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THE CASE FOR SPACE: EXAMINING THE VALUE

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED ELEVENTH CONGRESS

FIRST SESSION

OCTOBER 21, 2009

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

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FIRST SESSION

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THE CASE FOR SPACE: EXAMINING THE VALUE

WEDNESDAY, OCTOBER 21, 2009

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

The Subcommittee met, pursuant to notice, at 3 p.m. in room SR–253, Russell Senate Office Building, Hon. Bill Nelson, Chairman of the Subcommittee, presiding.

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

Senator NELSON. Good afternoon. This is a hearing of the Science and Space Subcommittee. I have been looking forward to this topic being discussed, getting it out there and on the record, and distributed so that people can understand some of the benefits of the spinoffs, and the extraordinary technology that has come as a result of the space program. Thank you for coming and participating today.

Tomorrow, the White House will receive the long-awaited "Augustine Report." A summary of the report was released last month. It stated that U.S. human spaceflight, once a program cherished as a source of the greatest level of national pride, I quote, "appears to be on an unstable trajectory," end of quote. The summary stated that, quote, "At present, our space program is being asked to pursue goals without the appropriately allocated resources," end of quote. We anticipate that the report that we will see tomorrow will say exactly the same thing. This, by the way, is what Senator Hutchison and I have been saying for a number of years.

The release of this report will provide the President with information to start to make a choice about the human spaceflight program. We can continue on the path that we're on, which is underfunding and underallocating our space program, or we can choose a different course of action. We can choose to act by ensuring that appropriate resources are allocated to meet the goals that we're trying to achieve.

Currently, the space program is funded at less than 1 percent of the total Federal budget. If you ask the average American what they think the program is funded at, they would think that it is a much higher figure than that. Less than 1 percent of the Federal budget. This is a testament to the value the average American places on our space program. They think it's funded at a much

higher level, and to the high levels of return that we gain on relatively small investments.

Our space program has always paid back extraordinary dividends, both tangible and intangible. The return is vastly greater than the initial investment. We're going to discuss some of those tangible and intangible benefits today.

A historical example of the intangible benefits of a well-funded space program—well, just look what happened to the generation that got inspired with the NASA of the 1960s and the 1970s. That generation has produced some rather terrific innovators. I'll just name a few: Sir Richard Branson, Jeff Bezos, Elon Musk. They got their motivation from seeing the extraordinary accomplishments of NASA. As they got inspired, they helped create new sectors of our economy: Bezos, founder of Amazon; Elon Musk, creator of PayPal; Branson, founder of the Virgin Group; and a whole spinoff of high-tech jobs for Americans. Each of those entrepreneurs is now returning to their first passion: space. Branson, Virgin Galactic, seeks to fly regular citizens into space. Bezos created Blue Origin. And Musk is aiming to have a commercial rocket.

An interesting turn of events, NASA, the original inspiration, may benefit from these new capabilities as we look to the commercial sector, which is part of the Augustine Commission Report. As those commercial capabilities mature, the result could be another stimulation of the economy and the creation of jobs. All of this stemming from NASA and the human spaceflight program, in particular, as the initial inspiration.

The International Space Station is another example. But, it is much more in a tangible sense instead of an intangible sense. While the initial investment in the ISS has been very high, this orbiting laboratory, named by Kay Bailey Hutchison as a National Laboratory, is just now starting to show a return on this investment. Just now. Its many economic, scientific, and social payoffs are soon to be realized. Breakthroughs in medicine, material science, Earth observation, renewable energy, and socially; as nations live together in a confined environment and continue to try to get along.

As NASA develops the architectures necessary to push these frontiers further out, beyond low-Earth orbit, the additional benefits will be realized. But realization of these benefits is not a given without Presidential leadership. In other words, President Obama's decision to fund NASA at the level commensurate with these lofty goals.

Last week, the President hosted schoolchildren on the South Lawn for a star party. The President took his children, and all of those young people had the opportunity to view, in vivid detail, the craters of the Moon, the rings of Saturn, the colors of Jupiter, and the belt of the Milky Way. The wonderment displayed in the eyes of those children, and oh, by the way, adults as well, proves once again that space inspires.

The Apollo program was prologue. Our future in space now is to be written. A suitably-funded space program is the best catalyzing element to gather and organize the energies and abilities of a Nation. That program is then going to return dividends, perhaps the most important of which is to inspire, encourage, and motivate the

next generation. A generation that will continue to produce scientists, engineers, mathematicians, and educators.

So, we want, in this hearing today, to look forward to exploring the benefits of a well-funded space program, and put on the record some of the things that many of us take for granted and some of us don't know about.

Senator Vitter?

STATEMENT OF HON. DAVID VITTER,
U.S. SENATOR FROM LOUISIANA

Senator VITTER. Thank you very much, Mr. Chairman. Thanks for calling this important hearing, and I certainly join you and Senator Hutchison in welcoming our very, very distinguished panel.

This is, you're right, exactly the sort of conversation we need, not just here in this Subcommittee, but over and over and over in all sorts of settings all across America, to remind ourselves of the tangible value and benefit the space program has brought us and can continue to bring us.

You know, virtually every public opinion poll on the subject shows great broadbased American public support for the NASA programs, but I think if you ask most of those people exactly why or what are some of the precise examples, they couldn't give that to you. And we really need to fill in those blanks and remind folks of some of those examples and some of that concrete evidence. And this discussion today will help do that.

In Dr. Fisk's statement, he put it a slightly different way, but I think it's somewhat the same idea. He said, "It may well be that we don't focus on that or know of those examples right off the top of our head because they're so pervasive, because the benefits of the space program and their utilization throughout our economy and society is so common and so broad, we just take a lot of this for granted." But, I think, it's important to highlight where many of these advances came from today and in future conversations.

So, we need to do that—again, not just in this conversation, but over and over—to remind ourselves of the tangible benefits, the connection, what has come out of it, and what continues to develop from space exploration. And obviously, we need to connect that in a very basic way to the ongoing discussion of the future of the program and the budget of the program. So, I look forward to being a part of the conversation.

Thank you, Mr. Chairman.

[The prepared statement of Senator Vitter follows:]

PREPARED STATEMENT OF HON. DAVID B. VITTER, U.S. SENATOR FROM LOUISIANA

I am delighted to be here at this important hearing, Mr. Chairman, and join you in welcoming our very distinguished panel. I believe this is an important discussion we are having today, and one that needs to be held over and over again with a great many people, not only in leadership positions, but around the country.

While I believe just about every national survey that asks about the value of space has seen very broad support for civil space—usually expressed as "NASA programs"—among the American public, I doubt whether very many of them—or many of us in the Congress—could provide a detailed answer to the question of why they feel it is important, or why they support its continuation. In Dr. Fisk's statement, I noted that he suggested it may well be that the reason for that is that the impacts and benefits of space exploration and utilization are so pervasive in our world today that we just take them for granted, and don't realize that they are really a result of prior investments in space activities and research.

I believe one of the reasons, Mr. Chairman, you wanted to hold this hearing—and I wholeheartedly agree—is to try to remind all of us that what we do in the civil space arena as a Nation, does, in fact, have a very important impact, not only in our daily lives, but on our very health, well-being, and security as a Nation.

We need to understand what is unique about space that enables it to play a critical role in technology development, scientific enhancement, and in fields like medical research. We need to hear the kinds of examples we will hear today to bring that message, if you will, "down to Earth" and make it easier for our colleagues and our constituents to see. We all need to be able to see that message clearly, as we face the enormous challenges facing our country, which sometimes lead us to forget the things that lead to longer-term stability and prosperity in our attempts to find answers to the immediate and pressing problems.

Gaining an understanding of how our civil space programs contribute to that underlying economic stability and even national security, is what I believe this hearing is about and I look forward to hearing from our witnesses. Thank you, Mr. Chairman.

Senator NELSON. I want to invite Senator Hutchison, who is the Ranking Member of the full Committee and who is as much a space advocate as I am, to make her statement. I've had the privilege of working with her on this Subcommittee for years.

Thank you for being here, Senator.

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

Senator HUTCHISON. Thank you very much, Mr. Chairman. And you have been the champion that has kept NASA and the importance of space exploration at the forefront of your priorities, and it is mine, as well. And I'm so glad that we have such committed people—and Dr. Vitter representing Louisiana, which has a huge NASA component, as well—Senator Vitter, sorry. Your brother's a doctor.

Senator VITTER. Look like I got a Ph.D. in the process——

[Laughter.]

Senator HUTCHISON. But, I really am so pleased that we're doing this because I have just a very special feeling and connection about the "National Laboratory" designation that we did put forward in our 2005 authorization, working then with my counterpart, Senator Nelson. And to me it was the most innovative thing that we have done in the process of authorizing NASA, to make sure that all of the investment that we are making in the Space Station, and have been making for all these years with the shuttles, would be fully utilized.

And when NIH became the first leader to step forward and say they wanted to be partners in the Space Station and have the ability to use the microgravity conditions—Senator Nelson and I were there, along with Senator Mikulski, at the great signing of the document between NASA and NIH.

So, I have to tell you that Jeff Bingham, who is my—well, he's not my Staff Director anymore, but he's yours—said his heart sang when he read your testimony, Dr. Katz—and mine, too—because now we are beginning to see the real results. And when you—I won't steal your thunder, but I do want you to take the time to point out the specifics. But, when you said that in the experiments already on the ISS that the salmonella bacterium becomes more infectious in microgravity and thus may become better inducers of immune responses, I just thought, that's an example of what we

can really do up there to accelerate research and see what can be done to start developing vaccines, of course, to treat diseases.

I also want to say, Dr. Becker, that in your testimony there was also reference to what can be done in the microgravity conditions, because if there is one priority I have, it is that we get our money's worth and see what can come from the Space Station, because we've already put the money in, and to walk away from it, without fully using it would be just foolish, and I don't want us to do that.

So, I will just say that I'm very excited about your testimony, all of you, but particularly the ISS part. And I want to just point out a few of the other examples that have made a difference in the quality of life on Earth because we went into space and made the investment in NASA itself: satellite-based communications, which have revolutionized communications globally; precise navigation capability on the ground and in the air—I mean I hardly get in a car anymore that doesn't have one of those global positioning mechanisms. I don't have one, I wish I could afford it, but maybe, with more research, we'll get it to be more affordable. But it's so exciting to see that because of the satellites, we can find anything on the ground, and, of course, also in the air. We have advanced diagnostic and medical treatment equipment and new drugs and medications have been made possible by the unique lab environment in microgravity. The need to reduce the weight of spacecraft led to microminiaturization processes that have been applied to manufacturing instruments and devices that have nothing to do with space but do impact our lives, such as electronic wrist watches, cell phones, video games—and believe me, I've got 8-year-olds who are addicted to Nintendo games; electronic teaching devices, and other examples of microtechnology.

And, the need to assure that Gemini and Apollo astronauts had safe food to eat during their missions led to the development of the most revolutionary institutional innovation to ensure food safety in our century. And since those projects were taken on for our astronauts, the FDA have now codified those processes in regulations, procedures that make all of our food safer.

So, the bottom line is, we have made a strong beginning. I am so pleased to hear those results start coming in, and the shuttles that are going to finish out the Space Station—really, I have to say that our committee had a hand in adding one more mission to the schedule of shuttles, to carry the alpha-magnetic spectrometer to the ISS because of the great testimony that we had from Dr. Sam Ting, the Nobel Laureate from MIT, in a hearing about being able to start looking into cosmic rays and dark energy and dark mirror, and the potential to use that for energy development. The shuttles did not have the alpha-magnetic spectrometer on the manifest of missions, and we were told that there would not be an increase in available missions. But, Dr. Ting was so compelling in one of our hearings that we have been able to add that flight, so that not only will we be able to use the Space Station, but to be able to start seeing if we can capture cosmic rays and see what they tell us about alternative energy sources for the future.

So, I'm very excited about your leadership, Mr. Chairman and Senator Vitter, and also all of you helping us utilize to the best of our ability the investments that we're making in space.

And I will just end by saying that we have a group of NASA employees from Johnson—if you'd raise your hands, we welcome you. You are doing——

[Applause.]

Senator HUTCHISON.—great work for us, and I know you're at a training program here this week, and it worked out that you changed your schedule to come and hear this very exciting testimony. And many of you in the audience are the reason that we have been able to make these great strides.

So, thank you, Mr. Chairman.

[The prepared statement of Senator Hutchison follows:]

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

Thank you, Mr. Chairman, for scheduling this important hearing to begin a comprehensive examination of the benefits and value of space exploration.

I say "begin," because a single hearing can merely scratch the surface of the benefits that our Nation and, indeed, the world have received during the past 50-plus years of the Space Age, not to mention, describing the potential value of future space exploration.

The numerous benefits attributed to our Nation's investment in space and research are all around us. Here are just a few examples: Satellite-based communications; precise navigation capability on the ground and in the air; advanced diagnostic and medical treatment equipment; new drugs and medications made possible by the unique laboratory environment in microgravity.

We tend to take these innovations for granted. We often forget that they are a direct or indirect result of space-based experimentation from advances in technology that were first required to meet the demands and challenges of space flight.

For example, the need to reduce the weight of spacecraft led to microminiaturization processes have since been applied to manufacturing instruments and devices that have nothing to do with space, but directly impact our lives. Whether through an electronic wrist-watch or a cell phone or a video game or an electronic teaching device, micro-technology has transformed our lives.

In addition, the need to ensure that Gemini and Apollo astronauts had safe food to eat during their missions led to the development of the "Hazard Analysis and Critical Control Point process," which has been hailed as "the most revolutionary institutional innovation to ensure food safety of the twentieth century." The essential principles of this process, which began in 1959, have since have been codified in FDA regulations and procedures, helping to make all our foods safer.

