COMMERCE, JUSTICE, SCIENCE, AND RELATED AGENCIES APPROPRIATIONS FOR FISCAL YEAR 2010

THURSDAY, MAY 21, 2009

U.S. SENATE,
SUBCOMMITTEE OF THE COMMITTEE ON APPROPRIATIONS,
Washington, DC.

The subcommittee met at 11:05 a.m., in room SD–192, Dirksen Senate Office Building, Hon. Barbara A. Mikulski (chairman) presiding.

Present: Senators Mikulski, Nelson, Shelby, and Voinovich.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

STATEMENT OF CHRISTOPHER J. SCOLESE, ACTING ADMINISTRATOR

OPENING STATEMENT OF SENATOR BARBARA A. MIKULSKI

Senator MIKULSKI. Good morning, and welcome to the Subcommittee on Commerce, Justice, and Science. I'd like to welcome Mr. Scolese from the NASA Goddard Space Flight Center in my State.

We have heard testimony from several Presidents' administrations, we've had Nobel Prize winners, and now we're actually going to have astronauts in space. As I understand it, it is the very first time that we will receive testimony from space.

One could make jokes about it, and maybe we've heard it before when it's been coming from outer space, but today it will be the real deal.

As we prepare for that, know that I've also asked one of our colleagues who is an astronaut Senator Bill Nelson, to join us for that part of the hearing. The Senate is a wonderful institution, we've actually had three astronaut Senators—John Glenn, Jake Garn, and Bill Nelson.

And one today which, really, with the Hubble, Senator Shelby and I have been together on the Hubble for 19 years, as was Senator Kit Bond.

I really want to pay tribute to both Senator Glenn—when I took over this subcommittee so many years ago he was a learned counselor and adviser to help me really understand the breadth and depth of the American Space Program.

I also want to pay tribute to Senator Jake Garn, who was my ranking member in those days and on a bipartisan basis we worked together to do many sound things to achieve a balanced space program. And Senator Garn brought a measure of great civility and

an enormous knowledge, and I feel that I was able to launch my career in trying to help the American Space Program because of the excellent guidance and tutelage, those two space astronaut Senators gave me.

So, with that, I also, want to welcome Chris Scolese to the hearing. He's no stranger to us, he's served as NASA's Chief Engineer since 2007, and was the Deputy Director of the Goddard Space Flight Center.

I want to thank Administrator Scolese for steering the NASA ship during this time of transition. It has indeed been in competent hands, and I want to thank you for your fidelity, for your competence, and for your stewardship. It exactly shows why we need a civil service, and why we need a NASA civil service. You truly have been part of that senior executive corps, providing hands-on leadership, as well as motivation of his staff, as we go through very difficult times.

So, I really want to thank you, and I think, you know, I want to just give you a little round of applause. I'm sorry more colleagues are not here, they'll be here for the more glitzy part of it, but we think you're glitzy, too.

Later on in the hearing, as I said, we're going to talk to 7 of our very daring and courageous astronauts from Space Shuttle Atlantis.

But let us get right to the heart of why we're here, which is the NASA 2010 budget request. It's for $18.7 billion—$1 billion above the omnibus level—and also, NASA has received $1 billion in the American recovery stimulus package. So, between the 2010 budget request, the Recovery Act, NASA will receive $2 billion more than they have in the past. This is a real victory.

Unfortunately, these gains don't continue into the future, and this is where we're deeply troubled. We're concerned that NASA is flat-lined after 2010.

But there's promising news within the 2010 budget, as well. We're heartened that science is funded at $4.5 billion, with greater investments in Earth science as we study our own planet, and look to distant stars.

We also note that in other areas of science, the budget totals of $4.5 billion, and NASA is being guided by the decadal reports prepared by the National Academy of Science. These are roadmaps for us, and we believe science at NASA saves lives, saves the planet, and creates jobs for the future. We're very heartened that we will continue to look at green science as we look at Planet Earth, but at the same time, to do other forms of science, related to planetary science, as well as solar science. And we're going to continue our mission development in telescopes, like the James Webb telescope.

In aeronautics research, the budget request is for $507 million, roughly the equivalent of the 2009 omnibus level. This is disappointing. The aeronautics budget in 1998 was $1.5 billion, 10 years ago, aeronautics was one of the keystones of the NASA budget. We've got to get back to this, because we believe that in order to maintain U.S. leadership in aeronautics, we need to make those public investments in development of technologies that increase our competitive edge in aircraft and airspace for safer, better, faster transportation.

The budget also reflects money for the Space Shuttle, and the space station, $3.2 billion for the Space Shuttle, $2.3 billion for the space station.

The budget calls for eight more flights to the space station, and we'll be discussing this in a very active way with the acting administrator. Eight more flights before the end of the fiscal year 2010.

We know the administration is committed to these remaining flights, and we know that delays that can occur in the Shuttle schedule, and we're concerned that there's no funding in the budget to keep a transition going.

As we retire the Shuttle, and we must do it with honor, we also have to acknowledge the wonderful workforce that has kept the Shuttle flying all of these years. And that this transitioning of the workforce is a major challenge for NASA, for the administration, and quite frankly for the Congress to work on a bipartisan basis with us.

The United States can't afford to lose this talent. Our talent in science and engineering continues to be needed, so we need to really take a fresh, creative way of looking at this workforce.

As our courageous astronauts perform amazing feats, we also need to know that with that Space Shuttle, safety has to be our number one concern, our number one priority that is a—absolutely needs to ensure. We need to ensure their safety, no matter what.

Now, this budget is a down payment on a balanced space program. Some years ago, a man by the name of Norm Augustine chaired a White House Commission for the President—a Republican President, I might add—and we've followed that for years, that we would have a commitment to human space exploration, a reliable and safe space transportation system and that we would do science, and we would do aeronautics.

Well, here we are again, where we're asking Norm Augustine to chair a Commission in terms of human flight. We look forward to the way that the Augustine review will take place, and hopefully it will help us, guide us on this.

Let me conclude, though, by saying we're deeply troubled by the cost overruns at NASA. Since 2006, 10 of the 12 NASA projects in development have exceeded baseline cost in schedules. This has cost credibility with NASA and the Congress. So, whenever they want to do something new that's dazzling, that's important to either our economics or to science, or to exploration, we wonder what we're getting into. And what we think we're getting into either doubles or triples or so on. And there is a growing concern among our colleagues that because of flawed estimates that there is a reluctance to begin what we need to do.

I believe we need to tackle this, and we're going to look for your ideas on how to do that.

But I want to conclude by saying this is a very special year in NASA's space history. It's the 50th anniversary of when NASA was created. It's the 40th anniversary, this July—July 20—of when we landed on the Moon. It's the 25th anniversary of when Dr. Sally Ride was the first woman to go into space, and of course, the beloved, and cherished Hubble Telescope, the people's telescope, is celebrating its 19th year in space, and like a lot of us, it's had ups and downs and needed a lot of help.

So, we look forward to hearing from you, we think the President has done a good job in making recommendations in this budget, but we think there's more work to be done.

Now I'd like to turn to my ranking member, Senator Shelby.

STATEMENT OF SENATOR RICHARD C. SHELBY

Senator SHELBY. Thank you, Madam Chairwoman.

Mr. Scolese, thank you for joining us today, and thank you for the work that you've done over the years at NASA.

This is a sizable sum with our budget, considering the funding constraints that the Federal Government faces. This is a $903 million, or 5.1 percent increase over the 2009 funding level.

This would provide—but it doesn't begin to provide enough for NASA to do all of the critical missions it has been asked to do.

The proposed budget has welcome increases in the areas of science and exploration, and maintains aeronautics funding at an acceptable level. However, more than 21 percent of NASA's budget, nearly $4 billion, is being set aside as a placeholder, while NASA turns its manned space program over to, what will hopefully be an independent, and unconstrained blue-ribbon panel.

While there are a few developments at NASA to be excited about, there are even more that are troubling.

For starters, we are just now receiving a budget proposal from the administration that claimed it was able to hit the ground running, and was ready to lead.

With the nominee for the Administrator's post that was barely announced less than a week ago, the administration, I believe, has chosen to let their budget proposal be the face of NASA until a successful nominee is confirmed, in order to shepherd this Nation's space priorities through Congress.

In the case of the future for human space flight in some lunar science missions, the administration has made Norm Augustine that Chairwoman Mikulski referenced, the de facto interim Administrator, further delaying any plan for over $4 billion of NASA's budget until weeks before the start of the fiscal year.

Such timing will not allow for NASA to potentially re-plan a major component of their budget, or for Congress to review the inclusion of this funding in fiscal year 2010.

Rather than rush such a monumental decision, any suggested changes should inform the development of the 2011 budget, once the ramifications of the recommendations can be fully vetted and authorized by Congress.

The proposed budget—while addressing issues of climate change, unmanned exploration and aeronautics research—shortchanges, I believe, our most viable and visible and inspiring manned space flight program. Instead of providing Constellation with funds to move forward, it is delaying the current mission, while seeking to have a do-over on plans that have been authorized by both a Republican and Democratic Congress.

I believe it should be remembered that, while the Hubble Telescope has brought us amazing images, and deepened our understanding of the universe, this marvelous instrument would still be on the ground, without our manned space program.

It is our distinct pleasure today to be able to talk to the crew—as Chairwoman Mikulski said—of the Atlantis, as they return to Earth from a successful mission. They will be the last, I believe, of Americans to travel farther away from the Earth than the Space Station for years to come.

I believe that manned space flight is something that is still in the realm of Government, because despite their best efforts, some truly private enterprises have not been able to deliver on plans of launching vehicles.

SpaceX claimed that they would be launched by 2004, and had a grandiose vision of manned flights launching by early this year. Unfortunately, the reality is that out of four attempts, they've only delivered a single dummy payload to space, have never delivered any payload to the Space Station, much less a human.

However grandiose the claims of proponents for commercial orbital transportation services, part D, they cannot substitute for the painful truth of failed performance, at present. For all of the hype, and the hundreds of millions in taxpayer dollars invested in cargo-only delivery, we still await the first successful completion of a single mission that delivers a real payload, not a simulated dummy.

I ask—is this the hope we will hitch our dreams of the future of manned space flight to? Will unproven cargo capabilities close the manned space flight gap faster than the work NASA has done on Ares and Orion? Are we to entertain the idea of placing people on a rocket that has yet to deliver a single real payload of any kind into space? I would have trouble, Madam Chairwoman, supporting a budget that is poised to eliminate a real manned space program, and instead maintains the fantasy of one.

This course, I believe, will only extend the time we will have to rely on the Russians to get our astronauts to a space station for which we have invested billions of dollars.

Without truly supporting and building upon the human and heavy-lift launch capabilities that are already under development, our astronauts will have no choice but to wave at the Russians, perhaps the Chinese, and possibly astronauts from India and other countries, as they pass by the Space Station on their way to exploring space.

As our astronauts endlessly circle the Earth in the future, astronauts from other nations, perhaps, will be exploring well beyond the edges of Earth's atmosphere and will become the inspiration of America's children. Is that what we want? I hope not.

We may be the leader in manned space flight today, but the eventual ramifications of this budget, as I understand it, has the potential to ensure that this lead will end, perhaps forever.

PREPARED STATEMENT

I look forward to hearing from you today, but the reality is that rocket science is tough, it is not a cheap venture, and it is not without risk. As a former NASA Administrator recently said, and I'll quote, "A fictional space program will always be faster, better, and cheaper than a real space program, but it won't be one."

Thank you.

[The statement follows:]

PREPARED STATEMENT OF SENATOR RICHARD C. SHELBY

Thank you, Madam Chairwoman. Mr. Scolese, thank you for joining us today to discuss the fiscal year 2010 budget proposal for the National Aeronautics and Space Administration (NASA). NASA's proposed budget is $18.7 billion. This is a $903 million, or 5.1 percent, increase over the fiscal year 2009 funding level.

This is a sizeable sum considering the funding constraints that the Federal Government faces, yet it still does not begin to provide enough for NASA to do all of the critical missions it has been asked to do. The proposed budget has welcomed increases in the areas of science and exploration, and maintains aeronautics funding at an acceptable level. However, more than 21 percent of NASA's budget, nearly $4 billion, is being set aside as a placeholder while NASA turns its manned space program over to what will hopefully be an independent and un-constrained blue ribbon panel.

While there are a few developments at NASA to be excited about, there are even more that are troubling. For starters, we are just now receiving a budget proposal from an administration that claimed it was able to hit the ground running and was ready to lead. Without even a nominee for Administrator, this administration has chosen to let their budget proposal be the face of NASA until a successful nominee is confirmed in order to shepherd the Nation's space priorities through Congress.

