenance procedures, resulting in a workable compromise where both research and maintenance are completed. The practice of using such internal metrics needs to be understood and kept separate from the metrics for evaluating Space Station.

In closing, I believe there are three useful types of metrics for evaluating Space Station: (1) for the mission metrics of a particular 6 person crew, (2) as an annual review of Space Station research and vehicle health, and (3) internal metrics used as administrative tools for allocation of resources and crew time. All three of these have a different emphasis and are each in turn useful when applied to their particular situation.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. BILL NELSON TO WILLIAM H. GERSTENMAIER

Maximizing ISS Utilization

Question. Now that construction of the space station is complete, the goal has shifted to getting the most out of the station's research capacity. What metrics would tell us we are doing a good job maximizing productivity of the station?

Answer. NASA tracks many metrics that show different dimensions of the productivity of the International Space Station (ISS). Monthly productivity metrics are collected on such metrics as numbers of investigations and investigators, science disciplines accommodated, facility occupancy, dedicated research crewtime, numbers of countries involved, numbers of students reached, and numbers of scientific publications. For example, the number of scientists participating in ISS research has grown to over 400 on every Expedition and the number of countries involved in ISS research and education activities during an Expedition is typically over 30. The ISS is a growing resource for the science community, serving such diverse science disciplines as biotechnology and biology, human research, physical science, Earth and space science, technology demonstrations and education. Over 31 million students in the United States have participated in demonstrations performed by crewmembers aboard the ISS over its lifetime. The ISS is stimulating young people to ask questions and pursue knowledge. With a careful review and adjustment of crew commitments, the crew time for research has consistently grown, and now typically exceeds the minimum requirement of 35 hours per week.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. BILL NELSON TO THOMAS REITER

Maximizing ISS Utilization

Question. Now that construction of the space station is complete, the goal has shifted to getting the most out of the station's research capacity. What metrics would tell us we are doing a good job maximizing productivity of the Station?

Answer. Any metrics (with the objective to compare the ISS "R&D productivity" with other terrestrial research establishment) is problematic as "routine" R&D on the ISS faces peculiar constraints and only recently changed from the build-up phase of ISS to an "steady state utilisation operation". Furthermore, research is not the only rationale for the ISS. Nevertheless, *e.g.,* the following (not always quantifiable) parameters should be maximized:

- Number and impact of articles in peer-reviewed scientific magazines (remark: the challenge in interpreting this count comes of the fact that it can take 5–10 years for a scientific impact to be known, and because today there is no real bench mark for comparison of what we accomplish in a space-based laboratory with research that can't possibly be done elsewhere)
- Number of patents or spin-offs (remark: the challenge in interpreting these comes of the fact that not all commercial intellectual property is patented or licensed, that commercial entities sometimes conceal the space provenance of their knowledge for competitive advantage)
- Degree of compliance/mapping of ISS utilisation projects with research priorities (as independently defined by scientific community)
- The degree to which we have minimized "turnaround time", *i.e.,* the time from the moment a proposal is accepted until the PI holds the data/samples in his/her hands
- Relevance of ISS utilisation for preparing/demonstrating crucial technologies for exploration
- Share of crew time spent for utilisation vs. non-utilisation activities (possible comparison with similar remote research facilities such as Concordia in Antarctic, NEEMO, etc.)
- Number of student internships and thesis, education events, student participation in science activities, etc. that are related to ISS utilisation
- Number of countries that can use the ISS for R&D (ESA *e.g.,* offers utilisation opportunities to all EU countries; this is of particular importance for Europe, where not all European states are member of ESA)

It should be noted that the productivity of the ISS unfolds in many dimensions, which cannot be all exploited to their maximum at the same time due to limited resources. For example a simultaneous maximisation of both scientific/institutional and industrial/commercial utilisation is not possible. In reality a natural balance (driven by demand and merits) is considered being more realistic and providing different benefits within the various domains.

NASA and ESA are working closely with the other ISS partners to track all research accomplishments and benefits jointly, and to coordinate our assessments and metrics of productivity. We look forward to working with NASA on new "science of science" approaches to address some of the measurement challenges mentioned above.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO JAMES D. ROYSTON

Maximizing ISS Utilization

Question 1. Now that construction of the space station is complete, the goal has shifted to getting the most out of the station's research capacity. What metrics would tell us we are doing a good job maximizing productivity of the station?

Answer. CASIS is focused strictly on quality opportunities to utilize Station, which is why all potential projects are subject to the Valuation and Prioritization process. This process was designed to identify projects with the most scientific merit and commercial promise and best return to U.S. taxpayers on their investment.

CASIS currently has over 30 projects under review representing a myriad of research interests. The breadth of both proposed research and sponsoring institutions, both academic and commercial, serves as a good metric of increasing interest and forthcoming productivity. Additionally, plans to increase the ISS crew to seven would boost available crew time from 33 hours to 75 hours per week. This would greatly increase R & D productivity.