Mr. Chairman, I look forward to hearing more examples from our witnesses today, and hope that we will all be better able to recognize the great value of our efforts in space exploration and the dramatic improvements in our daily lives that come from meeting the challenges of space exploration and using the unique environment to which it gives us access.

In my view, this is an area where the question should not be, "Can we afford to do this?" The real question is, if we are concerned about national security, scientific leadership, and economic competitiveness of our country, "How can we afford *not* to do this?"

Thank you again, Mr. Chairman. I look forward to hearing from the witnesses.

Senator NELSON. Thank you, Senator.

We have a star-studded panel: Dr. Katz, Dr. Pace, Dr. Fisk, Dr. Becker, and CEO Greiner. What I'm going to ask you to do is to take about 5 minutes each so that we can really get into some serious study with our questions. Your written statements will be part of the record in full, so if you all would try to adjust accordingly. Your testimony, that I have seen, is riveting, and we want everyone to have the opportunity to hear it.

Dr. Katz is the Director of the National Institute of Arthritis and Musculoskeletal and Skin Diseases. It's a position that he's held since 1995, and he's also the senior investigator in the dermatology branch of the National Cancer Institute. During this illustrious ca-

reer, Dr. Katz has trained a large number of outstanding researchers in the U.S., Japan, Korea, and Europe. Now they're leading their own high-quality independent research programs. He's the recipient of the Distinguished Executive Presidential Rank Award, the highest honor that can be bestowed upon a civil servant.

So, welcome, Dr. Katz.

Then I'll just go right on down the line with each of you.

Dr. Katz?

STATEMENT OF STEPHEN I. KATZ, M.D., PH.D., DIRECTOR, NATIONAL INSTITUTE OF ARTHRITIS AND MUSCULOSKELETAL AND SKIN DISEASES, NATIONAL INSTITUTES OF HEALTH, U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Dr. KATZ. Thank you very much, Mr. Chairman and members of the Subcommittee. I'm really delighted to be here to expand upon some of the points that I made in my written testimony.

As NIH is the primary Federal agency for conducting and supporting medical research, we manage a portfolio that addresses not only public health needs—current public health needs—but also we invest heavily in basic biology that will lead to future answers to our public's health needs.

I want to expand, in response to Senator Vitter, on some of the tangible benefits that we've seen, just to publicize a few of them; two of them, most notably, that I have in my written testimony that I'd like to expand on. One is the heart pump that has been devised and was started using an enormously-sized pump from the Space Shuttle. And over the past two decades, that pump has been reduced to a 4-ounce object that can actually be implanted in people or utilized while people are waiting for heart transplants. And now there's a grant from the National Heart Lung and Blood Institute to try to utilize that pump as actually an artificial heart, to obviate the need for transplantation.

Another notable advance that is going—that we will see in the very near future comes from the NIH's National Eye Institute, where a fiber optic probe has been used to identify very small changes in protein. And this was initially used on the Station to identify early crystal formation. Now what could the medical use of that be? Cataracts, when they form, the earliest identification of cataracts are seen as little clumps of protein in the lens. Now, the earlier you can identify those clumps, the earlier you can tell a person to obviate some of the habits—the lifestyle habits that they're utilizing. For example, avoid sun exposure, et cetera. So, this fiber optic probe is going to be used as a—it's going to be a handy thing, and it's going to be utilized by many physicians, and others perhaps, to be able to identify the very earliest cases of cataract, to warn people against this. Two very tangible advances that we've seen.

Now, the NIH is proud to continue its partnership with NASA. The partnership was going on for quite some time, but, as Senator Hutchison mentioned, in September 2007, we entered into a collaboration that helps American scientists use the Space Station. And it was really the designation of the Laboratory—you referred to Jeff Bingham, I will refer to Jeff Bingham, as well, because it was Jeff who really brought some of us together under the—onto

the—with the idea that this was a National Laboratory and should be utilized by all of us, in government and outside of government and outside of the country, as a National Laboratory.

So, we were very pleased that you and Senator Nelson were there—was—were there—and, as well, Senator Mikulski joined us—when the two heads of the agencies, both NASA and the NIH, signed the agreement to a—to have a Memo of Understanding that we are going to leverage resources for a common good to improve health on Earth by utilizing the Station for this particular effort.

We are enthusiastic partners. The NIH are made up of many institutes, and we are enthusiastic partners, because the Space Station offers an unprecedented opportunity for research that could benefit human health on Earth. The Station, the National Laboratory, provides a virtually gravity-free environment that can unmask cellular and molecular mechanisms that underlie human diseases. And it also provides a wonderful environment to test certain types of healthcare delivery as well as health monitoring technologies that many of us at NIH are interested in pursuing, and I know that people at NASA are, on the other hand, very interested in pursuing, as well.

My institute, the National Institute of Arthritis and Musculoskeletal and Skin Diseases, is particularly interested in what space can teach us and what space has taught us about human diseases, particularly diseases of the bones and muscles. One of the classic examples of what happens to humans after they've been in space for some time is, they loose a tremendous amount of bone mass, as well as muscle. This has been a problem for astronauts, but it also provides us with the knowledge of why actually does this happen and why does it happen so rapidly. Why do we see a 1- to 2-percent decrease in bone mass per month—on average—per month in an individual who goes up in space?

Well, it has taught us a lot about the basic biology of the cells that make up bone. When I was in medical school, we always thought of bone as being an end-stage organ that was just eroded with time—as you age, you lost bone—but now we know that bone is actually a highly-active metabolic organ which is constantly being built up and being broken down. And we're learning a lot from what's going on in space, and we hope to learn a lot more from some of the studies that are going to be done.

NASA personnel have conducted all National Laboratory experiments thus far without the benefit of—and I think it was mentioned—without the benefit of having a fully operational Space Station. The initial findings, however, have demonstrated that the weightlessness of space provides a unique platform from which scientists can do more than simply answer questions about the effects of space travel on the human body. There's a lot of basic biology that is to be explored.

As part of its partnership with NASA, the NIH is asking the Nation's biomedical research community to develop innovative hypotheses that astronauts could test on the Station.

So, this is really what has come out of that Memo of Understanding. There are nine institutes at the NIH that have signed on, a broad array of institutes that shows a broad interest in health—in various aspects of health—all dimensions of health, basically—

in order to support studies that will be performed by scientists. They will be designed on Earth, they will be carried out by our astronauts in space, and that means that there has got to be a very close coordination between the scientist who wants to do the science but is really doing it with a surrogate scientist in space. And, as you know, many of the astronauts are outstanding scientists who have carried out these programs for some years.

So, we have made a commitment to having three rounds of competitions for NIH support for these types of studies. Results from the first competition should be announced in the Summer of 2010. As I said, nine institutes have signed onto it, and the diversity of their missions really underscores the idea that we are very anxious to utilize this National Laboratory.

In closing, let me say that the Space Station, the National Laboratory, provides a special microgravity environment that Earth-based laboratories cannot replicate. One can try to simulate, but not replicate, what goes on in the Space Station. Congress's designation of the Station as a National Laboratory speaks to the importance that the American people place on scientific discovery, and I think it was the designation of the National Laboratory that really brought this leveraging between NASA and the NIH and crystalized that cooperation.

So, for that I thank you. And after the others testify, I'm happy to answer any questions to all of you.

[The prepared statement of Dr. Katz follows:]

PREPARED STATEMENT OF STEPHEN I. KATZ, M.D., PH.D., DIRECTOR, NATIONAL INSTITUTE OF ARTHRITIS AND MUSCULOSKELETAL AND SKIN DISEASES, NATIONAL INSTITUTES OF HEALTH, U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Mr. Chairman and members of the Subcommittee:

I am Dr. Stephen Katz, Director of the National Institute of Arthritis and Musculoskeletal and Skin Diseases at the National Institutes of Health (NIH), an agency of the Department of Health and Human Services. I am proud to represent the NIH as its liaison to the National Aeronautics and Space Administration (NASA) and recently finished serving on the NASA Administrator's Advisory Council. I am pleased to testify about the opportunities that access to the laboratory of space provides to researchers who are committed to improving the health of people on Earth.

As the primary Federal agency for conducting and supporting medical research, the NIH manages a portfolio that addresses immediate public health needs while encouraging basic science research that may lead to improved health. Much of its budget supports basic research into the biological processes underlying health and disease. It fills a void in our Nation's research and development pipeline by encouraging basic, clinical, and epidemiological studies that the commercial sector would not pursue because they may not be immediately profitable.

NASA Technologies that Improve Health on Earth

Most of my testimony focuses on medical discoveries that our continued investment in space exploration may produce. But first, I am going to highlight two technologies that are well on their way to addressing serious public health threats to American lives.

About 5 million people in the United States have heart failure, which causes about 300,000 deaths each year. The NIH's National Heart, Lung, and Blood Institute is funding a grant,[1] to improve a treatment for heart failure patients that is based on NASA's Space Shuttle technology. The original device began as a main-engine pump for the Space Shuttle that was the size of the Shuttle's deck but, over two decades, engineers miniaturized it into a 4-ounce version that surgeons can implant into patients to keep them alive until they can receive heart transplants. Now, NIH grantees are testing whether they can further modify it into a total artificial

[1] "A Novel Approach to Cardiac Replacement with Continuous Flow Pumps," NIH grant number R01–HL085054.

heart that would eliminate the need for risky transplants of human organs, which entail lifetime regimens of immunosuppressant drugs that leave patients susceptible to infections.

Earlier this year, researchers from the NIH's National Eye Institute demonstrated that a compact fiber-optic probe originally developed for the space program also has a medical application. The non-invasive probe detects cataracts well before doctors can diagnose them with conventional techniques. Cataracts are the leading cause of vision loss worldwide, but people can reduce their risk by making simple lifestyle changes. The new, non-invasive eye test detects the earliest damage. By providing a warning before vision-impairing damage occurs, the test could encourage people to take protective measures—such as decreasing sun exposure, quitting smoking, stopping certain medications, and controlling diabetes—that might preserve their eyesight by slowing or halting cataract formation.

The International Space Station's Potential Contribution to Biomedical Research and Technological Development

You may have heard of these, and many other, examples from NASA. The NIH is proud to continue its partnership with NASA to make additional discoveries through research activities such as the ones described above. The NIH also looks forward to the conceptual and technological breakthroughs that are likely to emerge from the unique environment of the International Space Station (ISS) National Laboratory, and expects some of these advances will speed progress toward important medical interventions.

In September 2007, the NIH and NASA entered into a collaboration that helps American scientists use the ISS. Chairman Nelson, Senator Hutchison, and Senator Mikulski joined the heads of both agencies at a ceremony at the U.S. Capitol to celebrate the signing of a Memorandum of Understanding. The event, which marked a milestone in a long partnership to advance scientific discovery, signaled the availability of the ISS as a platform for biomedical experiments that extend beyond NASA's core interests.

The NIH is an enthusiastic partner because the ISS offers an unprecedented opportunity for research that could benefit human health on Earth. Compared with the Earth-bound laboratories where more than 325,000 NIH-funded scientists conduct experiments every day, the ISS National Laboratory provides a virtually gravity-free environment that can unmask cellular and molecular mechanisms that underlie human diseases. It also provides an extreme environment for testing health care delivery and health monitoring technologies.

As Director of the National Institute of Arthritis and Musculoskeletal and Skin Diseases, I am especially interested in what space can teach us about human diseases of the bones and muscles. Since the beginning of the space program, researchers have known that prolonged periods of weightlessness cause bones and muscles to deteriorate. The ISS provides a stable platform on which scientists can study the molecular basis of these effects for the eventual benefit of people who suffer from fragile bones or from muscle-wasting diseases. Because the deterioration experienced in space is similar to conditions associated with aging, such findings could affect everyone who is fortunate enough to live beyond middle age.

The near-absence of gravity also provides researchers with opportunities to better understand the human immune system. In 2001, when the ISS was barely a year old, NASA astronauts and NIH-funded researchers were addressing important questions about the mechanisms that are involved as the immune function becomes compromised. The National Laboratory also can provide insights into how bacteria and viruses cause disease. For instance, experiments on the ISS already have shown that agents like the *Salmonella* bacterium become more infectious in microgravity and thus may become better inducers of immune responses.

NASA personnel have conducted all National Laboratory experiments thus far without the benefit of a fully operational ISS. The initial findings, however, have demonstrated that the weightlessness of space provides a unique platform from which scientists can do more than simply answer questions about the effects of space travel on the human body. The data have taught us that true microgravity cannot be simulated on Earth, and it affects individual cells and multicellular organisms in ways Earth-based experiments can hardly predict. Moreover, they proved that the ISS has the potential to revolutionize how we view:

- basic biological or behavioral mechanisms associated with maintaining health or developing disease,
- normal or pathological physiology and metabolism, and
- cell repair processes and tissue regeneration that occur naturally or are enhanced through medical interventions following injury or aging.

NIH Activities to Encourage the Use of ISS Resources

Most ideas for NIH-funded studies come from investigators at universities and medical schools around the country. Therefore, as part of its partnership with NASA, the NIH is asking the Nation's biomedical research community to develop innovative hypotheses that astronauts could test on the ISS. The agency is encouraging a new cadre of health researchers from a variety of disciplines to incorporate the space environment into their experiments, and it will support them as they prepare their experiments for launch and analyze their data following a mission.

Grant applications will be subjected to NIH peer review consistent with Federal regulation.[2] However, the application process for grants to conduct research on the ISS will differ slightly from that for most other NIH grants. Because very few people outside of NASA have experience living and working in microgravity, applicants will need to work closely with NASA if they are to develop projects that are likely to give meaningful results. Astronauts have told us that life on the ISS is unlike anything most of us can imagine—flames burn differently, water flows differently, and chemical solutions mix differently. These distinctions, as well as the practical equipment, laboratory space, and personnel constraints facing every investigator who engages in collaborative research, will need to be considered as researchers who are looking to secure NIH dollars design their experiments. Ultimately, NASA personnel on the ISS will be using space-based laboratory equipment and data processing capabilities to conduct the experiments that the NIH funds—so the sooner biomedical researchers engage them in the process, the better their likelihood of success.