In the case of the future for human space flight and some lunar science missions, the Administration has made Norm Augustine the de facto interim administrator, further delaying any plan for over $4 billion of NASA's budget until weeks before the start of the fiscal year. Such timing will not allow for NASA to potentially replan a major component of their budget, or for Congress to review for inclusion this funding in fiscal year 2010. Rather than rush such a monumental decision, any suggested changes should inform the development of the 2011 budget once the ramifications of the recommendations can be fully vetted and authorized by Congress.

The proposed budget, while addressing issues of climate change, un-manned exploration, and aeronautics research, shortchanges our most visible and inspiring space program, manned space flight. Instead of providing Constellation with funds to move forward, it is delaying the current mission while seeking to have a do-over on plans that have been authorized by both a Republican and Democratic Congress.

It should be remembered that while the Hubble telescope has brought us amazing images and deepened our understanding of the universe, this marvelous instrument would still be on the ground without our manned space program. It is our distinct pleasure today to be able to talk with the crew of Atlantis as they return to Earth from a successful mission. They will be the last Americans to travel farther away from Earth than the space station for years to come.

I believe that manned space flight is something that is still in the realm of government because, despite their best efforts, some truly private enterprises have not been able to deliver on plans of launching vehicles. Space-X claimed that they would be launching by 2004 and had grandiose visions of manned flights launching by early this year. Unfortunately the reality is that out of four attempts, they have only delivered a single dummy payload to space, have never delivered any payload to the space station, much less a human. However grandiose the claims of proponents for Commercial Orbital Transportation Services part D (COTS–D) are, they cannot substitute for the painful truth of failed performance at present.

For all the hype and the hundreds of millions in taxpayer dollars invested in cargo only delivery, we still await the first successful completion of a single mission that delivers a real payload, not a simulated dummy.

I ask, is this the hope we will hitch our dreams of the future of manned space flight? Will these unproven cargo capabilities close the manned spaceflight gap faster than the work NASA has done on Ares and Orion? Are we to entertain the idea of placing people on a rocket that has yet to deliver a single, real, payload of any kind to space?

I would have trouble supporting a budget that is poised to eliminate a real manned space program and instead maintains the fantasy of one. This course will only extend the time we will have to rely on the Russians to get our astronauts to a space station for which we have invested billions.

Without truly supporting, and building upon the human and heavy lift launch capabilities that are already under development, our astronauts will have no choice but to wave at the Russians, the Chinese, and possibly astronauts from India, as they pass by the space station on their way to exploring space. As our astronauts endlessly circle the Earth, the astronauts of other nations will explore well beyond the edges of Earth's atmosphere and will become the inspiration of America's children. We may be the leader in manned space flight today, but the eventual ramification of this budget has the potential to ensure that this lead will end forever.

The reality is that rocket science is hard. It is not a cheap venture, and it is not without risk. As the former NASA Administrator recently said, "a fictional space program will always be faster, better, and cheaper than a real space program."

I look forward to working with NASA and the Administrator, once one is nominated and confirmed, to move the real space program at NASA and its exploration goals forward in the next fiscal year.

Thank you.

Senator MIKULSKI. Senator Voinovich, are you prepared to stay for the hearing, so we could go to Scolese?

Senator VOINOVICH. I am, but I have a short statement.

Senator MIKULSKI. Would you like to make it?

Senator VOINOVICH. Yes, I would.

Senator MIKULSKI. Sure.

STATEMENT OF SENATOR GEORGE V. VOINOVICH

Senator VOINOVICH. Thank you very much for having this hearing, and it's my first opportunity to be on this subcommittee, and Mr. Scolese, thank you for your participation here.

I want you to know that NASA is very close to me, I'm wearing this watch that was given to me by the crew of the STS–70, the all-Ohio crew that happens to have the OSU Buckeye sign on it.

We're all aware of what NASA's done, and their engineering and scientific accomplishments. Given the complexity and uniqueness and variety of the missions that are managed under the NASA umbrella, it's of utmost importance that the Agency have adequate human capital framework to ensure their success, and I just want you to know how pleased I am with the fact that NASA has used the additional flexibilities that we gave them in 2004 so that you could go out and recruit the best and brightest people to work for NASA.

In addition to that, I'd like to thank you and former Administrator Griffin for the fact that you came up with a program at a very difficult time to maintain the 10 centers that we had throughout the United States. And I want to applaud you that you took back in work that was going out to other contractors to try and maintain the in-house capability of NASA.

I am also please, Madam Chairwoman, that when there was a concern about whether or not you were going to continue your commitment to aeronautics, and I agree with you, Madam Chairwoman, that that budget for aeronautics ought to be reviewed.

But I'm also grateful that you identified our, as Glenn, for the CEV and for the launch vehicle, that we now have a new mission.

I think the real challenge now is to make sure that we allocate these resources in the places that it makes the most difference. And I think that Senator Shelby makes a very good point about dealing with some of the real-world things, and I think the American public is going to demand that, and I'm certainly hoping that Mr. Augustine takes that into consideration when he comes back to make his recommendations to NASA.

I have to say that I was concerned about what the administration would do about the NASA budget. There was many of us that felt that because of other priorities, that the NASA budget would be shortchanged. That hasn't been the case—as Senator Shelby says, there's been an increase of 5.1 percent. So, somebody did a

pretty good job with OMB, convincing them that this program was worthwhile.

PREPARED STATEMENT

And I keep emphasizing—as I had when I was mayor, and Governor of Ohio—that too often NASA does not do a good enough job in letting the folks of this country know how the work that they're doing has so many other things that make a difference in people's lives. In other words, not just up in space, but all of these things that you're doing, do impact—remarkably—the quality of life of people here in this country.

And we've seen this at Cleveland Clinic. They've taken a lot of stuff that you guys have developed, and put it to work to save people's lives.

So, I'm anxious to hear your testimony today.

[The statement follows:]

PREPARED STATEMENT OF SENATOR GEORGE V. VOINOVICH

Good Morning. Thank you Chairwoman Mikulski and Ranking Member Shelby for convening today's hearing. Thank you Mr. Scolese for participating. I am looking forward to hearing more about the administration's fiscal year 2010 budget request and what NASA has in store for the future.

NASA's engineering and scientific accomplishments have long been a symbol of America's innovation and technological excellence.

Given the complexity, uniqueness, and variety of missions that are managed under the NASA umbrella, it is of utmost importance that the agency have an adequate human capital framework to ensure mission success. That is why I have utilized my role on the Homeland Security and Government Affairs Subcommittee on Oversight of Government Management, the Federal Workforce and the District of Columbia to work with NASA to improve its workforce development.

I am proud that the agency has made substantial and commendable strides in its human capital management since 2004, when my legislation, the NASA Flexibility Act, was signed into law. NASA has certainly done a much better job in recruiting, developing, and retaining the staff it needs to execute the agency's missions.

As a former mayor of Cleveland and governor of Ohio, I have been concerned for many years about NASA Glenn's struggle to obtain an identifiable mission. When I spoke with several of NASA Glenn's administrators a few years ago, we were all worried about restoring NASA's aeronautics funding and setting NASA Glenn on a clear mission forward.

In 2005, when Mike Griffin became NASA's administrator, I met with him to discuss the future of NASA Glenn, and he assured me he was not only focused on keeping NASA centers around the country functioning, but also that he was committed to finding a new mission for Glenn. I was pleased with Griffin's leadership. He did a great job managing and maintaining the ten NASA research centers at a time when the agency was going through a difficult transition.

I am so glad he was able to work with Lockheed Martin to see NASA Glenn secure an identifiable mission that included testing and certification of the Crew Exploration Vehicle (CEV) as well as overseeing the development of several Crew Launch Vehicle (CLV) upper stage systems.

But the staffs at NASA Glenn and at the Plum Brook facility are eager to do more.

Glenn is renowned for its blend of aeronautics and space flight experience. Together, NASA Glenn Research Center and the Air Force Research Lab at Wright-Patterson Air Force Base have helped shape Ohio as a global leader in aerospace design and production.

I am generally pleased with where NASA has been headed, but concerned that with the impending retirement of the Space Shuttle, and its replacement by the next generation of human space flight systems that shifting priorities within NASA could lead to the transfer of NASA Glenn Research Center's mission responsibilities to other NASA centers.

It is my hope that the vitality of Glenn be maintained, and that the Obama Administration and its future nominee for NASA administrator would continue its commitment to the "10 Healthy Center Concept."

Mr. Scolese, thank you again for joining us, I am eager to hear your thoughts on the future NASA.

Senator MIKULSKI. Mr. Scolese, please proceed.

STATEMENT OF CHRISTOPHER J. SCOLESE

Mr. SCOLESE. Thank you, Chairwoman Mikulski, Ranking Member Shelby, and members of the subcommittee. Thank you for inviting me here today to discuss the President's fiscal year 2010 budget request of $18.686 billion for NASA.

The President's request is $903.6 million above the fiscal year 2009 omnibus appropriation.

First, let me note that NASA's fiscal year 2009 budget is $18.8 billion, or about $1.2 billion above the fiscal year 2009 request. This reflects an increase of $168 million in the regular appropriations, and about $1 billion in the Recovery Act.

NASA is appreciative of the support of this committee, and the Congress, for the full funding of the fiscal year 2009 request, and the additional Recovery Act funds, which will enable NASA to meet critical priorities.

The President's fiscal year 2010 request includes $4.5 billion for science. In Earth Science, NASA is continuing to work aggressively to implement the recommendations of the decadal survey. The first two decadal missions—SMAP and ICESat–II, continue formulation. The next two DESDynI and CLARREO—will be accelerated and NASA will issue its first Venture-class announcement of opportunity this year.

Over the next year, we plan to launch the Glory and Aquarius missions, the GOES–O mission for NOAA, and complete the development of the NPOESS Preparatory Project.

We will continue development of the foundational missions, including the global precipitation mission, the landsat data continuity mission, and initiate work on a thermal infrared sensor.

NASA is currently assessing options to recover from the disappointing loss of the Orbiting Carbon Observatory, and we will keep you informed of our findings and plans.

In planetary science, we are continuing the exploration of the solar system with the Juno mission to Jupiter, the Mars Science Laboratory, and the MAVEN Scout mission to Mars.

In astrophysics, I'm pleased to report that the final Hubble servicing mission EVA was completed on Monday, and earlier this week, the Space Shuttle successfully released a revitalized Hubble Space Telescope. We look forward to many more years of discoveries from Hubble. Development continues on the James Webb Space Telescope, which passed its confirmation review last year, and has an Agency commitment to launch in 2014.

NASA's fleet of heliophysics missions located throughout the solar system is providing researchers the first ever comprehensive view of solar influences on the Earth and other planets.

The fiscal year 2010 budget request of $507 million renews NASA's commitment to a strong program in aeronautics, that will continue to contribute to the economic well-being and quality of life of Americans through its partnerships with industry, academia, and other government agencies.

Our Airspace Systems Program continues to collaborate with the Joint Planning Development Office to enhance the capacity, efficiency, and flexibility of the National Airspace System.

In exploration, the President's fiscal year 2010 budget request of $3.963 billion is an increase of $457 million above the fiscal year 2009 omnibus appropriations level, and $225.4 million above last year's plan. This increased budget will support continued progress to advance the development of the next-generation human spaceflight system to carry American crews and supplies to space and return Americans to the Moon. Specifically, the Lunar Reconnaissance Orbiter and the Lunar Crater Observation Sensing Satellite spacecraft are ready for launch next month. Later this year, two major test flights will be conducted: the Ares 1–X developmental test flight from KSC, and the Orion Pad Abort I test at the White Sands Missile Range.

At the request of the Director of the Office of Science and Technology Policy, NASA is initiating an independent review of U.S. human space flight plans, conducted by a panel of outside experts, chaired by Norm Augustine. The review will examine ongoing and planned NASA human spaceflight development activities and potential alternatives, and present options for advancing a safe, innovative, sustainable, and affordable human spaceflight program in the years following Shuttle retirement. It will also evaluate options for extending ISS operations beyond 2016. The panel will present its results by August 2009. During the review, the NASA workforce will continue to work on all current exploration projects, including the Ares I and Orion.

The President's fiscal year 2010 budget request includes $6.176 billion for Space Operations, which funds the safe flight of the Space Shuttle to complete the eight remaining scheduled flights to the ISS and then retire the Shuttle. We believe these flights can be accomplished by the end of 2010. This month, the ISS will host its first six-person crew, and next month, the STS–127 mission will deliver the third and final component of the Japanese Kibo laboratory, setting the stage for full research utilization of the ISS.