ISS Commercial Research

Question 2. Mr. Royston, what is the status of the transfer of existing National Laboratory agreements from NASA to CASIS?

Answer. All existing commercial agreements have been transferred to CASIS, with the exception of two. In accordance with the process established with NASA, agreements with other Federal agencies are next in line to be transferred to CASIS.

Question 3. Please explain the "extenuating circumstances" you mention in your written testimony preventing the transition of two projects.

Answer. One SAA is with Astrogenetix, a commercial space-based research company from Austin, Texas. The original research performed by Astrogenetix on ISS was in the area of virulence and vaccine target development as part of the initial NL Pathfinder research program. The transfer agreement has been under review by Astrogenetix since February 2012, and they have not yet decided if they want to continue this project.

The other remaining agreement is with Arizona State University's Bioscience Institute. The Institute's research in the area of virulence and vaccine development was part of the initial NL Pathfinder research program. CASIS has worked with ASU to address questions about the transition and a Memorandum of Understanding is currently being negotiated. They requested additional information about the CASIS Valuation and Project Approval process that was provided to ASU's legal department in July 2012. CASIS is confident the transition should take place soon.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. AMY KLOBUCHAR TO WILLIAM H. GERSTENMAIER

Question. Mr. Gerstenmaier, we were saddened to hear on Monday of the loss of the first American female astronaut, Sally Ride, to cancer. She will be remembered as a courageous pioneer who inspired girls everywhere to be excited about science. 25 years later in 2008, Minnesota native Dr. Karen Nyberg became the 50th woman to enter outer space and is scheduled to return to the ISS in May of next year. Despite such advances, entrance among girls and young women into fields such as physics and engineering continues to be disproportionately lower than men.

Twenty-nine years after Sally Ride's first trailblazing mission, what can NASA do to inspire more women to enter the STEM fields, which are so critical to America's continued prosperity?

Answer. We were equally saddened by the loss of Dr. Ride. She was an American hero, and a role model for generations of girls. NASA has a longstanding education partnership with Sally Ride Science, and they manage the EarthKam activity for the Agency, which allows middle school students to study the Earth using a camera installed on the International Space Station. We also agree with you that it is important to continue working to increase the number of women entering the STEM fields. NASA is taking advantage of its unique resources, including people, assets, and facilities to further inspire women and girls.

Recent data released this year by the Girl Scouts Research Institute shows that girls are already interested in math and science. However, they are also interested in numerous other fields of study, which compete with STEM fields when choosing majors in college and careers thereafter. A major finding of the study showed that female mentors in STEM fields and exposure to those fields is important when girls choose their future paths. As such, NASA is committed to providing mentors and numerous outreach opportunities to young women and girls. The following are only a small representation of the varied opportunities NASA offers across the nation, in hopes of inspiring the next generation of young women and girls to enter and remain in science, technology, engineering, and math careers.

The referenced Girl Scouts Research Institute Report can be found here: *http://www.girlscouts.org/research/publications/stem/generation_stem_what_girls_say.asp*

NASA facilitates volunteer opportunities for our STEM employees for the mentoring of young girls through the following programs:

- Aspire 2 Inspire (*http://women.nasa.gov/a2i*)
- NASA G.I.R.L.S. (*http://women.nasa.gov/nasa-g-i-r-l-s*)
- NASA WISH (*http://women.nasa.gov/wish*)
- NASA SISTER (*http://women.nasa.gov/outreach-programs*)

NASA is committed to allowing our employees to perform outreach activities as their schedules permit. Many of these outreach activities focus on underrepresented groups in STEM. For example, through NASA's Teaching From Space program, the program targeted female middle school students with the development of a "Women in STEM" video. In collaboration with NASA Public Affairs Office, Teaching From Space used the STS–131 mission and the role of crewmember Dottie Metcalf-Lindenburger, a former classroom teacher turned astronaut, to showcase NASA career opportunities for females (*http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Women_at_NASA.html*). NASA also maintains a Speaker's Bureau to provide speakers for public inquiries, often responding to requests to speak to women and girls.

NASA is committed to communicating the message that STEM is for everyone using role models young women and girls have in areas outside of STEM fields. One such example is collaboration with award-winning recording artist Mary J Blige to encourage young women to pursue exciting experiences and career choices through studying science, technology, engineering and mathematics. A public service announcement featuring Associate Administrator for Education and veteran NASA space shuttle astronaut Leland Melvin and Blige can be viewed here: *http://www.nasa.gov/offices/education/programs/national/summer/media/blige_melvin.html*

NASA is committed to creating opportunities for students in STEM programs at the Nation's universities. The Motivating Undergraduates in Science and Technology (MUST) project awards scholarships and internships to undergraduates pursuing degrees in STEM fields. In FY 2010, the MUST project hosted 100 students, of whom 55 percent were women and 27 percent of the scholars self reported being the first in their family to attend college.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK WARNER TO WILLIAM. H. GERSTENMAIER

Question 1. Mr. Gerstenmaier, with the retirement of the Space Shuttle, the United States is in need of finding a means to transport cargo and experiments to and from the International Space Station (ISS). In order to serve this need, the United States will surely be looking at possible launch sites to serve the ISS. It is my understanding that the flight trajectory from the NASA Wallops Flight Center to the ISS has some advantages, and could be viewed as more favorable and efficient than other sites located around the U.S. What do you see as the future of NASA Wallops in terms of its relationship with the ISS?