NIH is hosting three rounds of competitions. Results from the first should be announced in the summer of 2010. The NIH Institutes and Centers that agreed to participate in this initiative are the:

- National Cancer Institute
- National Center for Research Resources
- National Heart, Lung, and Blood Institute
- National Institute on Aging
- National Institute on Alcohol Abuse and Alcoholism
- National Institute of Arthritis and Musculoskeletal and Skin Diseases
- National Institute of Biomedical Imaging and Bioengineering
- *Eunice Kennedy Shriver* National Institute of Child Health and Human Development
- National Institute of Neurological Disorders and Stroke

The diversity of their missions underscores the promise that the National Laboratory holds for human health. Any NIH-funded project that uses ISS resources will be consistent with existing NIH priorities and will be relevant to improving human health. Prospective researchers will articulate the questions they are asking, design the experiments that astronauts will perform in space, and provide cogent explanations as to why the microgravity environment of the ISS is essential for their studies.

In closing, the ISS provides a special microgravity environment that Earth-based laboratories cannot replicate. Congress's designation of the ISS as a National Laboratory speaks to the importance that the American people place on scientific discovery. Thank you for the opportunity to present this snapshot of how NIH activities with NASA should contribute to biomedical research and technological development. I will be happy to answer any questions that you may have regarding the potential of research in space to improve our public's health.

Senator NELSON. Thank you, Dr. Katz.

Dr. Scott Pace is the Director of the Space Policy Institute, and he's a Professor of the Practice of International Affairs at the George Washington University. His experience includes service in the Department of Commerce, the National Space Council, the RAND Corporation, the White House, and, most recently, within NASA.

Welcome, Dr. Pace.

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[2] 42 CFR Part 52h.

STATEMENT OF DR. SCOTT PACE, DIRECTOR, SPACE POLICY INSTITUTE, ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS, THE GEORGE WASHINGTON UNIVERSITY

Dr. PACE. Thank you, Mr. Chairman. It's an honor to be here. And thank you for the opportunity to discuss this important topic.

As has been remarked in the opening, there's really no question about the importance on unmanned space activity, whether GPS or communication satellites and so forth. But, I would suggest that the future of human space exploration is in the balance, and therefore it'll be the focus of my remarks.

Last week I attended an annual conference of the International Astronautical Federation in Daejeon, South Korea. The President of South Korea actually came and spoke at the opening ceremony and said that, quote, "Space technology is the growth engine that will open the future of mankind. It has become a necessary tool for our own survival." And it was very striking to see the excitement of space activity there in Korea. International representatives from Europe and Asia presented their own plans for exploration of the Moon and missions to Mars.

There is an impressive spirit of international cooperation, not only among our Space Station partners, but also with other space powers, such as India and China. And China, in particular, was particularly open with its plans for activities in exploration beyond low-Earth orbit.

Now, this spirit has been in development for the last several years based upon a U.S. diplomatic strategy that resulted in 14 space agencies approving a global exploration strategy so that people would be moving out together in coordination, something pretty unique in space history.

And, unfortunately, I have to say that the internal U.S. debate, this past summer, combined with the realities of the Fiscal Year 2010 NASA budget, have created an air of uncertainty over U.S. intentions. And to borrow a phrase from Mr. Augustine, "You know, it's hard to get others to work with you on your garden if you're pulling up flowers to check the roots." This is a time when other countries are looking to us and asking what are we going to be doing.

And I think it's important that, in looking to the future, that we have to be actively planning for what comes after the ISS. I completely agree with Dr. Katz's comments on the importance of ISS as a National Lab. The continuation of Station operations, I think, is absolutely critical to get the value out of the investment this Nation has made. But, if we're not planning for what comes after the ISS, the government is, in effect, getting out of the human spaceflight business. Because if we're not going beyond low-Earth orbit, I would suggest that we are ignoring both the recommendations of the Columbia Accident Investigation Board and also running against the reality of globalized space activity, the number of other countries that are looking to work with us.

In moving forward in all areas of space activity, we will be needing to build friends and allies around us in what Secretary Clinton has called a "multipartner world." We need friends and allies to secure the global commons of space upon which we all depend for our national security, our economic, and our diplomatic interests, to

make sure the space environment remains free of interference. I have to say, nothing focuses the mind in the space debris community than the idea that there may be risks to astronauts aboard the Space Station. Unmanned satellites are one thing, humans are another. And that has focused attention on the need to keep that environment as pristine as we can to secure our own interests.

We need to inspire a new generation of Americans to take on many of the demands of a globally competitive environment driven by scientific and technical innovation. And therefore, I think the conference in Korea kind of underlined that energy.

The interdisciplinary demands of spaceflight, whether in biomedicine or engineering and physics, and in human spaceflight in particular, I think can be a highly effective school as we're driven to do things that are unusual and different that we're not going to do here at home, but that, by doing them in space, we will learn new skills that will help us be competitive.

And finally, I have to say that it's important to understand that it's not just our machines that we send to travel into space, but the values we carry with us, that the international norms for human space activity will be shaped by those who are there in space; they will not be shaped by those who stay behind. If we want to be—see a part of the human future in space that reflects our values—this country's values, the values of our allies—then we have to be a part of that effort. And ambitious goals and rhetoric require difficult actions and serious resources or the symbolism in actuality of human spaceflight will ring hollow. The United States is facing a generational transition away from the period represented by the Space Shuttle, and this transition is upon us now, both at home and abroad, as we see that others are not delaying their entries into space. And we have to ask what this Nation will do.

Thank you very much for your attention, and I'd be happy to answer any questions at your convenience.

[The prepared statement of Dr. Pace follows:]

PREPARED STATEMENT OF DR. SCOTT PACE, DIRECTOR, SPACE POLICY INSTITUTE, ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS, THE GEORGE WASHINGTON UNIVERSITY

Thank you, Mr. Chairman, for providing an opportunity to discuss this important topic. Understanding the value proposition of space, from low-Earth orbit to geosynchronous orbit, to the Moon and beyond, is of fundamental importance to many national interests. Our national security and public safety, global economic competitiveness and scientific capabilities, are all reliant on access to space and space-based capabilities. There is no question as to the important of unmanned space activity, but the future of U.S. human space exploration is in the balance and will be the focus of my remarks today.

Globalization and Space

Last week I attended the annual meeting of the International Astronautical Federation in Daejeon, South Korea. There was a statute of South Korea's first astronaut, Yi So-Yeon, on the main boulevard. The President of South Korea, Lee Myung-bak, spoke at the opening ceremony and said, "Space technology is already being applied in various areas of our daily lives. Space technology is the growth engine that will open the future of the mankind, and it has become a necessary tool for our own survival." Representatives from Europe, Japan, Russia, China, India, and Korea presented their increasingly specific plans for explorations of the Moon and missions to Mars.

NASA also presented current U.S. plans for replacing the Space Shuttle, and the images of the hardware being built and tested were quite impressive. Just as impressive was the expressed spirit of international cooperation and coordination, not

only among International Space Station partners, but rapidly rising space powers such as India, China, and Korea. This spirit has been in development for 3 years, based on an inclusive U.S. diplomatic strategy that resulted in 14 space agencies agreeing to a common Global Exploration Strategy.

Let me quote from that strategy:

> *Space exploration follows a logical set of steps, starting with basic knowledge and culminating, it is hoped, in a sustained human presence in space. This journey requires a variety of both robotic and human missions. The Global Exploration Strategy provides a framework to coordinate the efforts and contributions of all nations so that all may participate in the expansion into space and benefit from it.*

Unfortunately, the internal U.S. debate this past summer, combined with the realities of the Fiscal Year 2010 NASA budget have created an air of uncertainty over U.S. intentions. To borrow from Norm Augustine, it's hard to get others to work on a garden if we're pulling up flowers to check the roots. It's hard for many of our international friends to secure support for human spaceflight from their governments if we appear to have doubts about the value of the effort.

The United States is a founding member of the space club, but we're at risk of shifting to emeritus status while others with more energy step up. The Chinese in particular have laid out a careful, logical approach in which they plan to launch a mission in 2011 to test docking and rendezvous techniques, followed by a man-tended laboratory in 2015, and a three-man space station by 2020. The selection of 45 new taikonauts is underway along with plans for a lunar sample return missions and Mars orbiter by 2013. To be clear, I welcome peaceful Chinese space exploration efforts. However, I don't want them and other nations to be on the frontier of space without us. We may not be in a race, but we need to keep up.

The Apollo program was intentionally a unilateral U.S. effort. The whole point was to beat the Soviet Union to the Moon. The Space Shuttle included international contributions such as the Canadian robot arm and a European Spacelab. The space station began as a U.S.-centered international effort but evolved into the fully integrated partnership that is the International Space Station (ISS) today. After the loss of the Columbia, sustaining the ISS would not have been possible without the international partners.

Questions for Space

Today, we have the Global Exploration Strategy as an international common approach to human and robotic exploration of the Moon, Mars, and beyond. As I noted at the beginning, there is no question about the practical, scientific, and even diplomatic value of space exploration and this is recognized by other spacefaring nations as well. What about humans in space? That is the key question for our Nation's civil space policy.

What are the questions that will drive and sustain a human space exploration effort, if nation are not beating each other in cold war-like competitions for prestige?

Challenger forced the question of whether we should risk humans flying payloads that could be launched in other ways. The answer was no and we moved satellites to expendable launch vehicles operated by private companies.

Columbia forced the question of why are we risking humans at all. The *Columbia* Accident Investigation Board (CAIB) said that travel beyond Low-Earth Orbit was necessary if we were to justify the risks involved. The current U.S. Space Exploration Policy, past NASA authorizations by Congress, and Global Exploration Strategy are consistent with the views of the CAIB.

If we are not planning for what comes after the ISS, the government is, in effect, getting out of the human spaceflight business. There may be space tourists launched by U.S. companies—I certainly hope so—but tourism cannot sustain a major international cooperative human space exploration effort. If we are not going beyond low-Earth orbit, we are ignoring both the recommendations of the CAIB and the reality of the increasing globalization of space activity.

We should take a page from our science colleagues in asking simple, but profound questions to shape an implementation strategy. In science, questions such as "Does life exist elsewhere in the solar system?" or "What is dark energy?" help shape and sustain scientific strategies and programs over long periods.

What is the question for human spaceflight? I believe it's asking whether there is a human future beyond the Earth.

Dr. Harry Shipman posed two questions in his 1989 book *Humans in Space* whose answers lead to very different human destinies. The first is, "Can extraterrestrial materials be used to support life in locations other than Earth?" And the second is,

"Can activities of sustained economic worth be carried out at those locations?" Or as I shorten it: "Can we live off the land?" and "Can we make it pay?"

If the answer to both questions is yes, we will see space settlements and the incorporation of the Solar System into our economic sphere as former Science Advisor Jack Marburger has suggested. If the answer is no, then space is a form of Mount Everest—good for personal challenge and tourism but nobody really lives there. Other answers might see Antarctica-like outposts or perhaps a North Sea oil platform exploiting space resources but without sustainable human communities in space.

Many people seem to have faith-based answers to these questions but I would suggest a greater humility in admitting that we don't really know. And therefore our efforts should be to answer these questions as in the course of human and robotic exploration beyond the Earth. The quest to do so will teach us much of practical benefit as we seek to do things that are hard. The experiences we gain in exploration will give us new insights into what humans can do and who we are.

Value from Space

The practical benefits of sending humans beyond the Earth are the "acceptable reasons" of supporting national interests in science, technology development, and international relations. For many countries, these reasons are not just "nice to do" but serious reasons of state. For India, ambitious space efforts attract new human capital to the strategic aerospace sector, which must compete with a growing information technology industry. For China, human spaceflight experiences are training a new generation of technical specialists in many fields and raising the quality level of industrial suppliers. For Japan and Europe, space flight demands interdisciplinary skills that can increase competitiveness in aerospace and non-aerospace sectors. The sophisticated systems engineering demanded by human space flight are part and parcel of what a great nation does, and more importantly, what it is capable of doing.

Human spaceflight is the most demanding space activity, technically, financially, and organizationally. From the beginning it has also been the most symbolic activity, both at home and abroad. In the past, it responded to the question of who we were as Americans in the cold war. Today, it is a powerful symbol of cooperation among former adversaries on the International Space Station. The deep international relationships built through the ISS are among its most impressive and perhaps most enduring achievements to date.

The question of whether there is a human future beyond the Earth will not be answered in a decade or five decades. It is a question that will evolve, challenge, confound, and test us for a long time as we try to answer it.

For the future, we need to continue efforts to bind friends and allies to us in a *multi-partner world* in which space capabilities are globalized.

We need friends and allies to help secure the *global commons of space* upon which we depend, to ensure that the space environment remains free of interference and open to peaceful uses by all.

We need to inspire a new generation of Americans to take of the many demands of a *globally competitive environment driven by scientific and technical innovation*. The interdisciplinary demands of space flight and human space flight in particular can be a highly effective school for meeting those challenges.

It is not just our machines or even our DNA that travel into space but our values as well. What values to we want to see be the norm in human activities beyond low-Earth orbit? The international norms for human space activity will be shaped by those who are there, not by those who stay behind. If we want to see a human future in space that reflects our values then we must be part of that effort.

What will the United States do?

Ambitious goals and rhetoric require difficult actions and serious resources or the symbolism and actuality of human spaceflight will be hollow. The President is critical to effectively setting space policy priorities in budget requests to the Congress. All Presidents have put their stamp on the Nation's space efforts, from Kennedy and Nixon to Clinton and Bush. Their actions have typically reflected the broader international approach the United States seeks to play in the world.