Last December, NASA awarded two commercial resupply services contracts to develop vehicles needed to deliver supplies and experiments to the ISS. The benefits from NASA's human spaceflights programs are ultimately demonstrated in the inspiration of the next generation of Americans, which was reflected recently in the delighted faces of students who participated in the uplink phone call between President Obama and the combined Shuttle and Station crews last month.

Finally, the fiscal year 2010 request supports NASA's Education Program, to continue developing a future aerospace, technical, and scientific workforce, improving the technological competitiveness of our Nation's universities, and attracting and retaining students in science, technology, engineering, and mathematics disciplines.

PREPARED STATEMENT

This request also funds the NASA cross-agency support programs, which provide critical mission support activities, necessary to assure the efficient and effective operation and administration of the Agency and its Centers.

Madam Chair, thank you again for your support, and that of this committee, I would be pleased to respond to any questions you may have.

[The statement follows:]

PREPARED STATEMENT OF CHRISTOPHER J. SCOLESE

Chairwoman Mikulski and members of the subcommittee, thank you for the opportunity to appear today to discuss the President's fiscal year 2010 budget request for NASA. The President's fiscal year 2010 budget request for NASA is $18.686 billion. The fiscal year 2010 request represents an increase of $903.6 million above the amount provided for NASA in the fiscal year 2009 Omnibus Appropriations Act (Public Law 110–8). The fiscal year 2010 budget does a number of things: it supports the administration's commitment to deploy a global climate change research and monitoring system; it funds a strong program of space exploration involving humans and robots with the goal of returning Americans to the moon and exploring other destinations; and it supports the safe flight of the Space Shuttle to complete assembly of the International Space Station by the Space Shuttle's planned retirement.

Highlights of the Fiscal Year 2010 Budget Overview

With the fiscal year 2010 budget request, NASA advances global climate change research and monitoring. The NASA investment in Earth science research satellites, airborne sensors, computer models and analysis has revolutionized scientific knowledge and predictions of climate change and its effects. Using the National Research Council's recommended priorities for space-based Earth science research as its guide, NASA will develop new space-based research sensors in support of the administration's goal to deploy a global climate research and monitoring system. NASA will work to deploy these new sensors expeditiously while coordinating with other Federal agencies to ensure continuity of measurements that have long-term research and applications benefits.

The fiscal year 2010 NASA request funds a robust program of space exploration involving humans and robots. NASA's astronauts and robotic spacecraft have been exploring our solar system and the universe for more than 50 years. The Agency will create a new chapter of this legacy as it works to return Americans to the Moon by 2020. NASA also will send a broad suite of robotic missions to destinations throughout the solar system and develop a bold new set of astronomical observatories to probe the mysteries of the universe, increasing investment in research, data analysis, and technology development in support of these goals.

With the fiscal year 2010 request, NASA will complete the International Space Station (ISS) and advance the development of new space transportation systems and the unique scientific research that can be conducted onboard the ISS. The fiscal year 2010 budget request funds for the safe flight of the Space Shuttle to complete the ISS, incorporates an additional flight to deliver the Alpha Magnetic Spectrometer (AMS) to the ISS, and then retires the Shuttle. NASA is committed to completing these nine remaining scheduled Shuttle flights, including the current mission underway to service the Hubble Space Telescope, which we believe can be accomplished by the end of 2010. Funds freed from the Shuttle's retirement will enable the Agency to support development of systems to deliver people and cargo to the ISS and the Moon and explore other destinations. As part of this effort, NASA will stimulate private-sector development and demonstration of vehicles that may support the Agency's human crew and cargo requirements for ISS. In addition, the Agency will continue to utilize the ISS, the permanently crewed facility orbiting Earth that enables the Agency to develop, test, and validate critical space exploration technologies and processes, and to conduct microgravity research. NASA also will continue to coordinate with international partners to make this platform available for other government entities, commercial industry, and academic institutions to conduct research.

At the request of the Director of the Office of Science and Technology Policy, NASA is initiating an independent review of planned U.S. human space flight activities, with the goal of ensuring that the Nation is on a vigorous and sustainable path to achieving its boldest aspirations in space. This review will be conducted by a blue-ribbon panel of outside experts chaired by Norman R. Augustine. The panel will present its results in time to support an administration decision on the way forward by August 2009. This Review of U.S. Human Space Flight Plans will examine ongoing and planned NASA human space flight development activities, as well as potential alternatives, and present options for advancing a safe, innovative, afford-

able, and sustainable human space flight program in the years following completion of the current Space Shuttle manifest and retirement. The independent review panel will seek input from Congress, the White House, the public, industry, and international partners. In addition, the review will examine the appropriate amount of R&D and complementary robotic activities needed to make human space flight activities most productive and affordable over the long term, as well as appropriate opportunities for international collaboration. It will also evaluate what capabilities would be enabled by each of the potential architectures considered. And it will evaluate options for extending International Space Station operations beyond 2016. We will keep the Congress informed, as appropriate, with the progress of the review.

It is important to note that the President has submitted a fiscal year 2010 budget request for NASA Exploration Systems of $3.963 billion, an increase of $457.6 million above the fiscal year 2009 Omnibus Appropriations level. During the review, the NASA workforce will continue to focus on the safe flight and operation of the Space Shuttle and ISS, and continue to work on all current exploration projects, including Ares I, Orion, and Commercial Crew and Cargo efforts.

The President's fiscal year 2010 budget request includes $507 million for Aeronautics Research, renewing NASA's commitment to cutting-edge, fundamental research in traditional and emerging disciplines to help transform the Nation's air transportation system and to support future aircraft. NASA research will increase airspace capacity and mobility, enhance aviation safety, and improve aircraft performance while reducing noise, emissions, and fuel consumption. The Integrated Systems Research Program, a new program beginning in fiscal year 2010, will conduct research at an integrated system-level on promising concepts and technologies and explore, assess, and demonstrate the benefits in a relevant environment.

Finally, consistent with administration priorities, NASA is developing plans to stimulate innovation and increase investments in technologies for the future while ensuring that nearer-term Agency commitments are met.

NASA Initial Fiscal Year 2009 Operating Plan and Recovery Act Funding

Before I highlight key accomplishments and plans for activities across the Agency, I would like to summarize NASA's initial fiscal year 2009 Operating Plan, including Recovery Act funding, as recently submitted to the subcommittee. The initial fiscal year 2009 Operating Plan is $18,784.4 million, or $1,170.2 million above the President's fiscal year 2009 request, which reflects an increase of $168.2 million in the regular appropriation and $1,002.0 million in the Recovery Act. NASA is appreciative of the action by the Committees on Appropriations and Congress in providing regular appropriations for the Agency with full funding for Science, Aeronautics, Exploration, Space Shuttle, ISS, and Education. This total fiscal year 2009 appropriations level, with minor adjustments within the total, will enable NASA to meet critical priorities, in accordance with the direction from the Congress and the President. NASA also appreciates the efforts by the subcommittees to include funding for NASA in the Recovery Act. This funding will help NASA achieve programmatic goals in Science, Exploration and Aeronautics, and repair damage done to the NASA Johnson Space Center during Hurricane Ike, and support national recovery goals.

NASA has allocated the $1,002.0 million in Recovery Act funds as follows:

—Science, $400.0 Million
  —Earth Science, $325.0 Million
  —Astrophysics, $75.0 Million
—Aeronautics, $150.0 Million
—Exploration, $400.0 Million
  —Constellation Systems, $250.0 Million
  —Commercial Crew & Cargo, $150.0 Million
—Cross Agency Support, $50.0 Million
—Inspector General, $2.0 Million

I would be happy to address the objectives to which NASA is applying the Recovery Act funds in detail.

Science

NASA's Science Mission Directorate continues to expand humanity's understanding of our Earth, our Sun, the solar system and the universe with 57 science missions in operation and 31 more in development. The Science budget funds these missions as well as the research of over 3,000 scientists and their students across the Nation. The President's fiscal year 2010 request for NASA includes $4,477.2 million for Science.

The Science budget request includes $1,405.0 million for Earth Science in fiscal year 2010, and steadily increases Earth science funding in the outyears. NASA's 15

Earth Science missions in operation provide a large share of the global observations used for climate change research in the United States and elsewhere. This year, NASA's Earth Science satellites enabled research to understand how changes both in the tropics and in Arctic sea ice are changing ocean biology globally. NASA also recently conducted the first Ice Bridge aircraft campaign to demonstrate a new airborne laser capability to bridge the gap in time between ICESats 1 and 2. In fiscal year 2010, NASA plans to launch the Glory mission to map atmospheric aerosols and continue the long record of solar influences on climate, and the Aquarius mission to provide the first global measurements of sea surface salinity. NASA will complete development of the NPOESS Preparatory Project and continue development of the Global Precipitation Mission and the Landsat Data Continuity Mission (LDCM). The request fully funds development of a Thermal Infra-red Sensor (TIRS) at a total cost of approximately $150–175 million. A decision whether to fly TIRS on LDCM or another spacecraft will be made this summer; meanwhile, funding for TIRS is carried within the LDCM budget. The launch vehicle failure of the Orbiting Carbon Observatory (OCO) was a significant loss to the climate science communities, and NASA is assessing options to recover from that loss; we will inform the Congress of the results of these studies when they become available. NASA is continuing to work aggressively to implement the recommendations of the National Research Council Decadal Survey for Earth Science. The first two Decadal Survey missions, SMAP and ICESat-II, will continue formulation in fiscal year 2010, and the next two, DESDynI and CLARREO, will be accelerated and transition to formulation. NASA also expects to issue its first Venture-class Announcement of Opportunity later this year, implementing another important decadal survey recommendation.

The fiscal year 2010 Science budget request includes $1,346.2 million for Planetary Science. NASA's Planetary Science missions continue to return images and data from the far reaches of the Solar System. This year, the Mars Phoenix Lander completed its mission, conducting the first chemical test providing evidence of water ice on another planet. MESSENGER returned stunning imagery of portions of the planet Mercury never before seen. The Cassini spacecraft continues to provide unparalleled science of the Saturnian system; the spacecraft flew within 25km of Enceladus viewing the ejecting plumes and surface, and data from 19 fly-bys of Titan enabled creation of a radar map showing 3–D topography revealing 1,200-meter (4,000-foot) mountain tops, polar lakes, vast dunes, and thick flows from possible ice volcanoes. Development is continuing on the Juno mission to Jupiter for launch in 2011. NASA and ESA jointly announced they will work together on a Europa Jupiter System mission as the next outer planets flagship mission. The rovers Spirit and Opportunity continue to study the Martian surface and have exceeded their 5-year of successful operations. NASA is continuing development of the Mars Science Laboratory (MSL) for launch in 2011 and selected MAVEN, a Mars aeronomy mission, as the next Mars Scout mission for launch in 2013. NASA has integrated its lunar science research program with the Lunar Precursor Robotic Program into a single Lunar Quest Program under the Science Mission Directorate, which includes the LADEE mission, the U.S. nodes of the ILN, and a new virtual university research collaboration called the NASA Lunar Science Institute. The Moon Mineralogy Mapper (M3) was launched aboard Chandrayaan-1 and has begun making scientific observations of the Moon's composition. Development is continuing on the GRAIL mission to map the Moon's gravity field for launch in 2011. NASA has issued an Announcements of Opportunity for the next New Frontiers mission, and will do so for the next Discovery mission later this year.

The fiscal year 2010 Science budget request includes $1,120.9 million for Astrophysics. 2009 is the International Year of Astronomy, and NASA's Astrophysics program will deploy exciting new capabilities for studying the cosmic frontier. The Kepler mission, launched in March, is NASA's first mission dedicated to the search for Earth-like planets in our galaxy. ESA will launch the Herschel and Planck missions in April, carrying several NASA instruments, to study the far-infrared sky and the cosmic microwave background. The final Hubble Space Telescope serving mission aboard STS–125, currently in progress, is upgrading the observatory to its peak scientific performance. Late this calendar year, NASA plans to launch the Wide-field Infrared Survey Explorer (WISE) as part of its highly successful Explorer Program, following on the recent successes of the Fermi Gamma-ray Space Telescope (launched as GLAST in July 2008), which has provided the best-ever view of the gamma-ray sky revealing energetic sources in our solar system, our galaxy, and galaxies billions of light-years away. Development is continuing on the James Webb Space Telescope, which passed its Confirmation Review in 2008 and has an Agency commitment to launch in 2014. Development continues on the NuSTAR mission to study black holes for launch in 2011, along with a Soft X-ray Spectrometer to fly

on Japan's Astro-H mission in 2013. Development continues on the airborne Stratospheric Observatory for Infrared Astronomy or SOFIA, which will conduct open door flight tests in 2009 and early science flights in 2010, with planned full operational capability in 2014. Conceptual design is continuing for ambitious future mission concepts to investigate the origins of planets, stars, and galaxies; to search for Earth-like planets around nearby stars; and to examine the nature of dark energy, dark matter, gravity waves, and black holes. These and other mission concepts are currently under consideration by the NRC's decadal survey for Astrophysics, or Astro 2010, which will be completed during 2010, and will provide recommendations to NASA on the science community's highest priority science questions and strategic missions for the next decade.