Answer. NASA currently has two companies under contract to provide resupply services to the ISS. One of the two companies, Orbital Sciences Corporation, selected Wallops Flight Facility (WFF) as its launch location for ten scheduled missions (two development flights and eight cargo flights). By virtue of Orbital's selection, WFF will be providing integration and testing services and launch operations support for 2–3 launches annually for the duration of Orbital's existing contract, and potentially longer.

Question 1a. What benefits does NASA Wallops have in serving the ISS?

Answer. Due to the inclined orbit of ISS, only two established U.S. launch sites are suitable to support resupply missions, the USAF's Eastern Range in Florida, and NASA's Wallops Flight Facility (WFF) in Virginia. The geometry of the ISS orbit results in a slight technical advantage for launches conducted from WFF, allowing additional mass to be lifted to the same orbit using a comparable rocket. In addition, as a NASA facility, WFF offers the opportunity to leverage already-funded NASA launch range and institutional capabilities, resulting in cost savings. The current arrangement of two contractors operating from different launch sites also provides NASA with increased flexibility and reliability, assuring that critical resupply needs are not interrupted due to launch range schedule conflicts, a launch vehicle fleet technical issue, or facility damage resulting from severe weather.

Question 2. Mr. Gerstenmaier, as we have previously discussed, there is a lot of promise in pharmaceutical research in the microgravity environment of low-Earth orbit in which the International Space Station operates. Can you provide a status update on your efforts for pharmaceutical research in micro-gravitational environments?

Answer. The best known of the recent pharmaceutical projects using the ISS—the vaccine development work of Astrogenetix—has completed flight experiments needed to identify mutant bacterial strains the company believes will enable the development of effective vaccines against Salmonella and methicillin-resistant Staphylococcus aureus infection. Astrogenetix is seeking venture funding to support clinical trials and further development.

Future ISS-based research in pharmaceutical development will be conducted through the organization selected in 2011 to manage non-NASA use of the ISS National Laboratory, the Center for the Advancement of Science in Space (CASIS). The initial CASIS Board of Directors includes a cross-section of leaders from several scientific disciplines and pharmaceuticals research. CASIS is currently developing lines of research identified by a panel of biomedical scientist from a survey of prior space research as holding significant promise for commercial participation, and the 7-member board recently named will select an additional 8 members with the intent of including prominent individuals from various industries.

Question 2a. Are pharmaceutical companies interested in partnering on this initiative?

Answer. CASIS, through the science team assembled to steer the development of its pharmaceutical research plans, has conducted surveys to identify corporate interest in new research thrusts. There is an interest and recognition on the part of industry of the value of pharmaceutical research in the microgravitational environment, and the level of corporate interest, and corporate willingness to invest in space research, is a major factor in selecting new research projects. It does take time, however, to translate that interest into investment.

Question 2b. What obstacles are you encountering in seeing that this research gets done?

Answer. Some research projects involve new operational challenges. The upcoming experiments with mice on the ISS, for example, will be the first experiments on the ISS with rodents, and the mice will be flying for the first time in a SpaceX Dragon capsule. Another obstacle is the increasingly cautious investment climate for commercial research and development, including pharmaceutical research. The pharmaceutical industry is scaling back its expenditures in basic research, and focusing on more mature concepts. They're looking for comprehensive evidence to justify investments. That is a challenge in an exploratory field like space biology.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. AMY KLOBUCHAR TO JAMES D. ROYSTON

Question. Mr. Royston, in your testimony you stated that CASIS is currently working with NASA regarding the handling of Intellectual Property and Data Rights. As you said, it is paramount to get this right in order to secure commitments from commercial users. For some of these potential users, the assurance that their IP is safe and protected could be the difference in deciding whether or not to conduct research and development on board Station. Ultimately, the IP issue could very well determine the success CASIS has in its overarching goal of maximizing

ISS utilization. What is CASIS doing to provide this assurance to companies, that if they choose to do research with ISS NL their IP is safe and secure?

Answer. CASIS is working with NASA to establish a legal regime that protects researcher data rights and intellectual property in compliance with applicable Federal law. Without such guarantees, commercial interests are unlikely to commit to any significant use of the ISS National Lab. Efforts are ongoing and expectations are that a solution will be found that will encourage commercial use of station.