The United States is facing a generational transition away from the period represented by the Space Shuttle that is just as profound as the transition from Apollo was. We are facing a transition not just of hardware and contracts, but also of leadership and values. The transition is upon us at home and abroad, just as we see that others are not delaying their entries into space. What will this Nation do?

Thank you for your attention. I would be happy to answer any questions you might have.

Senator NELSON. Thank you, Dr. Pace.

Dr. Lennard Fisk is the Thomas Donahue Distinguished University Professor of Space Science at the University of Michigan, where from 1993 to 2003 he was Chair of the Department of Atmospheric, Oceanic, and Space Sciences. From 2003 to 2008, he was the chair of the National Academy of Sciences Space Studies Board. Before he came to the University, he was the distinguished Associate Administrator for Space Science and Applications at NASA. Professor Fisk is the author of more than 160 publications on energetic particles in plasma phenomena in space.

Welcome, Dr. Fisk.

STATEMENT OF LENNARD A. FISK, PH.D.,
THOMAS M. DONAHUE DISTINGUISHED UNIVERSITY PROFESSOR OF SPACE SCIENCE, UNIVERSITY OF MICHIGAN

Dr. FISK. Thank you very much, Mr. Chairman and members of the Subcommittee. I also appreciate very much being able to testify on this topic of the case for space.

I'd like to base my remarks, in large measure on this National Academy's report that we just issued, "America's Future in Space: Aligning the Civil Space Program with our National Needs." And in that report, we addressed the issue of civil space taken in its entirety; and so, let me begin by defining "civil space," as I want to use it in my remarks.

Civil space is all aspects of space that are not pursued for military purposes. And so, it's going to be NASA and it's going to be NOAA, it's going to be commercial space, and it's even going to be the civil use of military assets, such as Senator Hutchison noted, of the GPS signals, of which we are all quite dependent.

If you take civil space in this broad context, civil space occupies a central position in the American way of life and our national goals. And you can make a long list here. It assists our everyday lives; GPS being an example—weather forecasts, communication satellites, direct broadcasting—all those items that—on which we are quite dependent. You can argue convincingly, I think, that it helped create the globalized world in which we live. We have an economy these days which is global. We do business worldwide. In part, that has resulted because we have knowledge of other societies and comfort in investing in them in a way we would not have if we did not have the information that comes through communications satellites and remote-sensing satellites and all the infrastructure of space.

It—civil space program satisfies our innate curiosity about the majesty of the universe. It will help determine the future of the Earth. It can drive the development of technology on which our economic future depends. It inspires us to believe that tomorrow can be better than today. It's an essential component of our national image, and it helps us—makes it possible for us to be strategic leaders in a world full of challenges.

Well, given that centrality of civil space, it sort of makes you wonder why it is we have to defend its value. And, as Senator Vitter noted, I suspect part of that is this lack of appreciation results because space is now endemic in our society. It's pervasive in our

daily lives and our national identity; and so, we no longer, perhaps, appreciate or fully recognize its value, as a result.

It's also true that we're not particularly well organized as a Federal Government to fully realize the benefits that civil space offers our society. So, one of the key recommendations of the America's Future in Space report is that the President of the United States should task senior Executive Branch officials to align the agencies and the departments involved in civil space—align their strategies, identify the gaps in the program, and identify the shortfalls in policy coverage, policy implementation, and, in particular, in resource allocation.

The America's Future in Space report also recommended that we should—whether it's through policy implication and resource allocation, we should actually formulate, and we should execute, a civil space program in the United States that is closely aligned with, and clearly serves, our national needs.

We need a civil space program that allows us to protect the Earth and its inhabitants through the use of space research and technology. The global perspective of space, which is enabled by space observations, will be essential to monitor climate change.

We need a civil space program that allows us to pursue scientific inquiry, advancement of knowledge, which is, frankly, fundamental to a Nation's health. A Nation that asks questions about the universe and wants to learn is a richer Nation.

We need a civil space program that develops advanced technologies. We need a civil space program that actively pursues human spaceflight, extending the human experience into new frontiers, challenging technology, bringing global prestige, and exciting the public's imagination.

And the standard that we should hold our human spaceflight program to is not just, "What is everybody else doing?" but it should be held to the same standard that we expect for the rest of our civil space program; it should be transformative in its cultural impacts, in its scientific impacts, in its technology outcomes. That's the standard that we should hold our human spaceflight program to.

We need a civil space program that inspires current and future generations. We need a civil space program that allows us to pursue international cooperation in space proactively as a means to enhance U.S. strategic leadership and meet national and international goals.

Now, there are impediments in this which are called out in this report, and we have to recognize them. One of them, cited a moment ago, was the lack of cohesive and coordinated national space strategy. We also need a competent technical workforce and a properly sized and structured infrastructure.

And so, if I were summarizing what my remarks and what this report said, it's basically that the civil space program of the United States has a central role in our society today and our goals as a nation. The role, however, is not often recognized or appreciated, and, as a result, our civil space program is not adequately coordinated, nor are its priorities properly aligned with pressing national needs with adequate resources provided, nor are its deficiencies recognized and removed. And, of course, the goal is to reverse that

situation, to construct a civil space program that is truly aligned with, and capable of serving, the national needs; and when we do so, America does have a future in space; but, even more important, space can help ensure America's future.

Thank you.

[The prepared statement of Dr. Fisk follows:]

PREPARED STATEMENT OF LENNARD A. FISK, PH.D., THOMAS M. DONAHUE DISTINGUISHED UNIVERSITY PROFESSOR OF SPACE SCIENCE, UNIVERSITY OF MICHIGAN

Mr. Chairman and members of the Subcommittee, I appreciate very much the opportunity to testify on the important topic of the Case for Space: Examining the Value. My name is Lennard Fisk, and I am the Thomas M. Donahue Distinguished University Professor of Space Science at the University of Michigan. I also served from 1987 to 1993 as the NASA Associate Administrator for Space Science and Applications, and from 2003 to 2008 as the Chair of the National Research Council Space Studies Board.

My remarks today will be based in large measure on the recent National Academies Report: *America's Future in Space: Aligning the Civil Space Program with National Needs*,[1] which was Chaired by Gen. Les Lyles (Ret.), and for which I served as one of the Vice Chairs. My remarks, of course, are entirely my own.

I would like to talk today about civil space in its entirety, and so let me begin by defining civil space. For my purposes, civil space is all aspects of space that are not pursued for military purposes. It is the space activities of NASA and NOAA. It is all of commercial space: communication satellites, remote sensing satellites, and the many entrepreneurial activities that are now blossoming. It is also the civil use of military assets such as the commercial use of the signals from Global Positioning Satellites (GPS).

Taken in this broad context, the civil space program of the United States touches the lives of every American, each and every day. We are dependent upon GPS signals for transportation; we coordinate our telecommunication networks, Internet infrastructure and electric grid and financial systems through the timing signals available from GPS. Our weather forecasts are based upon satellite observations. We have information on what is happening everywhere in the world at all times, in large measure due to satellite communications and observations.

Indeed, we can argue that the globalized world in which we live, where manufacturing is worldwide and economies are thoroughly intertwined, was able to develop because of space. The knowledge that we have about other societies and our ability to communicate instantaneously, transmitted through satellites, have given us a level of comfort to invest throughout the world. And because of this we live in a safer world, where now many nations have a vested interest in each other's success.

We also live in a world of challenges, one of the main ones being global climate change. Whether or not you agree on the causes of climate change, nonetheless we must all accept that the climate of Earth is changing, and the outstanding question is what are the regional consequences to which we must prepare to adapt. The Department of Defense has stated that global climate change is a strategic threat to the United States, in recognition that climate change in the developing world can be de-stabilizing, and lead to increased threats from, for example, terrorism.

The knowledge of global climate change and its regional consequences will come uniquely from the civil space program. Comprehensive observations from the global perspective of space will be required. We may enter into treaties limiting fossil fuel emissions and other contributions to the greenhouse gases in the atmosphere. Only the global perspective of satellite observations will allow us to monitor compliance by the treaty signatories. "Trust but verify" will work equally well in climate treaties as it did for treaties limiting nuclear weapons.

We also live in a world of opportunities. We have the capabilities these days to use our civil space program to ask and to answer very fundamental questions about the universe in which we live: what is the origin, the evolution, and the destiny of our Sun, our solar system, and the universe beyond. Is there life elsewhere in the universe? Do we not also, as a rich and powerful nation, have the obligation to seek and to provide these answers on behalf of all humankind?

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[1] *America's Future in Space: Aligning the Civil Space Program with National Needs,* report of the National Research Council Committee on the Rationale and Goals of the U.S. Civil Space Program, published October 2009.

Our economy is reeling and the clear way forward to long-term economic growth and job creation is investments in innovative technologies. The civil space program can require the development of technologies that benefit the economic growth of the Nation and it can unleash and encourage the entrepreneurial spirit on which the American economy is founded.

Our human space flight program has been able to inspire us to consider the endless opportunities of space. It also plays an important geopolitical role. Space has been and will always be the playground on which developed nations demonstrate their technological prowess. Our position in the world is in part determined by what we are able to accomplish in space.

Indeed, our entire civil space program permits us to define the image we wish to project as a nation. There are a growing number of nations with capabilities in space, and so dominance by the United States is no longer likely, nor for that matter desirable. Rather, we can use our civil space program to exert strategic leadership, in which we lead by example and in cooperation, and are valued in the world for what we are able to accomplish on behalf of all humankind.

Our civil space program can also make us more secure. We have military assets in space, which are judged to be vulnerable. It is reasonable to assume that they will be safer if space becomes a routine place for science and for commerce, just as rules-of-the-road make our oceans a lawful, not a lawless domain.

Our civil space program thus occupies a central position in the American way of life and our national goals. It assists our everyday lives; it helped create our globalized world; it satisfies our innate curiosity about the majesty of the universe; it will help determine the future of Earth; it can help drive the development of technology on which our economic future depends; it inspires us to believe that our tomorrows will be better; it is an essential component of our national image, and helps make it possible for us to be a strategic leader in a world full of challenges.

Given the centrality of the civil space program to our way of life and national goals it is somewhat troubling that we need to defend its value. I suspect this lack of appreciation results in part because space is now endemic in our society. It is so pervasive in our daily lives and national identity that we no longer fully recognize or appreciate its presence.

It is also true that we are not organized as a Federal Government to fully realize the benefits that our civil space program offers the Nation. "National space policy is too often implemented in a stovepipe fashion that obscures the connection between space activities and other pressing needs of the Nation. Consequently, the senior policymakers with broad portfolios have not been able to take the time to consider the space program in the broad national context. Rather, policies have been translated into programs by setting budget levels and then expecting agencies to manage to those budgets." [2]

Thus, one of the key recommendations of the *America's Future in Space* report is that "the President of the United States should task senior Executive Branch officials to align agency and department strategies: identify gaps or shortfalls in policy coverage, policy implementation, and resource allocation; and identify new opportunities for space-based endeavors that will help to address the goals of both the U.S. civil and national security space programs." [2]

The *America's Future in Space* report further recommends that we should, through policy implementation and resource allocation, formulate and execute a civil space program in the United States that is closely aligned with and clearly serves our national needs. The service to national needs is the basis on which our national investment in civil space has and ought to be made. We have entrusted the future of our Nation and our sense of wellbeing as a people to the performance of our civil space program, and we need to insure that our investments in civil space are adequate and the emphases that we place best serve our national needs.

We need a civil space program that allows us to protect the Earth and its inhabitants through the use of space research and technology; that employs the global perspective enabled by space observations to monitor climate change and test climate models, to help manage Earth resources, and mitigate risks associated with natural phenomena such as severe weather and asteroids. "NASA and NOAA should lead in the formation of an international satellite-observing architecture of monitoring global climate change and its consequences and support the research needed to interpret and understand the data in time for meaningful policy decisions." [2]

We need a civil space program that allows us to pursue scientific inquiry and advancement of knowledge, which are fundamental to a nation's health: "the results inform and excite the public, stimulate technology development, create an interest

[2] Quoted from the NRC report: America's Future in Space: Aligning the Civil Space Program with National Needs.

in learning, and generally improve the capability of the Nation to compete and to lead. A nation that asks question about the universe and wants to learn is a richer nation."[2]

We need a civil space program that develops advanced technology, "engaging the best scientific and engineering talent in the country wherever it resides in universities, industry, NASA centers, or in other government laboratories."[2] The research conducted should address the needs of the Nation's entire space portfolio, both government and industry, and by doing so encourage the economic development of the Nation.

We need a civil space program that actively pursues human spaceflight, "extending the human experience into new frontiers, challenging technology, bringing global prestige, and exciting the public's imagination."[2] The criterion by which we judge our human spaceflight program should not be based upon the capabilities or aspirations of other nations. Rather, our human spaceflight program should be held to the same standard we apply to the rest of our civil space program: "It must be capable of producing transformative cultural, scientific, commercial or technical outcomes."[2]

We need a civil space program that inspires current and future generations; "that builds upon the legacy of spectacular achievements to inspire our citizens and attracts future generations of scientists and engineers."[2] We live in a world of many immediate concerns, from a weakened world economy, to regional conflicts and global terrorism, to threats of the consequences of climate change and limited energy sources. "A vigorous civil space program provides a strong signal that our future as a nation is promising; that life can be better; that our prospects are boundless."[2]

We need a civil space program that allows us to pursue international cooperation in space proactively as a means to advance U.S. strategic leadership and meet national and mutual international goals. "Space is viewed by many countries of the world as global commons, a resource not owned by any one nation but crucial to the future of all humankind. Indeed, human beings around the world view space not just as a place, but rather as symbolic of the future itself. Thus, for the U.S. to exert strategic leadership there is no venue more special than space. True strategic leadership will be achieved not by dominance, which in many cases is no longer possible, but by example and in cooperation with other nations. In addition to protecting those activities in space that are judged to be essential to U.S. national interest, and for which the United States must be an undisputed leader, there should also always be concern for the larger world and for how the United States is viewed as a benevolent nation with foresight and determination to make a better world for all humankind."[2]

We need to recognize also that there are impediments to the success of a civil space program that best serves the national needs, and these will need to be overcome. There is the impediment cited above of the lack of a cohesive and coordinated national space policy that ensures that all participants have the capabilities, whether by policy or through resource allocation, to serve their functions in this broad national endeavor. There are also impediments at the foundational level.