The fiscal year 2010 Science budget request includes $605.0 million for Heiophysics. The fleet of NASA Heliophysics missions strategically placed throughout the solar system is providing researchers the first ever solar system-wide view of solar influences on the Earth and other planets, and the dynamic structures of space itself. This virtual "Great Observatory" is in place and functioning for the next solar magnetic activity cycle, and has already detected the first signs of a new solar maximum anticipated for 2011–2012. Late this year or early next, the launch of Solar Dynamics Observatory will add to this fleet the capability to observe the solar atmosphere to a depth one-third of the Sun's radius to study the flow of plasmas that generate magnetic fields and the sudden changes that produce coronal mass ejections that we experience as space weather. Also this year, NASA plans to select two Small Explorer (SMEX) missions in response to an Announcement of Opportunity issued in 2008, which could be either Heliophysics or Astrophysics missions depending on the proposals selected. Development of the Radiation Belt Storm Probes mission to study the interactions of space weather events with Earth's magnetic field is continuing for launch in 2012. The Magnetosphere Multi-Scale mission to observe the processes of magnetic reconnection, energetic particle acceleration, and turbulence in Earth's magnetosphere will undergo a Confirmation Review this year for a planned launch in 2014. Finally, NASA is continuing early formulation work on the Solar Probe-Plus mission that will travel into, and sample, the near-Sun environment to probe the origins of the solar wind.

Aeronautics Research

NASA's fiscal year 2010 budget provides $507 million for Aeronautics Research. Over the past year, the Aeronautics Research Mission Directorate has continued to pursue long-term, innovative, and cutting-edge research that develops revolutionary tools, concepts, and technologies to enable a safer, more flexible, environmentally friendly, and more efficient national air transportation system. NASA Aeronautics Research also plays a vital role in supporting NASA's space exploration activities.

A primary goal across Aeronautics Research programs is to establish strong partnerships with industry, academia, and other government agencies in order to enable significant advancement in our Nation's aeronautical expertise. NASA has put many mechanisms in place to engage academia and industry, including industry working groups and technical interchange meetings at the program and project level, Space Act Agreements (SAAs) for cooperative partnerships, and the NASA Research Announcement (NRA) process that provides for full and open competition for the best and most promising research ideas. To date, 68 SAAs have been established with industry partners across all programs and 375 NRAs have been awarded to academia, industry and non-profit organizations. NASA Aeronautics has continued to collaborate with the Joint Planning Development Office (JPDO), Federal Aviation Administration (FAA), U.S. Air Force, Army, and other government organizations.

New for fiscal year 2010, $62.4 million has been provided for the Integrated Systems Research Program (ISRP) to conduct research at an integrated system-level on promising concepts and technologies and explore, assess, or demonstrate the benefits in a relevant environment. The research in this program will be coordinated with on-going, long-term, foundational research within the three other research programs, and will be closely coordinated with other Federal Government agency efforts. The project within ISRP will be the Environmentally Responsible Aviation (ERA) Project, a "green aircraft initiative," that will explore and assess new vehicle concepts and enabling technologies through system-level experimentation to simultaneously reduce fuel burn, noise, and emissions. The ERA project will transfer knowledge outward to the aeronautics community so that aircraft and propulsion system manufacturers can confidently transition these technologies into new products, as well as transfer knowledge inward to the Fundamental Aeronautics Program when the need for further development at a foundational level is identified.

NASA's Airspace Systems Program (ASP) has partnered with the JPDO to help develop concepts, capabilities and technologies that will lead to significant enhance-

ments in the capacity, efficiency and flexibility of the National Airspace System. For fiscal year 2010, ASP has been reorganized from the NextGen Airspace and NextGen Airportal projects into the NextGen Concepts and Technology Development project and the NextGen Systems Analysis, Integration and Evaluation project. The distinctions between airport operations, terminal-area operations and en-route operations were sometimes confusing, leading to time expended determining the line of demarcation between the responsibilities of the two projects. A more significant distinction is the development of air traffic management concepts and the technologies that enable air traffic management improvements and the evaluation of these concepts and technologies at a system level. The previously planned work on airspace concepts, technologies and systems will continue. This new project structure is better aligned to the nature of the work being performed. A notable accomplishment for ASP is the successful completion, by NASA researchers in collaboration with academia and the FAA, of a series of human-in-the-loop experiments that explored advanced concepts and technology for separation assurance, which ensures that aircraft maintain a safe distance from other aircraft, terrain, obstacles, and certain airspace not designated for routine air travel. The technology being developed by NASA and its partners is critical to relieving air-traffic controller workload, a primary constraint on airspace capacity that is expected to increase in coming years. In the future, this Program will continue to develop new technologies to solve important problems such as surface traffic planning and control, and initial algorithms for airport arrival and departure balancing as well as developing traffic flow management concepts for increased efficiencies at the regional and national levels for different planning intervals.

NASA's Fundamental Aeronautics Program (FAP) conducts research in all aeronautics disciplines that enable the design of vehicles that fly through any atmosphere at any speed. For fiscal year 2010, all ARMD research into planetary entry, descent and landing (EDL) has been consolidated into the Hypersonics project in FAP. EDL is an integral part of many space missions and is not easily divided into distinct hypersonic and supersonic phases. This change will provide more focus to technical developments and will also yield technical management efficiencies. The FAP program has supported the testing of various new concepts that will help enable much improved capabilities for future vehicles. For example, wind-tunnel testing was conducted for several promising powered lift concepts. Powered lift concepts increase lifting force on an aircraft at slow speeds (e.g., at take-off and landing) without increasing drag under cruise conditions. Successful use of the concepts will enable short take-off and landings on runways less than 3,000 feet, which will increase next-generation air transportation system capacity through the use of shorter fields and improved low-speed maneuverability in airport terminal areas. Testing was also completed for a Smart Material Actuated Rotor Technology (SMART) helicopter rotor, which offers the potential for significant noise and vibration reduction in rotorcraft. Future work includes technologies and advanced tools to evaluate the trades between noise, emissions, and performance of future aircraft entering service in the 2012–2015 timeframe. Additionally, with the transfer of technologies to be matured to system-level within ISRP, the Subsonic Fixed Wing (SFW) project is streamlining its research content. This is enabling new efficiencies across the foundational disciplines remaining in the project. The integrated system-level research in this program will be coordinated with on-going, long-term, foundational research within the three other research programs, and will focus specifically on maturing and integrating technologies in major vehicle systems and subsystems for accelerated transition to practical application.

NASA's Aviation Safety Program (AvSP) continues to develop tools and technologies to improve on today's incredibly safe air transportation system, while ensuring that future technologies can be safely incorporated to the system. Examples of advances that support this development include NASA's ongoing and new research into aircraft icing. For example, with current knowledge we cannot extrapolate how ice forms on a straight wing such as found on a turbo-prop to how it will form on a swept wing, or a radically new aircraft configuration. The Aviation Safety Program is tackling this with a combination of computational models and experiments in NASA's Icing Research Tunnel. We are establishing that, in high and cold flight conditions, ice can form deeper in jet engines than previously understood. NASA is working collaboratively with the FAA, industry and international partners, such as the National Research Council of Canada, to conduct tunnel tests of the underlying physics, to fly our instrumented S–3 Viking into such engine icing conditions, and design upgrades to our Propulsion System Lab in which jet engines may be tested in detail. Additional future work in Aviation Safety includes addressing gaps in validation and verification of critical flight software, developing new data-analysis capabilities to mine aviation operational data for safety issues, examining

the safety of new vehicle systems and structures, and tackling the biggest human factors issues in the NextGen flightdeck.

NASA's Aeronautics Test Program (ATP) is focused on ensuring a healthy suite of facilities and platforms to meet the Nation's testing needs including the development of new test instrumentation and test technologies. As part of its continuous efforts to improve facility operational efficiencies, ATP initiated the National Force Measurement Technology Capability, to address the severe erosion of NASA's capability to utilize strain gage balances in wind tunnel testing. The National Partnership for Aeronautics Testing, a strategic partnership between NASA and the Department of Defense (DOD), recently commissioned a study of government-owned, mid-to-large supersonic facilities necessary to fulfill future air vehicle test requirements. The Program will continue to develop a long-term strategic approach that aligns the NASA and DOD facilities to meet future requirements with the right mix of facilities and appropriate investments in facility capabilities.

Exploration Systems

Human space flight is important to America's political, economic, technological and scientific leadership. In the span of a few short years, NASA has already taken long strides in the formulation of strategies and programs to develop a robust program of space exploration. These critical steps will allow our Nation to build the next-generation space flight vehicles that will carry humans and deliver cargo to the ISS and the Moon, and on to other destinations in our solar system. The President's fiscal year 2010 budget request for Exploration Systems is $3,963.1 million, an increase of $457.6 million above the fiscal year 2009 appropriation and $225.4 million above the planned fiscal year 2010 level in last year's request. Based on the Recovery Act funds and the President's increased budget request for fiscal year 2010, the Exploration Systems budget plan includes about $630 million more in fiscal year 2009 and fiscal year 2010 than the previous plan. At this critical juncture, full funding at the President's requested level is essential for expediting development of new U.S. human space flight systems to support the International Space Station and explore the Moon and other destinations beyond low Earth orbit.

The Constellation Program will apply additional Recovery Act funds to critical activities related to the successful completion of the Orion, Ares I and Ground Operations projects. The Commercial Crew and Cargo Program plans to use Recovery Act funds to stimulate efforts within the private sector in order to develop and demonstrate technologies that enable commercial human space flight capabilities—efforts that are intended to foster entrepreneurial activity leading to job growth in engineering, analysis, design, and research, and to economic growth as capabilities for new markets are created.

Following the Review of U.S. Human Space Flight activities, the administration will provide an updated request for Exploration activities, as necessary. In the meantime, NASA is proceeding as planned with current Exploration activities, including Ares I, Orion, Commercial Crew and Cargo efforts, and lunar systems.

During the past year, NASA Exploration Systems continued to make significant progress in developing the next-generation U.S. human space flight vehicles and their associated ground and mission support systems. In the next several weeks, the first lunar robotic mission, the Lunar Reconnaissance Orbiter and the Lunar Crater Observation Sensing Satellite spacecraft, will be launched from the Cape Canaveral Air Force Station aboard an Atlas V, which will help NASA scout for potential lunar landing and outpost sites. Later this year, two major test flights for the Constellation Program will be conducted: Ares I–X is the first developmental test flight to support the design of the Ares I Crew Launch Vehicle; and the Pad Abort 1 (PA–1) is the first test of the Launch Abort System to be used on the Orion Crew Exploration Vehicle. NASA will continue to work with other nations and the commercial sector to coordinate planning, leverage investment, and identify opportunities for specific collaboration on Exploration activities.

The Constellation Program continues to complete the formulation phase of its projects—in particular Ares I, Orion, and major ground facilities. Major development work is underway, contracts are in place; and we have a dedicated group of civil servants and contractors who are all working hard to accomplish the Constellation Program's objectives. So far, NASA engineers have conducted about 6,500 hours of wind tunnel testing on subscale models of the Ares I to simulate how the current vehicle design performs in flight. These wind tunnel tests, as well as the Ares I–X test flight, will lay the groundwork for maturing the Ares I final design prior to its Critical Design Review (CDR). When launched later this year from NASA's Kennedy Space Center in Florida, the Ares I–X will climb about 25 miles in a 2-minute powered test of the First Stage performance and the First Stage separation and parachute recovery system. Work on the Orion Project also continues to advance.

Recently, NASA conducted testing of the water recovery process for the Orion capsule, and NASA also selected the material for Orion's heat shield. Later this year, Orion's PA–1 test will take place at White Sands Missile Range, New Mexico. PA–1 will demonstrate the Launch Abort System's ability to pull crew to safety should there be an emergency while the Orion and Ares I stack is still on the launch pad.

In September 2008, Ares I completed a key milestone with its Preliminary Design Review (PDR). PDR is the final step of the initial design process, and thereby a crucial milestone during which the overall project verifies that the preliminary design can meet all requirements within acceptable risk limits and within cost and schedule constraints, and identifies technical and management challenges and addresses approaches for eliminating or mitigating them. This fall, the Orion is expected to have progressed to the point of completing PDR, and obtaining Agency approval to proceed to Critical Design Review (CDR). Current plans call for Ares I to progress to the point of obtaining Agency approval by early 2010 to proceed to CDR.