There is need of a competent technical work force, "sufficient in size, talents and experience to address difficult and pressing challenges."[2] The aerospace work force, which serves the needs of both civil and military space, needs to be replenished, as part of a broad national effort to ensure that the Nation has the technical workforce necessary to maintain our competitive position in the world and that serves the needs of our people.

There is a need for a properly sized and structured infrastructure, which makes effective use of the full capabilities that the Nation has assembled to conduct its civil space program, whether in NASA centers, universities, industry, or other national laboratories. "The health of the institutional infrastructure is in question. NASA still maintains 10 large centers, as legacies of the much larger Apollo program more than 40 years ago. Responding to funding limitations and associated political pressures, NASA has elected to focus its support on its own centers. As a result, the broad national capabilities in universities and in industry have atrophied and are under utilized—in some instances imperiled—with serious consequences for U.S. capabilities for future innovation. In the case of universities, where research and education are pursued synergistically, the proper training of the aerospace workforce is in jeopardy."[2]

There is a need for a foundation of "sustained technology advances that can provide the development of more capable, reliable, and lower-cost spacecraft and launch vehicles to achieve space program goals."[2] "Yet, because of budgetary pressures and institutional priorities, NASA has largely abandoned its role in supporting a broad portfolio of advanced technology development for civil space applications, and the space technology base has been allowed to erode and is now deficient."[2]

In summary, the civil space program of the United States has a central role in our society today, and our goals as a nation. This role, however, is often not recognized or appreciated, with the result that our civil space program is not adequately coordinated; nor are its priorities properly aligned with pressing national needs, with adequate resources provided; nor are its deficiencies recognized and removed. The goal of course is to reverse this situation, to construct a civil space program that is truly aligned with and capable of serving the national needs. When we do, America does have a future in space, and even more important, space can help assure America's future.

Senator NELSON. Thank you, Dr. Fisk.

Dr. Jeanne Becker is the Vice President, institute Associate Director, and Chief Scientist for the National Space Biomedical Research Institute. Dr. Becker is currently serving as the Chair of the National Advisory Committee for the Women's Health Research Coalition. She's also a member of the Society for Gynecologic Investigation and a member of Women in Bio. She has served with NASA and the NIH. Dr. Becker is also the recipient of NASA's Space Life Sciences Directed Professional Achievement Award.

Welcome, Dr. Becker.

STATEMENT OF JEANNE L. BECKER, PH.D., ASSOCIATE DIRECTOR, NATIONAL SPACE BIOMEDICAL RESEARCH INSTITUTE AND CHIEF SCIENTIST, ASTROGENETIX

Dr. BECKER. Thank you so much—oh I did. OK.

Chairman Nelson, I'm very honored to be here. I'm kind of a nuts-and-bolts sort of person, and so I'm going to get to some very tangible points. But, before I do that, I want to tell you and your committee a little bit of history.

For my entire career, I've been involved in applying space-based biomedical research to on-Earth applications and problems. I started out my career as an Assistant Professor at the University of South Florida College of Medicine in Tampa, and that's where, with stars in my eyes, I got involved in bioreactor work, developing 3–D models for breast and ovarian cancer. That work continues to this day, and I want to update you that, actually, two patents have been filed on a companion technology that is pushing that toward commercializing a 3–D assay for determining cancer cell sensitivity. So, we're very proud of that.

I was also there on June 22, 1993, testifying—having the opportunity to testify before Chairman Hall's Subcommittee when the vote to even build a Space Station passed by one. And that was a very exciting time, and I remember it like it was yesterday. And now I have the opportunity to talk to you about the work that I'm involved with, with development of a salmonella vaccine based on changes of that organism in space, as was alluded to before. We all know about salmonella. It's a terrible problem with food poisoning, but it's also a major cause of childhood death in Third World countries. Salmonella has been investigated early on in spaceflight, and it was shown that the organism actually becomes more virulent—that is, increases its ability to cause disease—when it's cultured in the environment of space. As a group, we—we formed as a group, based on that basic science finding, to actually come forward with a commercial initiative, and we have a terrific team formed. The principal investigator is Dr. Timothy Hammond, and the work actually started out of his lab at Tulane University, and recently was

transferred to where his current institution is, at Duke/VA Hospital.

The hardware that we use to perform these experiments is provided by Dr. Louis Dodiak and his group, at BioServe, who have been phenomenal. And the funding, which we couldn't have done any of this without, is provided by a parent company, Astrotech—you might know them as SpaceHab, by their former name—and they have a privately-held venture called Astrogenetix, and Tom Pickens is the CEO of that. And he has got a lot of his father's characteristics, in that when he sees something that he believes is going to work, he goes for it. And so, they've been a terrific funding partner for us.

We're very fortunate to do this kind of work, because NASA has given us opportunities as a manifest on every remaining Shuttle flight. And so, I'm proud to report to you that we have actually accomplished six payloads in a period of 18 months, which, to those that haven't done it—and I know you've been involved in some of that yourself, Chairman Nelson—that's a lot of work. And we wouldn't be keeping on with this work unless we saw tangible results. And, the fact is, what happens in space happens in space. So, we're not just conducting research in microgravity; we're using what happens in space to answer questions. There's a big difference there. It's not just experiments we do up there; it's—we do them because changes occur in microgravity that you don't see here on Earth, changes in gene expression and protein expression of organisms that uncover new ways of identifying targets that you can find for therapeutics, for vaccine development, for new kinds of antibiotics and therapies that do not exist here.

Our initial work with salmonella allowed us to, in fact, identify a target for vaccine development. And right now we're pursuing that, and we're writing up an investigational new drug, an IND application, that will be submitted to the FDA based on this work.

We've been able to fly eight organisms, and we see remarkable changes in all of them. One of them is of particular interest that we're targeting for future development, and that's Methicillin-resistant Staph aureus, or MRSA. And, in fact, we're getting ready to fly on STS–129 that will launch in November, and MRSA will be the payload on that flight.

So, I'll stop there, but I'm happy to answer all your questions. And again, thank you so much for the opportunity to be here.

[The prepared statement of Dr. Becker follows:]

PREPARED STATEMENT OF JEANNE L. BECKER, PH.D., ASSOCIATE DIRECTOR, NATIONAL SPACE BIOMEDICAL RESEARCH INSTITUTE AND CHIEF SCIENTIST, ASTROGENETIX

Chairman Nelson, Ranking Member Vitter and distinguished members of the Subcommittee, thank you for the opportunity to speak to you on the benefits and applications of space based research. I have the privilege of serving as the Associate Director of the National Space Biomedical Research Institute and also the Chief Scientist for Astrogenetix, which has supported the International Space Station National Laboratory Vaccine Pathfinder missions. For the hearing today, I was asked to address two areas: (i) the potential benefits and applications of my research, and (ii) what makes the space environment unique.

For the duration of my academic career, I have been involved in applying results gained from space based research to on-Earth biomedical problems. My initial research experience with NASA based technology began in the early 1990s, with studies focused on three dimensional growth of human tumors, using the NASA-devel-

oped Rotating Wall bioreactor. This device was originally invented so that cells could be grown under conditions mimicking reduced gravity, and could be transported into space avoiding the harsh shear forces of launch and landing. The calm and quiescent culture environment provided by this device allows cells to assemble into large three dimensional aggregates, closely resembling the way cells grow within the human body. The three dimensional growth of tumor cells in this Rotating Wall bioreactor has proved to be remarkable for a number of reasons. As compared to the traditional means of growing cells flat, in a Petri plate, tumor cells cultivated in the bioreactor grow faster, are more biologically representative of native cancer tissue (that is, look and behave more like real human cancer) and are more aggressive, in that they become significantly more resistant to anti-cancer drugs. For example, the same dose of the chemotherapeutic agent taxol that kills breast or ovarian tumor cells in a Petri plate will not kill all the cancerous cells in these three dimensional clusters. The cancer cells in the three dimensional aggregates which are still alive following exposure to taxol then continue to grow, mirroring what happens in patients who fail chemotherapy. Ultimately, three dimensional growth of human tumor cells can be used as a way to more reliably test new drugs and other types of therapies before they are administered to patients, to give physicians a better first line of defense in determining which treatments will work for their patients.

Over the course of nearly two decades, the scientific literature has become filled with publications demonstrating the fidelity and usefulness of the Rotating Wall bioreactor for three dimensional culture of a wide variety of both normal and cancerous cells. However, taking a different perspective, if the Rotating Wall bioreactor is so effective at producing an environment which can replicate conditions in the body, is it necessary to conduct research on cells and tissue grown in space? One answer to this question can be found in the work of Dr. Leland Chung, the principal investigator for an experiment that launched on STS–107. The objective of this work was to characterize the interaction of prostate tumor cells and bone tissue by conducting a co-culture experiment in a bioreactor aboard the space shuttle. Although a tragic accident destroyed the crew and shuttle, data downlinked during the flight showed that within 3 days, the clusters of prostate cancer cells and bone had become the size of golf balls, relative to the same experiments conducted in the bioreactor on the ground, which showed three dimensional clusters one-eighth of an inch in diameter. An expert in prostate tumor biology, Dr. Chung maintains that this experiment had produced one of, if not *the,* best model of prostate cancer-bone interactions. This is an important accomplishment since advanced stages of prostate cancer commonly spread to bone making treatment options challenging and highly limited. Based upon the work of scientists like Dr. Chung, as well as my own personal experiences, I believe that we need experimentation in all types of environments, modeled microgravity, true microgravity and the 1G that we live in, to gain insight into how forces like gravity affect cell function and growth. We must utilize all options available for advancing the knowledge necessary to find new ways of treating devastating diseases, such as cancer. The International Space Station (ISS) is a critically important platform necessary to advance this science—there is no other means of conducting work in a sustained microgravity environment. ISS is the only laboratory of its kind.

Research in microgravity has also contributed to important advances in microbial biology. Previous space flight studies of the bacteria *Salmonella enterica* demonstrated that growth of this organism in the microgravity environment resulted in significantly enhanced virulence in mice when the space-grown bacteria were returned to earth and injected into the animals. Taking advantage of this knowledge, we reasoned that if the cause of the increased virulence could be identified, that is, targeted to a specific gene or set of genes, then a vaccine for this organism could potentially be developed. In order for a vaccine to be effective, it must be strong enough to induce an immune response in the host and strong enough to provide protection against future exposure to *Salmonella,* but weak enough to allow administration with no risk of illness, that is, it must not make the host sick. Working with the principal investigator for these studies, Dr. Timothy Hammond, we pursued development of a *Salmonella* vaccine using strains of the bacteria which were genetically altered to remove key genes associated with virulence, yet were still able to induce a good host immune response. A key factor for these investigations was the establishment of a host-pathogen model that would allow us to examine how the bacteria interact with, and infect, the host within the microgravity environment. For this, we developed an in-microgravity assay whereby the genetically altered bacteria are grown in the microgravity environment, then mixed with a tiny worm host, *Caenorhabditis elegans*. Interestingly, *C. elegans* exhibits many similarities with humans in their immune response to bacteria, making this a good model system. The

model works because *C. elegans* normally ingest bacteria as a food source. After the bacteria and worms interact on-orbit, the process is terminated and then returned to earth for determination of microbial virulence. If the bacteria are virulent, after being ingested by the *C. elegans* the bacteria kill the worm host, and continue to grow. If the bacteria are not virulent (that is, the removal of genes took away their ability to kill their host), the worms simply ingest the bacteria and the bacteria are removed from the system, so they cannot continue to grow. In post-flight analysis, altered bacterial strains not exhibiting virulence, due to the knock-out of specific gene(s), are potential targets for vaccine development. These investigations are made possible because of an extensive team effort, using the robust flight hardware and expertise provided by BioServe, under the leadership of Dr. Louis Stodieck and the funding provided by Astrogenetix.

To date, six flight studies have been conducted over a period of 18 months, and we are preparing for our next payload on STS–129 scheduled for launch in November of this year. We have successfully identified a gene target and a vaccine for *Salmonella enterica* is under development. This work has partnered academia and government with industry for the development of a commercial vaccine product based on results obtained in microgravity, and serves as a pathfinder mission to validate the use of ISS as a National Laboratory, that is, as a research and development platform, after station assembly is complete. As such, NASA has designated these flights as ISS National Laboratory Pathfinder missions and has provided a manifest on each of the remaining shuttle flights to enable iterative science to be conducted, as is necessary for tangible product development. Currently there is no *Salmonella* vaccine available for human use. Aside from being among the most common causes of food poisoning world-wide, *Salmonella* is a major cause of childhood death in Third World nations.

A variety of medically important microbes have been tested in the *C. elegans* model and the system has worked well. Recently initiated follow-on experiments are focused on the use of microgravity to identify targets for the development of therapeutics for methicillin resistant *Staphylococcus aureus,* or MRSA. In the past decade, infection and mortality due to this organism has increased drastically, exceeding the death rate for HIV. In this country alone, MRSA is responsible for 100,000 cases of severe infections and 19,000 deaths annually. Although once predominantly confined to the hospital environment, this organism is fast becoming a major problem outside hospitals, and community acquired MRSA is on the rise.

To summarize the accomplishments of this work:

- The findings made in space are the product of fundamental research.
- Multiple successful spaceflight payloads have been conducted with industry support.
- A lead product, a vaccine for *Salmonella*, is in development based upon results obtained in microgravity.
- Work with additional microbes is ongoing, for future pipeline development.

The ability to support and maintain investments made in ISS will require an ongoing commitment but also comes with the expectation that significant gains and advantages will come about as a result of the resources allocated. One important question to ask regarding the development of therapeutics using ISS as a platform is how exactly can using space change drug development on earth? Currently, the research and development pipeline for a single agent may take years of work to allow identification of viable candidates for pharmaceutical applications. At the end of this period, the possibly exists that the candidate agent is not suitable for continued development. The time, money and resources expended getting to this point could be minimized by using a process which identifies promising agents or drug candidates earlier in the development pipeline, for quicker testing to evaluate downstream efficacy and market potential. Using space, years may be eliminated from research and development pipeline activities, to allow for fast-tracking of promising agents, and termination of unsuccessful agents at earlier time points. In this manner, ISS may be not only a one-of-a-kind laboratory resource for the development of new and sorely needed pharmaceutical and therapeutic products, but could facilitate the generation of an entirely new kind of biotechnology industry based upon discovery in microgravity.

Outside of my own research, in my role as associate director of NSBRI, I have the opportunity to facilitate the work of over 180 investigators at 60 institutions across the country. The research of these scientists is also aimed at making advances in the space environment and applying this knowledge to benefit life on earth. From new technologies for noninvasive health monitoring, to advanced training techniques in areas such as ultrasound, to enhanced lighting devices to counter-

act fatigue, this work leverages the academic resources of our Nation's top tier institutions and the Federal funding of agencies such as the National Institutes of Health and the Department of Defense. The continued accomplishments of this body of work are strongly dependent upon the maintenance of ISS as a National research enterprise.

Mr. Chairman and members of the Subcommittee, in closing, I want to again extend my appreciation for affording me this opportunity to discuss the benefits and applications of research conducted in the space environment. At this critical time when National resources are hard fought, I sincerely believe that investments made in the International Space Station will yield tremendous benefits for new discovery to enhance health on earth. Vital to these successes are the collaborations and efforts of academia, industry and government, working together with your strong support. I would be pleased to answer any questions that you may have.

Senator NELSON. Thank you, Dr. Becker.

And when, for example, the Vasomer engine is attached to the Space Station in 2013, it will obviate the need to bring up fuel to keep boosting the Space Station, because it will have a continuous pulse. It will take the Station from microgravity, because of the drag, to near-zero gravity, which will all the more enhance your experimentation.

Dr. BECKER. Absolutely.

Senator NELSON. Our CEO of the panel is Ms. Greiner, Co-Founder of the iRobot Corporation, has served as President since 1997. She served as Chairman of that company from 2004 to 2008. Under her leadership, iRobot is delivering robots to the industrial, consumer, academic, and military markets.

I want you to explain these little devices, and what they're doing for the military that came out of our human space program.

Her 15 years of experience in robotic technology includes work at NASA's Jet Propulsion Laboratory and MIT's Artificial Intelligence Laboratory. She was named the Ernst & Young New England Entrepreneur of the Year, a Technology Review Magazine, Young Innovator of the Next Century, and one of World Economic Forum's Global Leaders of Tomorrow.

Welcome, CEO Greiner.

STATEMENT OF HELEN GREINER, CEO, THE DROID WORKS

Ms. GREINER. Well, thank you. Since my Ph.D. is honorary, I won't use it while sitting next to the real thing. So, thank you for that introduction. I'm honored to speak here today.

I am also serving as a Trustee for MIT, the Boston Museum of Science, the National Defense Industrial Association, and the Association for Unmanned Vehicle Systems International. I'm serving also as the elected President of the Robotic Technology Consortium, which is an industrial consortium that has the top-tier defense contractors, top universities and nonprofits, and over 120 small businesses. We have members in two-thirds of the states, and many of these companies and universities are funded to do space research by NASA. So, in other words, as you heard from my—the introduction, I'm an engineer, an entrepreneur, and I'm active in representing the robotics community.

So, my own career and the history of iRobot Corporation are inextricably intertwined with NASA. I was an intern at NASA's Jet Propulsion Laboratory, where I worked on manipulators for satellites. And this internship provided me with the opportunity to learn from NASA engineers, some of the best in the world, and also

provided me the funding that I needed to obtain an advanced degree from MIT.

When I graduated, I founded iRobot with Rob Brooks and Colin Angle, and NASA helped us. They helped us by purchasing some robots; specifically, an 18-Degree-of-Freedom Walking Robot and some tract robots. They were our very first sales. And I asked the program managers at NASA, a decade later, why they bought these robots, and their response was telling. They said, "We wanted to make sure an industrial base developed in robots." A lot of deep thinkers at NASA.

So, in addition, the iRobot Corporation is actually based on work that was funded by NASA at the Massachusetts Institute of Technology Artificial Intelligence Lab in the 1980s, and this research developed a new type of robot control that we call "behavioral control." And behavioral control is modeled on insects, because insects can get around anywhere, and they don't have large computational assets; in fact, they have these little bitty brains. And so, that kind of control system is also the kind of control system you need on a robot when it goes out to explore Mars or one of the further planets.

So, this groundbreaking work was one of the threads leading to the successful Sojourner Mars' Exploration Mission, but here on Earth it's also being used. This funding changed the paradigm in the way that robots are designed, and it currently runs on the iRobot Roomba Vacuuming Robot. And the Roomba—in case you haven't heard about it, we hope you have—they're small, completely autonomous vacuuming robots. And iRobot has now sold 3 million of them, which makes it the best-selling practical home robot in the world. So, you can go out and buy these spinouts of space technology at Costco, Target, and many other stores.

But, 50 percent, as Chairman Nelson alluded to, of iRobot's business comes from military and law enforcement. In 1997, the Defense Advanced Research Project Agency, or DARPA, started a program to build tactical mobile robots. And NASA, iRobot, and others worked on this program. NASA brought their technology to bear on the iRobot PackBot System, and, likewise, we spun technology from this program back into NASA in, for example, the lightweight rugged wheels that are used on the next set of Mars' rovers, Spirit and Opportunity.

The PackBots were first deployed in combat in 2002, and they were used to clear the caves in Afghanistan. Before the PackBots got there, they were actually tying ropes around the soldiers' waists and sending them into the caves. You know, there could be boobytraps, the last occupant was possibly an enemy combatant, and these robots are currently being used to remediate improvised explosive devices. So, the—one of the deadliest threats to our troops are these roadside bombs. And the PackBots now have been credited with the military with saving the lives of hundreds of soldiers and thousands of civilians. And because of this success, with team members from iRobot, NASA, DARPA, and the iRobot PackBot was inducted into the Space Hall of Fame in 2006, which we are very proud of.

So, because of these small investments that were made by NASA, the U.S. is leading the world in robot products. So, from autono-

mous vacuums to floorwashers to warehouse robots, to military robots, the U.S. has sold more robots than any other country. And it's entrepreneurial companies like iRobot and, my new company, The Droid Works, that are creating jobs and ensuring America's leadership in the global innovation economy. NASA funding is a national competitiveness issue.

So, in conclusion, at just—less than 1 percent of the Federal budget—NASA is not just exploring the planets, including planet Earth, but also supporting the next generation of engineers through internships, supporting entrepreneurs through their small business programs and other contracts, supporting cutting-edge research at universities, supporting our technology industrial base, and developing lifesaving technology. So, that's just less than 1 percent of the budget. NASA funding is a proven investment in U.S. competitiveness.

Thank you.

[The prepared statement of Ms. Greiner follows:]

PREPARED STATEMENT OF HELEN GREINER, CEO, THE DROID WORKS

My name is Helen Greiner. I am currently the CEO of a startup company called The Droid Works. I received my Bachelors Degree in Mechanical Engineering and Masters Degree in Electrical and Computer Sciences from the Massachusetts Institute of Technology. Between 1990 to 2008, I co-founded and served as President and later Chairman of iRobot Corporation, a company that went from an apartment based startup to a publicly traded company and is a worldwide leaders in robot product sales and cutting edge robotics research. I currently serve as a trustee for MIT, the Boston Museum of Science, the National Defense Industrial Association, and the Association for Unmanned Vehicle Systems International. I also serve as the elected President of the Robotics Technology Consortium, an industrial and academic consortium of 179 companies including top tier defense contractors, top universities and non profits, and over 120 small businesses—we have members from over 2/3 of the states. In other words, I am an engineer, entrepreneur, and active in representing the robotics industry.

My own career and iRobot's history is inextricably intertwined with NASA. I was an intern at NASA's Jet Propulsion Laboratory where I worked on manipulators for satellites. This internship provided the opportunity to learn from NASA engineers and the support that I needed to pursue an advanced degree. Upon graduating, I founded iRobot in 1990 with Rod Brooks and Colin Angle, and NASA helped by purchasing robots from us—specifically an 18 degree of freedom walking robot and two portable tracked robots our very first sales. I asked a decade later why NASA bought them and the response was "we wanted to make sure that an industrial base developed in robotics". In addition, iRobot Corporation is based on work that was funded by NASA at the Massachusetts Institute of Technology's Artificial Intelligence Lab in the 1980s—this research developed a new type of control for robots called Behavior Control. Behavior Control is modeled on insects that can easily navigate in unstructured environments—even though they lack large computation assets—in other words, they have little bitty brains. Behavior Control mimics how insect control systems work and was implemented on insectoid robots such as Genghis and Attila. This ground breaking work was one of the threads leading to the successful Sojourner Mars exploration mission. Here on earth this NASA funded paradigm has changed the way robots are designed. This NASA research grant funded the fundamental robot intelligence paradigm that currently runs on the iRobot Roomba Vacuuming Robot. The Roomba, in case, you haven't seen them, are small completely autonomous vacuuming robots. iRobot has now sold over 3 Million Roombas, making it the best selling practical home robot in the world.

Fifty percent of iRobot's business comes from military and law enforcement. In 1997, the Defense Research Projects Agency started a program to build Tactical Mobile Robot. iRobot, NASA, and others worked on this program. NASA brought their technology to bear on the iRobot PackBot System and likewise iRobot technology was spun back into NASA in, for example, the lightweight rugged wheels for the second set of MARS rovers, Spirit and Opportunity. The PackBot Robots were the first ground robot deployed in combat in 2002 to provide initial entry into the remote caves of Afghanistan where the Taliban were hiding their weapons caches.

They took the place of tying ropes around our soldiers and sending them in to face enemy combatants and booby traps. Currently PackBot's are being used to remediate Improvised Explosive Device, or roadside bombs, which are the deadliest threat to our troops in Iraq and Afghanistan. PackBots have been credited by the military with saving the lives of hundreds of soldiers and thousands of civilians. Because of this success, with team members from iRobot, DARPA, and NASA, the iRobot PackBot was inducted into the Space Technology Hall of Fame in 2006.

Because of the small investments made by NASA, the U.S. is currently leading the world in robot products. More robots from autonomous vacuums to floor washers to warehouse robots to military robots have been designed and sold by U.S. companies than any other country. The entrepreneurial companies, like iRobot Corporation, that make this happen are creating jobs and insuring America's leadership in the global innovation economy. NASA funding is a national competitiveness issue.

So in conclusion at just $17.2B or just ½ of 1 percent of the Federal budget, NASA is not just exploring the planets (including planet earth), but also supporting the next generation engineers through internships, supporting entrepreneurs through their Small Business program and other contracts, supporting cutting edge research at universities, supporting our technology industrial base, and helping develop life saving technologies. That's just ½ of 1 percent of the budget. NASA funding is a proven investment in U.S. competitiveness.

Senator NELSON. Thank you, Ms. Greiner.

I'm going to withhold my questions so my colleagues can ask questions.

Senator Vitter?

Senator VITTER. Thank you very much, Mr. Chairman, particularly since I'm going to have to excuse myself in a few minutes.

Sitting here listening to all of this, I thought of maybe a great tag line for the hearing. It's the opposite of Vegas: What happens in space doesn't stay in space.

Senator NELSON. There you go.

Senator VITTER. I'll consider some more ideas. You're obviously not——

[Laughter.]

Senator VITTER.—quite ready to put that on the cover of the hearing testimony yet.

Dr. Katz, thanks for your specific examples of developments that have very real use here on Earth, particularly in the area that involves the NIH. Now, some folks would say, "Well, 90-plus percent of that sort of stuff can be done without human spaceflight. And, perhaps, that is where we have to refine the argument and target the argument the most, as other panelists have alluded to, is human spaceflight." How would you respond to that, particularly with your NIH experience in mind?

Dr. KATZ. Well, thank you very much for that question.

The reality is that much of what we've learned with regard to basic biology has impacted on human spaceflight. So, for example, astronauts regularly exercise to have high-impact exercise so that their—and we know that bones are stimulated to increase their production rather than their destruction, in terms of keeping muscles and bones going. That doesn't obviate the bone loss, but it obviates it to a certain extent.

My focus—the focus of my discussion was really on the utilization of the Station as a National Laboratory, and obviously there have to be people up there who are doing the experiments; the experiments don't go on their own. So, whether it was a bioreactor, as Dr. Becker talked about, a bioreactor with human cells or with experimental animal cells or with bacterial or viruses, those types

of experiments need to be done by people who are in space on the Station.

So, if I understand your question correctly, "Do we need humans in space to do these types of experiments?," yes we do.

Senator VITTER. OK, thank you, Doctor.

And, Dr. Pace, a lot of your testimony was about international cooperation in space, and that's sort of obvious with the concept of the International Space Station. It's not as obvious when we look at next-generation activity, at least as it has been mapped out before this Administration. Assuming that architecture stays roughly the same, what do you think is the appropriate role of international partners and cooperation? How would you suggest we properly develop that role?