As part of the Commercial Crew and Cargo Program and its associated Commercial Orbital Transportation Services (COTS) cargo projects, NASA is completing its promised $500 million investment to the two funded COTS partners, Space Exploration Technologies Corporation (SpaceX) of El Segundo, California, and Orbital Sciences Corporation (Orbital) of Dulles, Virginia. Recently, SpaceX successfully operated the full complement of the first stage engines of the Falcon 9, the SpaceX launch vehicle. Orbital continues to progress in achieving engineering milestones, and completed its PDR earlier this month. In addition, NASA has two non-funded COTS partners.

The transition of NASA facilities, infrastructure, property, and personnel from the Space Shuttle Program to the Constellation Program continues to be a major activity. This joint effort between the Space Operations and Exploration Systems Mission Directorates includes the utilization and disposition of resources, including real and personal property; personnel; and processes in order to leverage existing Shuttle and Space Station assets for NASA's future Exploration activities.

NASA's Advanced Capabilities programs include the Human Research Program (HRP) and the Exploration Technology Development Program (ETDP). These programs continue to reduce risks for human explorers of the Moon and beyond by conducting research and developing new technologies to aid future explorers. HRP focuses on the highest risks to crew health and performance during exploration missions while also developing and validating a suite of human health countermeasures to facilitate long-duration space travel. For example, NASA is conducting research to better understand the effect of space radiation on humans and to develop effective mitigation strategies. This year, HRP delivered a space radiation risk assessment tool, provided cockpit display design requirements for the Orion spacecraft, and provided design requirements for the new Constellation Space Suit System. HRP is also conducting research onboard the ISS with regard to: the cardiac structure and function of astronauts; radiation shielding technologies; and, the effect that certain pharmaceuticals may have on the prevention of bone loss during long-duration missions. ETDP will conduct a range of activities, including testing cryogenic hydrogen and methane propulsion systems for future missions; developing a small pressurized rover for transporting astronauts on the lunar surface; and demonstrating the capability to produce oxygen from lunar soil. ETDP also is conducting experiments on the Space Station to investigate the behavior of fluids and combustion in microgravity, and operating instruments to monitor atmospheric contaminants on the Space Station.

Space Operations

The fiscal year 2010 budget request includes $6,175.6 million for Space Operations.

It is an exciting time for NASA's Space Shuttle Program. At this moment, the astronauts of Shuttle Atlantis are in orbit on STS–125, the final mission to service the Hubble Space Telescope. We anticipate that the work they are doing, which includes upgrading the Hubble's instruments, should extend the observatory's operational life several years. The President's fiscal year 2010 budget funds the safe flight of the Space Shuttle to conduct its remaining missions, including the AMS flight and completing assembly of the ISS. NASA is committed to completing the eight remaining scheduled Shuttle flights, which we believe can be accomplished by the end of 2010. These Shuttle flights will leave the ISS in a configuration to support a broad portfolio of research and to receive and be maintained by commercial cargo services. The fiscal year 2010 budget request includes $3,157.1 million for the Space Shuttle Program.

NASA and its Russian, European, Canadian, and Japanese International Space Station partners are working together to realize one of the most inspiring dreams

of the last 50 years: the establishment of a station in Earth orbit for the conduct of various types of research. We are now approaching two significant milestones. In May, the ISS will host its first six-person crew. The recent delivery of the Station's final set of solar arrays and other equipment by the crew of STS–119 represents the final step toward this goal. In June, the STS–127 mission will deliver the third and final component of the Japanese Kibo laboratory—the Kibo Exposed Facility. The addition of the Exposed facility enables the Kibo laboratory, with the European Columbus module and the U.S. Destiny module, to complete the three major international science labs on ISS, setting the stage for utilization of ISS as a highly capable microgravity research facility. The President's fiscal year 2010 budget request includes $2,267.0 million for the ISS.

The ISS will represent both an unparalleled international cooperative effort and a U.S. National Laboratory in orbit. Scientists will be able to conduct biomedical and engineering research from a unique vantage point. Some of the work will increase our knowledge of the effects of long-duration human space flight, which is critical for the design and operation of future human space vehicles, including those being developed under the Constellation Program to return U.S. astronauts to the Moon and explore other destinations. Other research will not be focused on space exploration at all, but may have significant applications right here on Earth. Medical research, for example, may be applicable to the development of vaccines; NASA's research into salmonella aboard the Space Shuttle and ISS has already increased our knowledge in this area. In the key areas of energy and the environment, the ISS serves as a daily demonstration of "green" technologies and environmental management techniques. The ISS receives 120kW of power from its solar arrays to operate the Station and run experiments. The ISS environmental system is designed to minimize the amount of mass that has to be launched from Earth to support the Station, so recycling is a must. STS–119 supplied ISS with a replacement Distillation Assembly for Station's water recycling system, which is key for supporting a full six-person crew for extended periods of time. Given the central role science and technology play in our society, it is important that the United States maintain a leadership role in these fields. The availability of a research laboratory in the microgravity environment of space will support this aim.

Another benefit from Space Shuttle missions and ISS research is reflected in the programs' ability to inspire the next generation of Americans. This was reflected recently in the delighted faces of students who participated in the uplinked phone call between President Obama and the crews of the ISS and STS–119 on March 24. The ISS will support the President's goal of making math and science education a national priority by demonstrating what can be accomplished through science and engineering, and by inspiring both teachers and students.

NASA is relying on U.S. industry to develop vehicles to deliver supplies and experiments to the ISS. In December 2008, the Agency awarded two Commercial Resupply Services (CRS) contracts for the provision of this critical capability. Cargo resupply is important for the continued viability of ISS. In addition, the vendors involved will gain valuable experience in the development and operation of vehicles that can (1) fly to the ISS orbit; (2) operate in close proximity to the ISS and other docked vehicles; (3) dock to ISS; and, (4) remain docked for extended periods of time.

The fiscal year 2010 budget request includes $751.5 million for Space and Flight Support, which supports Space Communications and Navigation, Launch Services, Rocket Propulsion Testing, Crew Health and Safety, and the new Human Space Flight Operations programs.

Education

The fiscal year 2010 budget request for Education totals $126.1 million and furthers NASA's commitment to Science, Technology, Engineering, and Mathematics (STEM) education. NASA will continue its successes in developing a future aerospace workforce, improving the technological competitiveness of our Nation's universities, attracting and retaining students in STEM disciplines, and engaging the public in NASA's missions. NASA will accomplish these goals by offering competitive research grants to universities, providing targeted educational support to Minority Serving Institutions, and strengthening curricula at 2-year community colleges. NASA's plans to streamline and centralize internship and fellowship application processes will realize cost savings and facilitate student access to information while attracting a wider, more diverse participant base. The Agency is also seeking new opportunities for student involvement in current space and aeronautics research missions and flight projects, including those using high altitude balloons, sounding rocket payloads, airborne sensors, and space satellites. NASA will further these efforts through a new project, Innovation in STEM Education, which will allow the Agency to investigate and offer opportunities for student and faculty to participate

in NASA-related research. In coming months, the Agency will complete award announcements for competitive grant programs in K–12, global climate change, and informal education, and revise and issue new solicitations using fiscal year 2009 funds.

NASA will further pursue a goal to attract and retain students in STEM disciplines in the upcoming fiscal year. Last year, the Interdisciplinary National Science Program Incorporating Research & Education (INSPIRE) program engaged over 200 high schools in STEM areas, and NASA Explorer Schools conducted instructional and enrichment activities that reached over 105,000 students. The March 2009 STS–119 mission also provided a unique educational opportunity as two Mission Specialists who are science teachers, Joe Acaba and Richard Arnold, were part of the crew. NASA Education continues to provide internships, fellowships, and research opportunities to help students and educators gain hands-on experiences in a range of STEM-related areas. These opportunities provide students with the motivation, inspiration, and experience needed to serve the Nation's current and future workforce needs. In fiscal year 2008, the Agency provided more than 3,000 summer internships, reached 5,331 students through significant research experience or grants, and provided 139 grants to underrepresented and underserved institutions.

NASA will also engage elementary and secondary school and informal education audiences by using Earth and deep space observations, the flight experience of Educator Astronaut Dorothy Metcalf-Lindenburger aboard STS–131, as well as future missions to the Moon and other destinations. New technologies such as social networks, Internet collaborations, a new virtual magnet school, and remote control of science instruments will expand and enhance these efforts. In fiscal year 2010, NASA also plans to provide an online professional development system for students training to become educators, in-service teachers, and informal educators. Additionally, NASA will promote continuous public awareness of its mission and improvement to STEM literacy by partnering with informal education providers, which allows Agency partners to share the excitement of NASA missions with their visitors in meaningful ways.

Cross-Agency Support

NASA Cross-Agency Support provides critical mission support activities that are necessary to ensure the efficient and effective operation and administration of the Agency, but cannot be directly aligned to a specific program or project requirement. These important functions align and sustain institutional and program capabilities to support NASA missions by leveraging resources to meet mission needs, establishing Agency-wide capabilities, and providing institutional checks and balances. Cross-Agency Support includes Center Management and Operations, Institutional Investments, and Agency Management and Operations. The fiscal year 2010 budget request includes $3,400.6 million for Cross Agency Support.

Center Management and Operations funds the critical ongoing management, operations, and maintenance of nine NASA Centers and major component facilities. NASA Centers continue to provide high-quality support and the technical talent for the execution of programs and projects. The fiscal year 2010 budget request includes $2.084 million for Center Management and Operations.

Institutional Investments funds design and execution of non-programmatic revitalization construction of facilities projects, demolition projects for closed facilities, and environmental compliance and restoration activities. The Construction of Facilities Program makes capital repairs and improvements to NASA's critical infrastructure to improve safety and security and improve NASA's operating efficiency by reducing utility usage. NASA continues to right size the infrastructure by demolishing facilities that are no longer needed. Emphasis has been placed on energy and water conservation. Currently, NASA has five buildings that are certified under the Leadership in Energy and Environmental Design (LEED) criteria, three additional buildings that are built and awaiting certification as LEED Silver facilities, and 13 buildings in various stages of design and construction as High Performance Buildings and are expected to be LEED-certified when completed. The fiscal year 2010 budget request includes $355.4 million for Institutional Investments.

NASA's fiscal year 2010 request includes $961.2 million for Agency Management and Operations, which funds the critical management and oversight of Agency missions, programs and functions, and performance of NASA-wide activities, including five programs: Agency Management, Safety and Mission Success, Agency Information Technology Services, Innovative Partnerships Program, and Strategic Capabilities Assets Program.

—The fiscal year 2010 budget request provides $412.7 million for Agency Management, which supports executive-based, Agency-level functional and administrative management requirements. Agency Management provides for the oper-

ational costs of Headquarters as an installation; institutional and management requirements for multiple Agency functions; assessment and evaluation of NASA program and mission performance; strategic planning; and independent technical assessments of Agency programs.

—The fiscal year 2010 budget request provides $183.9 million for Safety and Mission Success activities required to continue strengthening the workforce, training, and strengthening the fundamental and robust cross-checks applied on the execution of NASA's mission, and to improve the likelihood for safety and mission success for NASA's programs, projects, and operations. The engineering, safety and mission assurance, health and medical independent oversight, and technical authority components are essential to NASA's success and were established or modified in direct response to many of the key Challenger and Columbia accident board recommendations for reducing the likelihood for future accidents. Included under Safety and Mission Success is the Software Independent Verification and Validation program.

—The fiscal year 2010 budget request for Agency Information Technology Services is $150.4 million, which encompasses cross-cutting services and initiatives in IT management, applications, and infrastructure necessary to enable the NASA Mission and improve security, integration and efficiency of Agency operations. NASA plans significant emphasis on continued implementation of five major Agency-wide procurements to achieve the following: (1) consolidation of IT networks leading to improved network management, (2) consolidation of desktop/laptop computer services and mobile devices to improve end-user services, (3) data center consolidation to provide more cost-effective services, (4) Agency public web site management to improve access to NASA data and information by the public, and (5) Agency business systems development and maintenance to provide more efficient and effective business systems. NASA will also continue to improve security incident detection, response, and management through the Security Operations Center.

—The request for the Innovative Partnerships Program (IPP) is $184.8 million. IPP works with all four Mission Directorates to provide innovations meeting NASA's technology needs, and transfers NASA technology for broad Spinoff applications that improve quality of life and contribute to economic growth. Included in the IPP portfolio are: NASA's SBIR/STTR Programs seeking out innovative high-technology small businesses; a new Innovative Technology Project seeking high-impact revolutionary research and technology projects; a Seed Fund to address technology needs through cost-shared, joint-development partnerships; use of commercial flight services by the FAST program to demonstrate new technologies; Innovation Ambassadors to exchange ideas; and the Centennial Challenges prize program for the citizen inventor. IPP seeks partnerships through offices at all 10 NASA Centers.