Dr. PACE. Well, I think that—it's a wonderful question. And I think that current exploration program actually represents a maturation over several years of U.S. space efforts. I mean, the Apollo program was obviously a unilateral U.S. effort. That was the whole point, in terms of beating the Soviet Union. The Space Shuttle had international contributions from Canada and Europe, in the case of the Space Lab. The Space Station is a true international partnership, as we all know.

When looking at the exploration strategy that has been laid out over the last several years, the architecture itself is something that's being developed in collaboration with the other major space agencies. So, there are international lunar architectures—there's a Mars sample return architecture—that are being discussed among all the agencies on the basis of deep collaboration from the beginning.

So, I think that the model is already there. And I think that the question really becomes—is, What are the roles that each of the various countries are going to play? I think sometimes there's an assumption that if the U.S. is not playing a strong role, that other countries will come fill the vacuum. I don't think that's really quite true. I think that if other countries don't see the U.S. as a strong partner and a strong leader, that they themselves will have, maybe, second doubts about it, and will not necessarily fill that vacuum.

On the other hand, many countries have decided that being in space is important for their economy, for their security, and for their citizens. And they are moving out into space; and I think it's important that we be present with them to shape that future environment.

So, I think we have partnerships ready to go, I think there is a moving interest in space; and therefore, I think this is really our opportunity to lose if we don't step up.

Senator VITTER. OK, thank you, Doctor.

Dr. Fisk, to get the proper national strategy you were talking about, what sort of organizational changes do you think we need to look at within the Federal Government, particularly the relevant executive agencies? And then, personally, I'm hoping you're not going to use the term "space czar" in any part of you answer, but——

[Laughter.]

Senator VITTER.—I'll leave that up to you.

Dr. FISK. No. Well, certainly not, Senator.

[Laughter.]

Dr. FISK. No.

Well, let me make a couple of comments. In this report that I referred to, we thought it was presumptuous of us to try and organize the Federal Government, which is probably not possible anyway.

But, if you say, "Who has the mandate in this?" it's probably the President's science advisor and the national security advisor. Those are the people for whom space is important in the White House.

So—and I don't think you ever want to reorganize the Federal Government on an agency level. There's too much baggage and overhead associated with that for anything productive to happen.

But, if you look at the highest levels of the government—the Director of OMB, the President's science advisor, the national security advisor—you get them together and you say, "OK, this is what is important for the Nation in space. We recognize that civil space touches all parts of our society and our national image, and, you know, how we will deal with our foreign policy, how we will deal with other nations, how we will deal with all these things." And then you ask yourself, "OK, do we have a coordinated activity in Space—and are—there funding gaps in this?" There are obvious funding gaps; we talk about them here. But, if those funding gaps can be filled, in recognition of the role that agency and program plays in this broader national agenda, then I think we create something which is capable of serving the national need.

Senator VITTER. But, Doctor, just to quickly follow up, don't you think for that to happen and to continue to happen—versus a, you know, sort of one-time push—there needs to be some structural mechanism to make sure it keeps happening? I'm not saying redo a bunch of agencies, but——

Dr. FISK. Right.

Senator VITTER.—but at least have some continuity?

Dr. FISK. Well, there has always been discussion of resurrecting the Space Council, in some sense. But, you have to do it differently than it was done before if you do that, because before, it was viewed by many of the participants—and some of this, you know, is from my time at NASA—as more impediment than help. And so, the question is, Can you create something that actually assists in producing this coordinating activity? It's obviously a challenge, right? Because if you have something that is so pervasive in your society, you don't want a space czar, because that's too limiting; you want some mechanism in the White House that is capable of the coordination. I think, in large part, you have to examine how the White House actually works today, which is well beyond either my paygrade or knowledge. But, it seems to me the President should set something up that makes it effective in however he is choosing to run the many dimensions of our society. You recognize space as just as important as other aspects that are—the White House is trying to coordinate, and use a similar mechanism to produce the coordination for space.

Senator VITTER. OK.

And my final question for Dr. Becker and Ms. Greiner, to sort of go back to the same topic as for Dr. Katz. In the work you high-

lighted, the tangible results we've seen here on Earth related to space activity, how much of that work absolutely depended on humans in space versus nonhuman space activity?

Dr. BECKER. All of our work, with doing Pathfinder vaccine work, has required crew to be trained so that they can start the hardware and so that they can stop the hardware. And without that, we could not have done these studies. It's that simple.

Senator VITTER. OK.

Ms. Greiner?

Ms. GREINER. And we build robots, so—but I would like to just add that the, you know—sometimes you can't predict where innovation is going to end up. No one would have predicted that the work that was targeted for, you know, having remote exploration of the Martian services would result in robotic vacuums. And, you know, we're not going to be able to predict everything, but when you have these large national efforts that are developing technology, there are going to be lots of tangible benefits that really can't be predicted up front. There are ones that can be predicted up front, like what we've heard about in medicine, but there's going to be so much more that comes out of it that can't be predicted up front.

Senator VITTER. Thank you.

Thank you, Mr. Chairman.

Senator NELSON. As I ask a series of questions of you all, I want you to be thinking about, at some point, I will want each of you to talk about examples of the tangible benefits from the space program, specifically the human space program, and the intangible benefits.

I'll start in reverse order, with you, Ms. Greiner. In your testimony, you obviously had this personal relationship with NASA, and it was an enabler for you to help you to reach where you are now. What will a properly funded NASA enable other entrepreneurial activities such as yours to do, what will happen in the next 10 years?

Ms. GREINER. Well, both underfunding from NASA to small businesses, or even large businesses, and even companies that just look at what's going on in NASA, to commercialize the results in medicine, mechanics and materials, you know, that has been a very effective way for us to not have to start from scratch and develop all the technologies.

I can tell you that, you know, it's happening a lot in the robotics community, and stories like mine are duplicated with entrepreneurs all over the country. We took iRobot from an apartment-based startup to a publicly-traded company that's creating jobs and keeping the U.S. ahead in this one particular field of robotic technology. And, you know, you can make lists of the number of companies that have gotten started by working with—you know, in conjunction with NASA, you'll find it's a large number that's adding to our economic base.

Senator NELSON. You've seen these incredible wheelchairs that can climb stairs?

Ms. GREINER. I certainly have. Dean Kemen's company.

Senator NELSON. Did some of that technology come out of the space program?

Ms. GREINER. I can't answer concretely, but I know that the space program has put quite a lot of effort into both the—you know, what's needed mechanically and electrically for autonomy, but also what's needed to make these space probes and make these rovers autonomous. Because when you are on a different planet, like Mars, the delays in the radio signals—you can't totally operate or control these robots from Earth. They really have to be on their own. And that technology feeds back into having these types of systems—like the robots for the military, the robotic vacuums, floor washers, warehouse supply-chain management type of robots—right here on Earth.

Senator NELSON. It has been suggested that NASA have a DARPA for these advanced projects. Do you think that would allow more entrepreneurial activity?

Ms. GREINER. I'm not an expert in, you know, what's going on in those particular discussions, but I can tell you that having the kind of mechanism that DARPA has, you know, it works with DARPA, with the Internet being the primary example, because they're given the freedom of being able to, you know, not have constraints. They have the freedom to take risks. And you really need freedom to take risks to really push technologies to, you know, the next level; rather than just evolutionary design, really more revolutionary designs.

Senator NELSON. Dr. Becker, Senator Hutchison had mentioned the alpha-magnetic spectrometer and the fact that, as you know, the big accelerator in Geneva, Switzerland, they haven't been able to get it going. The idea is to try to find out what is down in those subatomic particles that make up matter and energy and so forth. When we get the AMS up in space, which is going to be attached to the Space Station. By the way, that's to the credit of the President; he mandated an extra flight of the Space Shuttle to accommodate the AMS. They were not even going to fly this billion-and-a-half-dollar piece of experimentation equipment. It's sitting on the ground ready to go, and they weren't going to fly it. NASA wasn't going to fly. We're going to get that up, and then it's going to capture these atomic particles that are flying through space so that we can analyze them.

There's a good example of human spaceflight, because it's made by humans, it's going to be taken up by humans, it's going to be put up there, and its results are going to be analyzed by humans. Who knows, we may get the same information that we'd get on Earth building an accelerator that's several miles around.

In your written testimony, you state that the ISS is a critically important platform necessary to advance this science and that there are no other means of conducting work in a sustained microgravity environment. "The ISS is the only laboratory of its kind," is what you state. In your experience, do you think the U.S. and its partners will see a substantial return on this rather enormous $100-billion investment?

Dr. BECKER. It's hard for me to answer that question—(a) because I'm not a physicist, I'm a cell biologist. And as a scientist, in general, it's hard to answer to questions about data outcomes without having data. And I think, to cutoff the possibility of not having that data, you can't even answer that question. So, I don't

know about dollars, in terms of actual return on investment, but I do know that unless you do that work, you will not really answer that question. There's no other way to do it.

There are many ways to simulate microgravity. There are various models. And there are some good models, and all of them have their positives and negatives. But, there's no true way to have sustained microgravity unless you go up there and experience it in the Station. There just isn't any other way. And when Station was passed, by that one vote, I was there, and I know that the arguments that were made that day were around science and they were around using this unique environment to answer questions we can't answer here, because we can't replicate that here. And so, let's build a laboratory like no other that will answer these questions. And now it's almost finished, and I've been waiting this whole time to be able to see work come out of that and to really utilize this amazing laboratory.

The salmonella work we've done is a taste of, I think, what we can possibly see in the area of infectious disease, which is billions and billions of dollars, industry in this country. And the bugs are winning. And unless we find new ways to combat that, they will continue to win. If space can give us new answers and uncover new discovery and targets, we're obligated to go there for the citizens that live here on Earth.

Senator NELSON. How far along are you in the process of developing a salmonella vaccine?

Dr. BECKER. We have reproduced the data several times. We're absolutely committed that we have the right gene target. We have filed patents. We are currently speaking to industry experts that help people write up investigational new-drug applications; we're doing that right now. And it's our full intent—being supported by industry, I might add. This is an academic-industry-government partnership. Without each of those factors, it wouldn't go forward, and so I really do want to give credit to each of the sectors that have made this work possible. We're really—we're pushing forward with IND submission.

Senator NELSON. And you say it's because of microgravity that this strain of salmonella gets more virulent, and it's because of that fact that you can then develop a salmonella vaccine?

Dr. BECKER. What happens is the science—the basic science finding told us that the bacteria become more virulent. And so, as a group, we reasoned, If we can understand the genetic cause behind that virulence, if we can take that away, then perhaps we can create what's called, in jargon, in science words, an "attenuated vaccine," and that is a vaccine that induces a good immune response; it's strong enough to be administered, so all the parts of the immune system will see it and react; it's strong enough to protect against future exposure to salmonella, but it doesn't make the host sick. And what we did is, we pinpointed genes and we took—we knocked them out, and we sent up a series of genetically-altered bacteria with these genes knocked out, and, in fact, one of them took away the virulence effect while still maintaining the immune-response effect. And so, we made a home run. And that's what we're pursuing to get into testing on the ground to, in fact, see how it does clinically down the road.

You know, one of the things that I want to bring to the attention of you and your committee is, what this potentially has done is streamlined a very, very lengthy process that might have been found on the ground, but would have taken years. I mean, we still don't have a salmonella vaccine, after all this time of trying to develop one.

If that works for this organism, and if we see similar changes in other organisms, which is what we are seeing, it's very possible that this becomes attractive to pharmaceutical companies so they can identify, early on in their development pipelines, what is a viable agent for development and what is not. And "the what is not" part is just as important, because you can eliminate those possibilities early without spending time and effort and resources in developing them, only to get to a point where you realize this is not going to work.

Senator NELSON. Did anything come of the growth of crystals in space. You're trying to grow a crystal that is more pure in zero G so that we could determine its molecular structure easier?

Dr. BECKER. I know for a fact that Tom Pickens is very interested in pursuing that avenue with this little venture, Astrogenetix—again, based on the space data. I know that there are arguments for and against what happened in space, in terms of the quality of the crystals that came out, but I think one thing that's important to remember is, these experiments were done either on Shuttle or were done in a situation where construction wasn't completed, which really impacts—the quiet environment is absolutely necessary for crystal formation, as you well know. And I'm not a crystallographer, but I do know that those discussions are happening now.

Senator NELSON. If the ISS were abandoned in 2016, what potential research do you think would be unrealized?

Dr. BECKER. Would be unrealized? Honestly, I believe that we are on a threshold of creating a new kind of industry in biotechnology based on new discovery in microgravity. And I think that by eliminating the operations of the Station, that that would never fully be realized.

Senator NELSON. It's only taken us 15 years to get here. We'd better now utilize what it has taken 15 years to build.

Dr. Fisk, the National Research Council's report, America's Future in Space, made several recommendations. I'm picking up on your previous testimony. Let me just get down to the bottom line.

You want to coordinate all these things, get the Executive Branch to task to align agency and department strategies. What about a National Space Council in the White House?

Dr. FISK. Let me—I'll answer this is just a sec.

I wonder if you'd permit me to cycle back on one——

Senator NELSON. Absolutely——

Dr. FISK.—issue here.

Senator NELSON.—and it's open to any of you all. Please, chime in if you want to answer somebody else's question.

Dr. FISK. Well, it's—I want to make sure a thought isn't lost here someplace.

Senator NELSON. Good.

Dr. FISK. Coordination is wonderful. I mean, we should coordinate. We should also fund. That's part of the dilemma we have. Whether it's because of lack of coordination or because of lack of appreciation, we do not fund our space program at the level that we should and therefore, it does not contribute to the national agenda as it could.