—Finally, NASA is requesting $29.4 million in fiscal year 2010 for the Strategic Capabilities Assets Program (SCAP). This program funds the costs required to sustain key Agency test capabilities and assets, such as an array of flight simulators, thermal vacuum chambers, and arc jets, to ensure mission success. SCAP ensures that assets and capabilities deemed vital to NASA's current and future success are sustained in order to serve Agency and national needs. All assets and capabilities identified for sustainment either have validated mission requirements or have been identified as potentially required for future missions.

Conclusion

The President's fiscal year 2010 budget request for NASA supports the administration's commitment to deploy a global climate change research and monitoring system, funds a robust program of space exploration involving humans and robots with a goal to return Americans to the Moon by 2020 and explore other destinations, and funds the safe flight of the Shuttle to complete assembly of the ISS through its retirement, planned for the end of 2010. The fiscal year 2010 budget request funds continued use of the ISS to enable the Agency to develop, test, and validate critical exploration technologies and processes and, in coordination with our international partners, to make the ISS available support other government entities, commercial industry and academic institutions to conduct unique research in the microgravity environment of space. It will also stimulate private sector development and demonstration of vehicles that may support NASA's cargo and crew requirements. And it renews NASA's commitment to aeronautics research to address fundamental aeronautics, aviation safety, air traffic management, and mitigating the impact of aviation on the environment. NASA's diverse portfolio of science, technology, engineering and mathematics (STEM) educational activities is also aligned with the administration's goal of improving American innovation and global competitiveness.

NASA looks forward to working with the subcommittee on implementation of the detailed fiscal year 2010 budget request.

Madam Chair, thank you for your support and that of this subcommittee. I would be pleased to respond to any questions you or the other members of the subcommittee may have.

HUMAN SPACEFLIGHT

Senator MIKULSKI. Thank you, Mr. Scolese. My areas of questioning will be in three categories, which of course, the Spaceflight and the reliability of our space transportation system for the remaining eight missions, space—the scientific endeavors that are supported in the President's budget which is really a robust commitment to science; and also, the acquisition issues.

Let me go to the Spaceflight issue. The administration is committed to flying the Space Shuttle 8 more times to finish the Space Station. The budget assumes that this can be done by 2010. The Shuttle program is a $3 billion a year program, so here is my question. One, can you envision a scenario where you would keep flying the Shuttle past 2010, and second, if you have to, if you can't complete the 8 missions, where will the money come from if the Shuttle flights have to be extended?

Mr. SCOLESE. Yes, as I mentioned earlier——

Senator MIKULSKI. In other words, do you have an ending date where you blow a whistle and the racks come down, and it's goodbye to the Shuttle?

Mr. SCOLESE. No, we don't have an ending date. We are committed to flying the manifest, which is the remaining eight flights, we look at that regularly, almost weekly, to look at what our logistics chain is, and what's available and what the current situation is.

As of today, we believe that we can complete those missions by the end of September 2010. Clearly, if we run into any serious difficulties, that we have to slip, and we would have to go beyond the September date.

We don't foresee those at this stage of the game. We have margin in the date to September 2010. However, if we did have to slip, if it was a significant slip, months or more, we will have to find additional resources to cover that slip. And we would either have to come in and ask for an increase in the budget if we knew early enough about it, or we would have to go off and take resources from other parts of NASA.

Senator MIKULSKI. But the administration is counting on these 8 flights to be done by 2010.

Mr. SCOLESE. Yes.

Senator MIKULSKI. And there is no contingency plan beyond that, except, "If we get to it, we'll deal with it?"

Mr. SCOLESE. Well, as I was saying, based on what we see we believe—that we can make that date. We have not working towards a date, I need to be careful about that—but our planning indicates that 2010 is a very achievable date.

SOYUZ

Senator MIKULSKI. Right, well let me move ahead, then.

Let's go to the Soyuz, which is our only way that, if our astronauts get into difficulty, we can return them safely.

There's been much in the press about the Soyuz, number one, its ongoing reliability, and also what they're charging us to do—to be this standby vehicle, which we're absolutely dependent upon. Could you tell us, number one, what is in the budget to—how many—what are we, essentially, what is our—what is it that we're requesting of the Russians, how many Soyuz flight guarantees and, is the money in the budget to do that, and do you believe that those—that money is reasonable, or does it require some diplomatic negotiation?

Mr. SCOLESE. Well, today we believe the money is reasonable. As you pointed out, we've been relying on the Soyuz for crew rescue since the initiation of the Space Station. So, it's always been a part of the program for that aspect of it. And, of course, following the *Columbia* tragedy, we were relying on the Soyuz to take our crew up to the Station and back.

In the time between Shuttle retirement and the availability of Orion to take crew up and back, we will be relying on the Soyuz. We do not buy Soyuz, so to speak, we buy seats. We buy the training, the flight up, the flight back, and all of the logistics associated with a long-duration mission, and that's how we negotiate with the Russians. We're in the process of negotiating with them for the duration of that gap. And, to date, as we're saying, we're still negotiating, it's about $47 million a seat, today. And the press has reported, but we're still negotiating, about $51 million for the future.

Senator MIKULSKI. Well, my time has expired, I think that it goes through those. I do have workforce questions, and then science and acquisition, but let me turn to my colleagues and we'll come back for another round.

NASA'S SPEND PLAN

Senator SHELBY. Thank you, Madam Chair.

The Congress explicitly provided $400 million to the exploration program in 2009 economic stimulus bill to close the gap between the Shuttle and constellation programs, as I understand it.

It's my understanding that NASA's spend plan included the redirection of $150 million for new initiatives related to commercial, crew, and cargo. Based on what little detail we've learned from NASA, it appears these funds are for entirely new activities that have not even been formally presented or reviewed by the Congress. What's going on, here? What other options were examined for Ares and Orion with the $150 million, prior to it being proposed for commercial studies, as I understand it. Tell us what's going on, here?

Mr. SCOLESE. Certainly. Of the $400 million that was appropriated, $250 million is being used to accelerate and improve the situation for Ares and Orion, by procuring long-lead materials that we needed——

Senator SHELBY. Why do you need to use it all?

Mr. SCOLESE. Well, I'll get to that. And certainly more would allow us to do more. We did look at the overall system when we came up with the plan, and we invested $150 million in commercial crew.

It's broken into two fundamental categories—$70 million is something that will broadly support not only commercial activities, but all activities associated with the Space Station.

One example of those is the human rating requirements. Human rating—we do these missions so infrequently that we need to go off and catalogue those so that anybody that wants to come to the Space Station will clearly understand what it is that we need to do. Anybody that wants to fly a NASA astronaut will understand how we want to fly.

And then $80 million is available through competition, but first, we're going to go off and issue a broad area announcement to see if there is interest in providing commercial crew capabilities, and then we will—and only then—will we obligate those funds.

SECTION 505 OF THE OMNIBUS

Senator SHELBY. It's my understanding that section 505 of the omnibus clearly prohibits funding for new activities. Did Congress approve what you're doing, here, for the redirection of the funds?

Mr. SCOLESE. Well, we submit it as part of our operating plan, so——

Senator SHELBY. But you hadn't had an approval of it, had you? By the Congress.

Mr. SCOLESE. Not at this time.

Senator SHELBY. Don't you think you need—if section 505 of the omnibus prohibits funding for new activities, did you consider that?

Mr. SCOLESE. Well, I think we had authority to go off and work commercial activities, and that's what we're trying to do here, and we submitted it as part of the operating plan. I'd have to go back and look at the details——

Senator SHELBY. Will you check that for the record?

Mr. SCOLESE. I will check that for the record, sir. Yes, sir.

[The information follows:]

FISCAL YEAR 2009 RECOVERY ACT SPEND PLAN

Section 505, Title V, Division B of the fiscal year 2009 Omnibus Appropriations Act (Public Law 111–8), states that "None of the funds provided under this Act, or provided under previous appropriations Acts . . . shall be available for obligation or expenditure through the reprogramming of funds that creates or initiates a new program, project or activity."

Since NASA's initial Operating Plan defined the activities that would be undertaken by the Agency in response to the American Recovery and Reinvestment Act of 2009 (Public Law 111–5), the Operating Plan does not represent a re-programming from a previous baseline. The Recovery Act funds did not identify specific activities, so the initial Operating Plan represents the proposed baseline for these funds. While some of the specific activities may be new or identified uniquely for the first time, they are all supporting NASA's existing authorized and appropriated programs and projects.

ARES-V

Senator SHELBY. Because some of the people on our staff are concerned about this.

Ares-V delay—NASA has repeatedly stated that the constellation programs will continue as usual while the human space flight review is underway. While this may be true for Ares I and Orion, other facets of constellation—it's my understanding they're being held back. The heavy-lift vehicle, Ares-V, has been specifically de-

layed, pending an altered request due to the human spaceflight study, it's my understanding.

If constellation is moving forward, then why is Ares-V, the heavy-lift rocket, that is essential to landing a man on the Moon, being delayed? This is unusual business. What's going on, here?

Mr. SCOLESE. Well, you're absolutely right—Ares-V is absolutely critical if we're going to get humans back to the Moon, and outside of low Earth orbit, plus for other activities. We are not stopping work on Ares-V. There is continued work——

Senator SHELBY. You're still committed to Ares-V, aren't you?

Mr. SCOLESE. I'm sorry.

Senator SHELBY. NASA's committed to Ares-V.

Mr. SCOLESE. Oh, absolutely. We have to have that type of a vehicle, Ares-V, in order to get out of low-Earth orbit. And, in fact, work being done on Ares I is directly applicable to Ares-V, the solid rocket motor, the J2X engine in the upper stage, plus we have, you know, individuals at our space flight centers, also continuing to work on Ares-V.

Clearly there could be implications as a result of the review that's going on this summer, but as the President's budget said, they want to return humans to the Moon, and there's only one way to do that, with the heavy-lift launch vehicle, and Ares-V is the one that's on the books today.

Senator SHELBY. How much of the $30 million for Ares-V in the 2009 bill will you spend? Will you spend that this year?

Mr. SCOLESE. I expect that we will, but I'd like to get back to you for the record.

[The information follows:]

ARES-V

The fiscal year 2009 Operating Plan contains $30 million for the Ares-V. That money is expected to be fully expended in 2010.

Senator SHELBY. You going to get back in the next 10 days or so?

Mr. SCOLESE. Yes, sir.

Senator SHELBY. Does the action by NASA at that point, dealing with Ares-V delay indicate there's already a pre-determined outcome, as it relates to Ares-V?

Mr. SCOLESE. No. I mean, as I said earlier, the only way we're going to get out of low-Earth orbit is with a vehicle, and a substantial vehicle, and Ares-V is the one that——

Senator SHELBY. You've got to have it, hadn't you?

Mr. SCOLESE. You have to have that type of a vehicle, yes sir.

Senator SHELBY. Okay.

Thank you, Madam Chair.

Senator MIKULSKI. Senator Voinovich.

COST OVERRUNS

Senator VOINOVICH. Thank you, Madam Chair.

I'd like to first commend the Agency for a decision that they made a couple of years ago, and that was in regard to the Plumbrook facility. I was quite impressed with the fact that when I talked with Mr. Griffin about that facility, he was not knowledgeable about its potential or its condition, and the Agency had—along

with Lockheed Martin—decided they were going to do something else in terms of testing the CEV.

And I was impressed with the fact that he came out, and they looked at it, and NASA is investing, I think, some $54 million into that, which will do the testing for a lot of the things that NASA's doing, and also put it in the position where they can take in some commercial work. I think that kind of work on your part is very important.

I'm also concerned about the fact that Senator Shelby said, some of these overruns. And what does NASA do about these? What's does NASA do about these in terms of contractors, do you hit them over the head, trying to get them to perform? Is there any provision that says that if they have these overruns and don't make good on what they say they're going to do that they won't get further business from NASA?

Mr. SCOLESE. Overruns—we work those very carefully, and yes, there are penalties for overruns, but we also have to understand what the reasons for them are. Sometimes it's due to underestimates in the beginning that we, indeed, plan for. And sometimes it's due to the fact that we change requirements. As you know, NASA is a research and development agency, we do things, typically, for the first time. And that requires learning as we're going along, so if we adjust the requirements it is not an overrun by the contractor, it is us adjusting the requirements, and adjusting the contract.

Senator VOINOVICH. How often is that the case?

Mr. SCOLESE. A fair amount. It happens relatively frequently. In fact, we tend to be the mission integrator, so, that will happen.

But, the budget that you want to look at is the NASA budget—how much do we say, it's going to cost to do a particular mission. And then we work with our contractors, when a contractor does not perform there are penalties. There are severe penalties, including terminating the activity. We clearly report on contractor performance, so that future work is judged by past performance.

But, we have to look first to see if we're changing requirements or if they're not performing.

Senator VOINOVICH. You're confident that you're doing what anyone else would do in terms of these contractors?

Mr. SCOLESE. Yes, I am.

U.S.-RUSSIA PARTNERSHIP

Senator VOINOVICH. Okay.

Recently I was in Brussels and heard Sergiev Levrov, the Russian Foreign Minister give a speech, and I was quite concerned about the tone of this speech. And I just wonder, in your negotiations with the Russians, in terms of the use of the Soyuz, have you seen any difference in attitude on their part, in terms of them being above-board, objective negotiators, or has this—I don't know—paranoia set in with their scientific agencies that you're working with?

Mr. SCOLESE. No, we haven't seen it. Russia has been a very good partner with us on the Space Station, and in our space activities, and they continue to be a very reliable partner. So, we have not seen that.

Senator VOINOVICH. In other words, you're dealing on a professional basis, with scientists, and the foreign policy thing hasn't entered into those negotiations? You feel that they're being fair and above-board?

Mr. SCOLESE. Yes, I mean, we're linked very tightly on this Space Station. They can't survive without us, and we can't survive without them. And we work very closely together, and it's been a good and productive relationship over the last several years.

TEN HEALTHY CENTER CONCEPT

Senator VOINOVICH. This undertaking of looking at the future of NASA, I think it would be very important for you to share with the folks that are doing this that, many of us are very happy with the 10 healthy center concept. And you know darn well there are people out there that are holding their breath, and hyperventilating, what are they going to get and what are they going to do? And I think the sooner that that's made clear to everyone, just what the deal is going to be, I think all of us will be feeling a whole lot better about things.

So, if you could share that with—if you have any input from your organization, that was a—something that we really, all of us supported, you did a good job of assigning missions to the various agencies, and we'd like to know that that's still part of the program.

Mr. SCOLESE. I certainly will. As you know, it's the people that make this all work, and we have some of the best people in the world, if not the best people in the world, in developing our spaceflight systems—human robotic and aeronautics. And we have some great capabilities in all of our centers, and we should utilize those to the fullest, and I'll make that known.

Senator VOINOVICH. Thank you.

SHUTTLE WORKFORCE TRANSITION PLAN

Senator MIKULSKI. Senator Voinovich raised some really important issues around workforce assurance, and also the acquisition and cost overrun issue.

Let me come back to the workforce issues—one, with the retirement of the Shuttle. As you know, it is a source of great concern in the communities, particularly in Florida and in Texas. We're talking about thousands of people who've really served the Nation with fidelity and reliability, I mean, they really kept the Shuttle going. And the Shuttle's had challenges, including the return to flight after the *Challenger*.

Could you tell us where NASA is in the workforce planning for this transition, and number two, is NASA, or the administration also in consultation with our colleagues and also the Governors of those respective States—it's a big deal.

Mr. SCOLESE. Yes, and you're absolutely right—the people that have built and maintained this Shuttle have done an incredible job and are truly dedicated. We see it every day. We see it with the flight that's going on today. We're going to rely on them until the last Shuttle returns to Earth.

Senator MIKULSKI. And they have to stay?

Mr. SCOLESE. And they have to stay.

Senator MIKULSKI. You know, so we're going to go ahead. I mean, I'm going to the edge of my chair, I'm going to sound like Bill Nelson, launching.

Mr. SCOLESE. I think we probably very much agree on this. They are doing an incredible job, and we are doing a number of things to retain and retrain—where that's needed—the workforce. We need them, as I said, to continue to fly the Shuttle safely, and we're relying on that.

So, in some cases we're doing retention bonuses, we're encouraging people to stay on that may want to retire or leave for other reasons.

Also, we are looking at people engaged in work on Orion and Ares or other elements of Constellation, so they can look, today, and know they're working on the Shuttle, and know that they're already working on the next-generation system, so that they know they will have a job when they are done.

For those people that may not be, available or may not be able to continue with the program, we're looking at other activities, other avenues for them, it may be at other centers, it may be retraining. That's what we can do within NASA.

Outside of NASA, we're working with our contractors. We don't have as much insight into that, but they're trying to do the same thing there, as well, we're working with them to provide retention bonuses, to encourage them to offer people opportunities to work, not only on the Shuttle, but on the next-generation system, that they may be operating, whether it's Orion, or Ares, or a component of that.

So, we're working, across the board to retain the workforce and retrain the workforce and allow for a smooth transition for those that may have to leave the Shuttle program at the end.

RETENTION

Senator MIKULSKI. I feel very strongly about this, and again, knowing first of all, the fact is that we need them now. And we need them to stay. And if I were in the room with Peter Orzag, working on this, and the President's science advisor, looking at the future of NASA, I'd say, "You know, everybody dumped buckets of money into the banks because they said we need their talent," well, they had no place to go. But here, we have these wonderful people who have a job that they're doing, and a job that we need them to do.

So we're going to ask for quarterly reports from NASA on how this transition is going on. And I gather—because it will be a phase-down, but also for the retention now. And do you think that there are sufficient resources in your appropriations request to retain the workforce that we have during these last flights, taking us into the end of the fiscal year 2011, and to really properly retain them as we also are looking at those who wish to retire, and those who wish to be retrained, and those who wish to be redeployed within NASA.

So, those are your, kind of, three tools, isn't it? Retirement, retraining, and redeployment?

Mr. SCOLESE. Yes. And we do believe we have the resources, as I mentioned, retention bonuses and other activities to do that, but

we're working specifically to make sure that we have people that can cover any issue that may come up with the Shuttle and its associated systems. So we are taking a very active look at making sure that we retain those—that dedicated workforce.

SCIENCE

Senator MIKULSKI. Right. And, as you know, now with 19 years, the Hubble servicing is coming to an end, and we have 300 people who have really served the Nation well in Hubble, and we also want that same attention to detail with retention, and also looking at what are the other projects at Goddard.

So, we would like to be in touch with the NASA Administrator on these issues.

Let me go to science. And let's go to the President's desire, we believe, to have a green science initiative, I believe, is the way of talking about it.

We are so proud, here, in this subcommittee, that we fund 80 percent of all climate change science. We are the green committee. Senator Boxer and I have had talks about this. NASA's portion is $1.2 billion, including science that comes from Earth-observing spacecraft, and then there is NOAA that also does very important work on climate research—$325 million.

So, $2 billion is spent by the Government on climate change science, but $1.5 billion comes from this subcommittee.

Let me go to what NASA's job is, and I would like, if you could, outline an inventory of the NASA projects in the budget request that will contribute to climate change science?

Mr. SCOLESE. Certainly. As you know, we have a number of on-orbit satellites that are, today, contributing to our understanding of climate change, they're supporting not just NASA researchers, but researchers throughout the world.

They're also supporting the operational agencies, as you mentioned, NOAA, USGS, other Department of the Interior organizations—Forestry, Agriculture. In addition, we have several missions in development, I could list some of them—the global precipitation mission is one, the Landsat data continuity mission is another. We have the decadal missions that are coming up, and we're very aggressively working to meet those.

In addition, we have relationship with NOAA that is very productive, where we've been producing the polar orbiting environmental satellites. We launched the last one, NOAA and Prime in January, and it's working well on orbit, it's been turned over to NOAA. We have a GOES–O launch scheduled for later in June, that is coming up. We have the NPOESS preparatory project, which is we are working in collaboration with, not only NOAA, but also the Department of Defense, on the next-generation weather satellites.

And while the Department of Defense is developing the Prime satellite, we were developing the preparatory project, which was intended to test out the capabilities, but now has become critical to the operational weather and climate communities, and we hope to launch that in the next year or so.

Senator MIKULSKI. Well, first of all, that's impressive. That is really impressive. I think what the committee would appreciate, and also the Congress would appreciate, as it looks at climate change legislation, for us to have an inventory of these very important climate projects. We're also going to ask for the same inventory from NOAA.

But what we want is not only a list of the projects, Mr. Scolese, but what is the information that we're going to get that will be useful to policymakers to really come up with really sound legislation to deal with the global climate crisis.

As you know, there's been incredible debate over the last couple of years about science, junk science, and everybody's got their arguments about the climate change situation. We believe science should speak for itself, and that the facts of science should speak for itself.

But, what the American people will want to know is, say, okay, we're going to spend $1.5 billion on science, and we've been spending it over time, and it's been enormously impressive. We would not know today about the global climate crisis if it were not for NASA. And then the very important work of NOAA, and our National Science Foundation.

As we've met with environmental ministers from around the world, the size and scope of the NASA endeavor has enabled them to also do their science. What would be useful to us in the debate is to know what we can continue to contribute for our colleagues, so that decisions, recommendations, policy initiatives and policy flashing lights would come from our science. So, could we have that from you? Because the people really need to have that in plain English.

We can hear GOES, NPOESS, they all have those names, et cetera, and I think it's often not seen. But we're ready to do legislation on the global climate crisis.

Which then takes me to something else. After—presuming we do have legislation—do you see that it is our science that will also be able to provide ongoing monitoring to see whether we truly are making a difference? Will there need to be new things, or will what we're doing now be able to carry us, say, for the next 5 or 7 years?

Mr. SCOLESE. Well, I think what we're doing now will probably carry us for the next 5 to 7 years, the answer to your question is will we be able to do monitoring? Absolutely. We're doing that today in various areas. For instance, in ozone monitoring, we use satellites to measure the ozone, and have seen, you know, an improvement in the reconstitution of the ozone layer.

So, yes, our satellites can go off and provide a lot of that information, and will continue to do so. And I expect, as the decadal survey missions indicated, that we will need some new capabilities, as we gain new understanding and want to look at different effects, be they, solar effects or Earth effects, or, other climatological effects that we need to deal with.

So, yes, our satellites can, and will, continue to do that, and as you know, our data systems are out there providing that data to researchers, as I said, around the world. So, as I said, we're getting

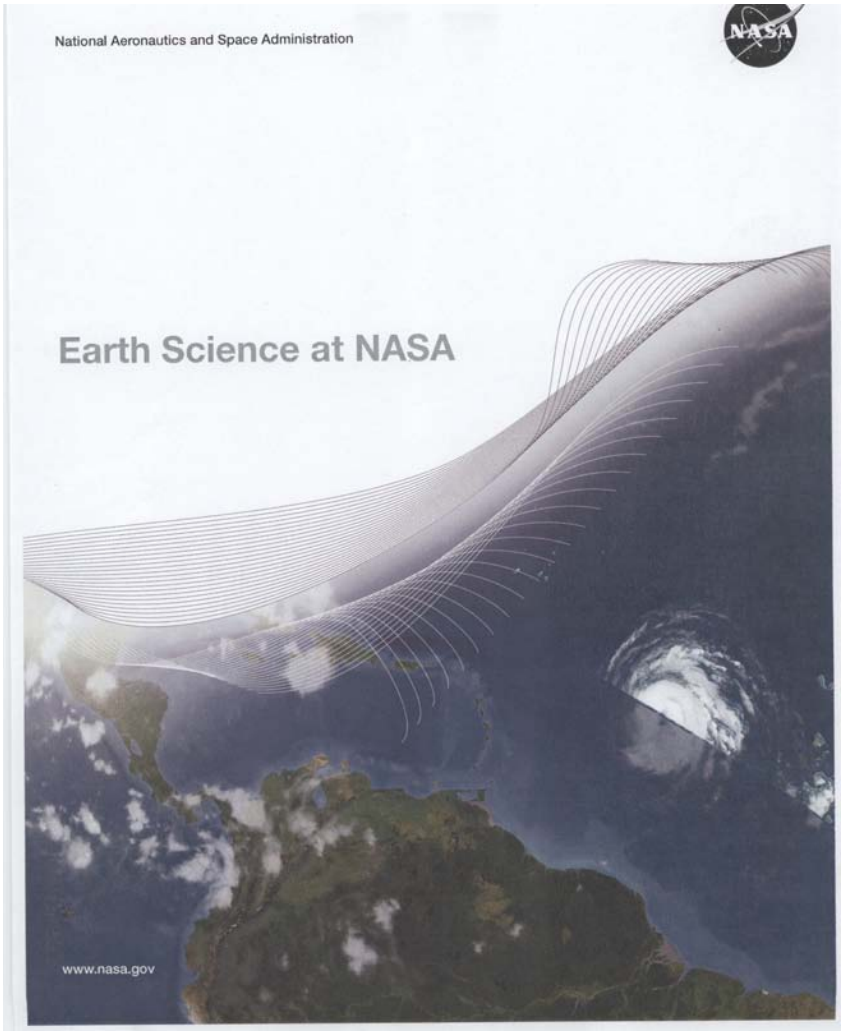
an objective look at the data, as well, to inform the decisions of the policymakers.