And when we talk about human spaceflight and the use of the ISS, we should never forget how much damage has been done over the last few years because we have inadequately funded the human spaceflight program, and, as a result, the need to build the next generation after Shuttle, the Aries and Orion, and the priority which was attached to it—which I won't even dispute, one way or the other—but there has been enormous collateral damage in the rest of the human spaceflight program as a result.

And when we talk about microgravity, don't forget the physical science side of microgravity, not just the biological side. That community has disappeared. We refer to it in the scientific community as "scientific genocide" on the part of NASA, because it was forced into this unfortunate budget situation that it had inadequate resources, and it needed to do something to replace the Shuttle, and it went where it could find some money. And the microgravity and physical science community suffered in this. The life science community suffered less, but it is nowhere near what it could be, in terms of payloads on the Space Station, if the resources had been there to do that.

We talk about R&D and NASA's role in reaching out into the broader R&D community. Again, there was a price to pay for this inadequate funding, and one of the prices was concentrating the R&D activities on those things that were most germane to the new launch vehicle. They were higher TRL—as we say, "technical readiness level"—items because they were needed. And what do you sacrifice? You sacrifice the things at lower TRL levels, the things that may give you breakthroughs, that may spinoff into the rest of the economy because they weren't immediately applicable to the space program, which NASA has done in its past, but cannot now reasonably afford to do.

And so, if we talk about how much money human spaceflight needs; Augustine gives recommendations and so forth. I hope somebody remembers that it's not just the price to pay for the new launch vehicle; it's also the price to pay for restoring the other parts of the human spaceflight program, which are of considerable value, which were sacrificed or wounded in the budget constraints that have existed over the last 4 years.

Now, as for coordination and Space Councils, again I don't have a crystal ball. You said it in your opening remarks; the President has to decide. He has to decide what civil space program he wants, and he has to recognize the importance that it has in all of his agenda items—many of the national agenda items; and he has to send the direction out to the troops to do that, and his OMB has to be given the funds and so forth. And somebody has got to orchestrate that event somewhere in his organization.

Different Presidents do it in different ways. We've had times of our history when the Vice President had a strong say in space program. We've had other times when that's less so, and so on. So, I

think it's important that the President recognizes the national importance of this event and creates both an organizational structure and a funding situation that allows him to achieve the goals that he presumably will set for the program.

Senator NELSON. I don't know to what degree they are seriously, down at the White House, thinking about a National Space Council.

Dr. FISK. I don't know, either. It was talked about in the campaign, but I have heard very little of it since then. And it may not be necessary. It may not be the appropriate vehicle. There are certainly a lot of reviews going on. That's always a sign of something, I guess. The President has directed the National Security Advisor to conduct a review of all of space. And you've got Augustine, and so on. So, presumably, the data comes in and somebody says, "OK, let's do this." I mean, we at least have an Administration that is actively determined to solve all problems simultaneously. So, maybe they'll put space up there someplace; probably not ahead of healthcare or Afghanistan, but at least on the list.

Senator NELSON. It better not be too far down the list.

[Laughter.]

Dr. FISK. I certainly—you would not find any dispute in this room.

Senator NELSON. Dr. Pace, what do you see as the primary impediment to having all of these policymakers down in the White House recognize that space pays dividends? I've written down specific things that you have talked about. I can talk until I'm blue in the face about them: heart pumps, fiber optic probes. I didn't know what a autonomous vacuum was, but I know what an autonomous vacuum cleaner is. You have excited me to want to go out and buy one.

[Laughter.]

Ms. GREINER. Go ahead.

Senator NELSON. And just turn it loose——

[Laughter.]

Senator NELSON.—in the house.

Ms. GREINER. I think that would be great.

Senator NELSON. Tell me, Dr. Pace, what do you think?

Dr. PACE. Well, I think there are a lot of obvious practical benefits that I think everyone deserves to understand and realize there are these specific issues out there. And I think that the dots that need to be connected are how space can support this Administration's priorities and values. The President has talked about a lot of things, in terms of our relationship with other nations of the world, talked about encouraging math and science education, talked about improving competitiveness, and yet, I think the frustration is, is that there has not been a recognition of the linkage that space can contribute to those issues. In fact, it's treated as sort of a very important, but still specialized, issue rather than the strategic issue that I think it is.

As I'm listening to the discussions about the—what can be done with biomedical research aboard Space Station, I think of the fact that space is a strategic advantage for this country, in terms of innovation. That is, other countries are doing IT and nanotech and materials and lots of other things, and they are really quite com-

petitive with us. So, what is a game-changer for this country? A game-changer is something that really only we or a small number of countries are uniquely able to do, to go places and do things that no one else can, to be a leader among the great powers. And I think space is something that contributes to that.

We understand how it does that in national security. I think we're starting to realize what it might mean for innovation, as exemplified by the ISS as a National Lab. And I think, in this post-Cold-War world, the importance of space as a tool for building relationships—if you—there's discussion about the CERN and the international cooperation that the CERN represents. Well, I would submit that there is no finer example of long-lived high technology challenging international cooperation—more complex, more technically difficult—than the International Space Station. The result of that—one of the primary products of Space Station today has been real, tangible, specific relationships between ourselves and other countries, at a working level, that would not have existed otherwise, and that has been—endured a number of different shocks to the system. That is a real, tangible value. It's not something that goes, you know, clunk on a desk, but it's something that affects relationships between countries, that binds them together. I think we ignore that.

So, I don't think there's quite an appreciation of the strategic value of space. I think sometimes it's seen as something which is part of a science project, and therefore, the science advisor, who actually is quite knowledgeable and quite expert, I would say, on space issues—he alone can deal with these issues. And I would submit not, that really it is the national security advisor, the domestic policy advisors, maybe led by and coordinated by OSTP, that really kind of have to get into the game.

Every President organizes his White House the way he sees fit. I wouldn't presume to suggest a Space Council is the right way to go. I was involved with the last one. I think it had some benefits, had some disbenefits. But, I think, this White House, the most important thing for it to do is to articulate how space connects to and supports their agenda and their priorities. Because, I think if they do that, they will be very pleasantly surprised at how useful a space regime can be.

Senator NELSON. Well, Dr. Katz, I come back to you. Picking up on the idea that you talked about of the ISS as a National Laboratory. I am sure, especially after the Augustine Commission has said, "Don't deorbit it in 2016, keep it going until 2020," that that's going to be one of the recommendations that will be implemented. So, we're going to have a decade in which to do research in the microgravity with a full-up laboratory.

Look to the future. You're from NIH. Tell us, what are we going to discover? What diseases, what new treatments, what medications, what do you think?

Dr. KATZ. Well, I would build on Dr. Pace's point, that innovation is one of our great strengths. And bringing the NIH together with NASA enables a whole new group of scientists to utilize this laboratory, which is really unique. Whether it's microgravity or leads into zero gravity, as you said, it's unique.

So many of our institutes have signed on to this initiative because they see something in the future that will benefit people on Earth. So, whether it's the Neurology Institute that—or the Deafness and Communication Disorders Institute—that is interested in vestibular dysfunction, or motion sickness, or whether it's the Cancer Institute that's particularly interested in evasiveness or metastasis, these are all areas for exploration, and they have not really been pursued, and that's what, I think, this Memo of Understanding brings to the table.

So, do I see many innovations? I do. We are preceding, along with our colleagues at NASA, in thinking that these experiments are going to go on for some years. So, basically, what we're doing is we are providing for 5-year grants and we are actually committed to three rounds of these on an annual basis. So, if you think about that, we're going out, now, 8 more years, to 2017 or 2018. So, we think that this—that continuing doing experiments on the Station will enable this type of innovation, whether it's drugs that block invasiveness using these bioreactors, whether it's the development of new noninvasive imaging technologies that the National Institute of Bioimaging and Bioengineering is particularly concerned with, for remote sensing of abnormalities—biological abnormalities or physiological abnormalities that can be transmitted to Earth via very, very good signals, but using noninvasive imaging techniques, whether it's the new adaptation, as I mentioned, for motion sickness, or, in the case of our Institute and the Institute on Aging, to better understand why these organ systems, like bone and like muscle, dissipate so quickly. I mean, it's rather dramatic, and, as a consequence of what we've learned from space, or even simulated space on Earth—not as good as what goes on in the Station—we have learned about cells, how cells adapt themselves, and what we can do to try to obviate some of that adaptation or to block that adaptation.

So, I think virtually every organ system—you've heard the advances that we will see as a tangible benefit with the fiber optic probe in identifying early crystal formation in the lens—it may be the same for other noninvasive diagnostic techniques.

So, in the area of diagnosis, in the area of understanding pathophysiology, and in the area of understanding basic mechanisms of how our body works and how our cells work together, I think there'll be many advances in this area.

Senator NELSON. The Augustine Commission is saying that we're basically flat if we don't get $3 billion more a year for NASA for the human spaceflight program; $30 billion over 10 years. What happens if President Obama won't support this and the Congress cannot produce it?

Any one of you.

Dr. PACE. Well, we're not going beyond low-Earth orbit, which means that we'll be simply there at the Space Station. And a lot of useful things will still be accomplished at the Space Station, but the danger is, is that there's nothing that goes beyond that. Now, extending the Space Station for another couple of decades, that probably would be something that might be—even be worthwhile, and we'll have the data upon which to judge that. But, if we're not traveling beyond lower Earth orbit and we're not really exploring,

then I think we're doing a disservice to the recommendations of the Columbia Accident Investigation Board, and I think we are ceding the future to others, who will move out maybe more slowly than we would, move out in a different way than we would, but I think it represents a stepping back of this country and an acceptance of a second position that I don't think that is in our long-range national interests.

I would submit that the monies that—being talked about, additional $3 billion—a gradual increase—I don't think all that money has to show up in one lump sum, but building back to that level. The NASA budget today, if it was at the same level of constant dollars that it was in at the end of Fiscal Year 1993, would be about $21 billion.

So, we're not talking about an agency increasing, in constant-dollar terms, in some dramatic level. In fact, we're really talking about restoring some of the decline that has occurred over the last decade and a half. And I fully echo Dr. Fisk's point about making sure that you restore that funding so that the kind of triage that was necessary, or felt necessary in other areas of human spaceflight, doesn't have to occur. Because I think everyone did regret those losses. But, they were necessary and painful without more money.

Senator NELSON. How so a disservice to the Columbia Accident Investigation Board?

Dr. PACE. Well, this goes into the issue of questions. At the *Challenger* accident, the Nation asked a question about whether or not it was worth risking human life to send unmanned payloads into orbit. And the answer was "no," and we shifted those payloads off onto expendable rockets.

Columbia raised an even more profound question, which is: For what purposes is it worth risking human life? And the answer that they came back with was not a specific plan or a specific architecture, but saying that we need to be playing for high stakes. It cannot simply be that to occupy low-Earth orbit. And if we're not going to play for high stakes to answer questions such as: Does humanity have a future beyond the Earth?

I mean, I think our science colleagues are really great at asking profound questions to which very, very detailed programs and strategies then result. I think a question for human spaceflight is, Does humanity have a future beyond the Earth? And the answer is either "yes" or "no," both of which are profound. What that future might be, how it might be contained, is worth risking human life, but simply staying in low-Earth orbit—and, again, with all recognition of the Space Station—I don't think is really going to be significant. And I think that is the reason why we would do a disservice to the *Columbia* results.

Senator NELSON. Dr. Fisk?

Dr. FISK. I'd liked echo a couple of thoughts. I view this as a watershed decision that we make as a Nation, because if we retreat, if we just say we confine ourselves to low-Earth orbit, we grant the high ground to whoever can get there from other nations. We can't just step back from human spaceflight. If we do we've stepped back from our image as a Nation as we have constructed it over 200

years, which is at the forefront, pressing the frontier, being a leader in the world, being a strategic leader in the world.

And so, this is not a small decision based on $3 billion; this is a decision, I think, that is based upon what we view as the future of the Nation and its role in the world as a strategic leader. And if we wish to maintain that position, human spaceflight and all of the space program is an integral part of that—the basis for our strategic leadership. And we cannot—we shouldn't abandon it.

Dr. BECKER. I would——

Senator NELSON. Dr. Becker?

Dr. BECKER.—I would like to echo very similar comments, in that, yes, our international colleagues will pursue with their initiatives, and they are looking to us to be a leader, but if we allow them to pursue with initiatives to go beyond low-Earth orbit, and we don't dedicate any resources to do so ourselves, we're not just a follower, we're a nonstarter. And I have to wonder, What kind of a message does that give to our young people in the country who are looking to be inspired and who—a lot of them now in schools are coming from other countries. And I—and for our own kids, what are we saying when we don't agree to explore, and what kind of limitations are we placing on ourselves as a nation?

And one thing that I—that comes to mind is, we've been talking a lot about science on ISS, but there's also the kind of science that inspires children. And there was a study funded, actually by NSBRI, and it was to look at how spiders and butterflies grow in space. What kind of webs do the spiders spin? And two spiders were sent up there in separate cages. There was a big spider and a little spider—and, actually, the little spider was more aggressive—and there were bets placed on who's going to win if something happens. The big spider got out of its cage, and this made CNN headlines. It was amazing how many people—kids, adults, everyone—wanted to know what happened to the spider. And, eventually, the spider wound up in the other one's cage, but that's the kind—you can't plan that sort of inspiration and excitement. And that happened in low-Earth orbit. I can only imagine what could happen beyond.

Senator NELSON. I think you all have captured the essence of the character of the American people, that we are, by nature, explorers and adventurers, and we've always had a frontier. If we give up that pursuit, we become a second-rate nation. This is a decision that the President is going to have to make. From your advice, which we hope will be made known to the White House counsels, it has built a very strong case for us to proceed to explore the Heavens.

So, thank you very much for this hearing.

And the hearing is adjourned.

[Whereupon, at 4:45 p.m., the hearing was adjourned.]

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