[The information follows:]

GLOBAL CLIMATE CHANGE

Provide an inventory of climate projects. Identify the types of information from them that would be useful to policy makers, with any "flashing lights" that would come from science results. Assess the sufficiency of monitoring activities over the next 5–7 years.

See Attached.



Introduction

The National Aeronautics and Space Administration (NASA) conducts a program of breakthrough research to advance fundamental knowledge on the most important scientific questions about the global integrated Earth system. NASA continues to lead the international scientific community to advance global integrated Earth system science using space-based observations. The research encompasses the global atmosphere; the global oceans including sea ice; land surfaces including snow and ice; ecosystems; and interactions among the atmosphere, oceans, land and ecosystems, including humans. NASA's goal is to understand the changing climate, its interaction with life, and how human activities affect the environment. Through partnerships with national and international agencies, NASA enables the application this understanding for the well-being of society. This document provides a describtive inventory of NASA's ressearch and observing activities in Earth system sceince, including climate science.

Much of the science community's present state of knowledge about global change—including many of the measurements and a significant fraction of the analyses which serve as the foundation for the assessment reports of the Intergovernmental Panel on Climate Change (IPCC) and the quadrennial ozone assessment by the World Meteorological Organization—are derived from NASA's Earth Science program. For example, using data from Earth observing satellites NASA-supported researchers are: discovering the abrupt rapidity of sea ice depletion in the Arctic cover and ice sheet motions in the Arctic and Antarctic; quantifying short-term and long-term changes to the Earth's protective shield of stratospheric ozone, including the positive impacts of the Montreal Protocol; developing robust relationships between increasing upper ocean temperature and decreasing primary production from the phytoplankton that form the base of the oceans' food chain; using a fleet of satellites flying in formation (the "A-Train") to study the effects of aerosols in the atmosphere on cloud formation and cloud cover; and using rainfall, vegetation, and other data to help predict food shortage conditions in developing countries. By flying satellites in formation through the A-Train, NASA is capable of making unique, global, near-simultaneous measurements of aerosols, clouds, temperature and relative humidity profiles, and radiative fluxes. Similarly, the use of satellites, aircraft, and ground-based monitoring stations provides NASA effectively calibration of new measuring capabilities and provides unprecedented views into numerous phenomenon, such as the origin of storms.

Our improved understanding of Earth System processes leads to improvements in sophisticated weather and climate models, which, in turn,—when initialized using the satellite data—can be used to predict natural and human-caused changes in the Earth's environment over time scales of hours to years.

NASA also makes strong investments in the development of new technologies that enable a range of scientific measurements, including those specified in the NRC's Decadal Survey, as well as make that data accessible for applications that benefit society. Technology funding now only supports the development of new sensors and instruments, but also advanced communications systems and computer modeling capabilities.

There is thus a strong synergy between our Nation's research satellites and our operational spaceborne systems. Near-real-time measurements from NASA research missions, such as the Tropical Rainfall Mapping Mission (TRMM), the Quick Scatterometer (QuikSCAT), and the Atmospheric Infrared Sounder instrument on the Aqua mission are used routinely by the National Oceanic and Atmospheric Administration (NOAA) and other U.S. and international agencies to improve weather forecasting. NASA works closely with NOAA and the other Federal agencies to transition satellite research measurement capabilities to long-term operations, as appropriate.

Inventory of Observing Capabilities

NASA presently has 15 satellite missions in orbit, as shown in Figure 1, each observing one or more aspects of Earth's climate system. Brief descriptions of NASA's current missions are provided in Table 1 and more detailed descriptions are provided in Appendix A.

On February 24, 2009, NASA's Orbiting Carbon Observatory (OCO) did not reach orbit altitude due to a launch vehicle failure.

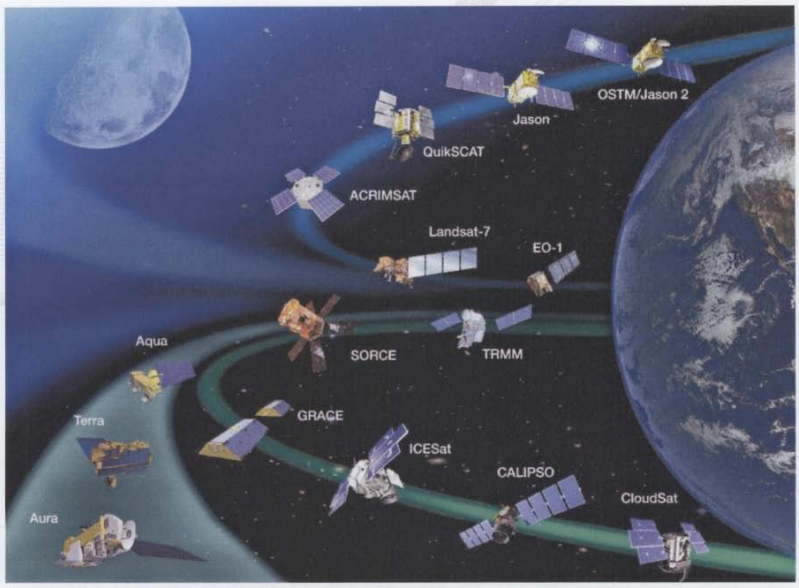


FIGURE 1
Currently operating NASA Earth Science missions that respond to the U.S. Global

NASA has five foundational missions in development for launch in 2010–2014, as shown in Figure 2. These missions were all planned prior to the 2007 NRC Earth Science Decadal Survey. Brief descriptions of these missions are provided in Table 2 and more detailed descriptions are provided in Appendix B.

The National Research Council's (NRC) Decadal Survey report "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond" (NRC, 2007) is the principal determinant of the priorities of NASA's Earth Science satellite missions beyond those

Table 1 Brief descriptions of NASA's Earth Science missions currently in operation

Satellite	Launch Dates	Pricipal Measurement
ACRIMSAT	December 1999	Total solar irradiance
Aqua	May 2002	Atmospheric temperature & humidity
Aura	July 2004	Atmospheric composition
CALIPSO	April 2006	Clouds and aerosol properties
Cloudsat	April 2006	Cloud vertical structures
EO-1	November 2000	Land cover
GRACE	March 2002	Earth's gravity field
ICESat	January 2003	Ice sheet topography
Jason	December 2001	Ocean surface height
Landsat-7	April 1999	Land cover/land use change
OSTM/Jason-2	June 2008	Ocean surface height (successor for Jason)
QuikSCAT	June 1999	Ocean surface vector winds
SORCE	January 2003	Total solar irradiance (successor for ACRIMSAT)
Terra	December 1999	Multi-purpose land, ocean, atmosphere
TRMM	November 1997	Rainfall over the global tropics

FIGURE 2
NASA Earth Science foundational missions under development.

currently in development. The NRC Decadal Survey recommended an integrated slate of missions in three sets (or Tiers, as NASA has come to call them), as shown in Figure 3.

Table 2 Brief descriptions of NASA Earth Science foundational missions currently in development

Satellite	Launch Dates	Pricipal Measurement
Aquarius	May 2010	Sea surface salinity
Glory	Late 2010	Aerosol properties & total solar irradianc
NPP	NET Jan 2011	Continue key measurements from Terra & Aqua
LDCM	Dec 2012	Land cover / land use change
GPM	2013	Global precipitation

Of the four Tier 1 missions, the Soil Moisture Active-Passive (SMAP) is in Phase A formulation and concept development study and the Ice, Cloud, and land Elevation Satellite (ICESat II) mission is expected to begin Phase A in FY 2010. The other two Tier 1 missions, Climate Absolute Radiance and Refractivity Observatory (CLARREO) and Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI), are currently the subject of engineering studies to prepare them to enter the formal mission formulation process. Detailed descriptions of these missions are provided in Appendix C.

In addition, the NRC Decadal Survey recommend NASA implement a new Venture class line of small, innovative research and applications missions. This class can be implemented as sub-orbital missions (e.g. on Unmanned Aerial Vehicles), instruments on other platforms, or dedicated small satellite missions. The first solicitation for Venture class missions was issued in July 2009.

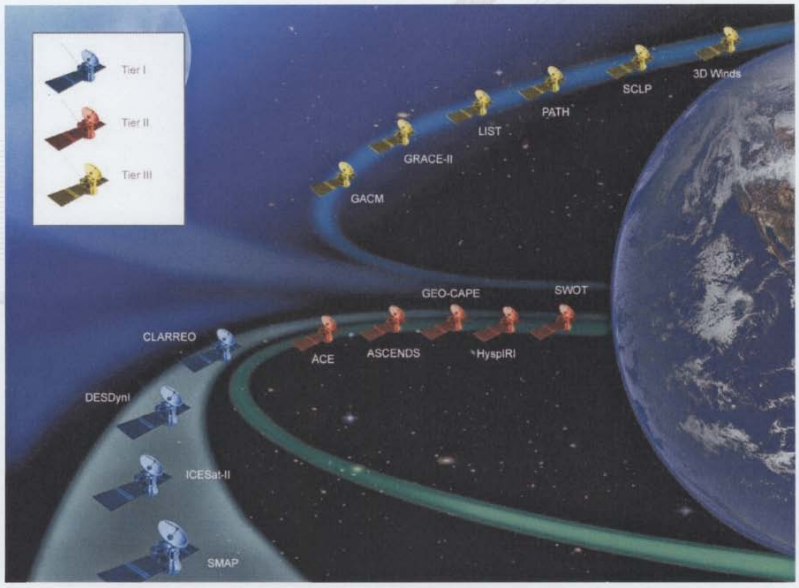


FIGURE 3
NRC Decadal Survey Missions, arranged by Tiers.

NASA aircraft- and surface-based instruments are used to calibrate and enhance interpretation of high-accuracy, climate-quality, stable satellite measurements. NASA, in recording approximately 4 terabytes of data every day, maintains the world's largest scientific data and information system for collecting, processing, archiving, and distributing Earth system data to worldwide users. NASA supports state-of-the-art computing capability and capacity for extensive global integrated Earth system modeling using satellite observations.

One recent example of NASA's use of airborne assets to measure climate is the Arctic Research of the Composition of the Troposphere from Aircraft and Satellites (ARCTAS) field campaign carried out in the spring and summer of 2008. In the ARCTAS campaign, data from three NASA aircraft based in Canada and Alaska, making flights as far away as Greenland, studied the gas phase and particulate composition of the troposphere, emphasizing their distribution in the atmosphere over North America and the Arctic. In particular, in the summer campaign, numerous observations of air affected by forest fires were made. By combining data from aircraft and satellites, scientists are now better able to understand the regional scale impacts of fires and long-range pollutant transport on air quality and the implications for climate.

Ground networks help provide global, in situ measurements of important climate parameters through partnerships between NASA and other institutions around the world. For example, as the AErosol RObotic NETwork (AERONET) program provides globally distributed observations of aerosols in order to measure how much sunlight reaches the ground.

Through NASA's twelve Distributed Active Archive Centers (DAAC's), Earth Science data from these different sources are processed, archived, documented, and distributed to researchers and the general public. Each DAAC specializes in specific science disciplines in order to better support that community. Complete information on the DAAC's is available at: http://nasadaacs.eos.nasa.gov/index.html.

Inventory of Research Programs

Consistent with the goals of the U.S. Global Change Research Program, NASA pursues climate research activities focused on key areas of interaction in the climate system, specifically Atmospheric Composition, Climate Variability and Change, Water and Energy Cycles, Carbon Cycle and Ecosystems, Weather, Earth Surface and Interior, Modeling Strategy, Decision Support Resources Development, Observing and Monitoring the Climate System, and Data Management and Information.

Research Area: Atmospheric Composition

Atmospheric Composition studies changes in the Earth's atmospheric chemistry and composition, which determine air quality and affects weather, climate, and critical constituents such as ozone and carbon dioxide. Research in this area is geared toward creating a better understanding of changes in atmospheric composition and the time scales over which they occur, the forcings (man-made and natural) that drive the changes, the reaction of trace components in the atmosphere to global environment change and the resulting effects on the climate, the effects of global atmospheric chemical and climate changes, and air quality. NASA's research for furthering our understanding of atmospheric composition will provide an improved prognostic capability for issues such as the recovery of stratospheric ozone and its impacts of surface ultraviolet radiation, the evolution of greenhouse gases and their impacts on climate, and the evolution of tropospheric ozone and aerosols and their impacts on climate and air quality.

Figure 4 Research Highlight: Predicting Ozone Loss in the Arctic in development

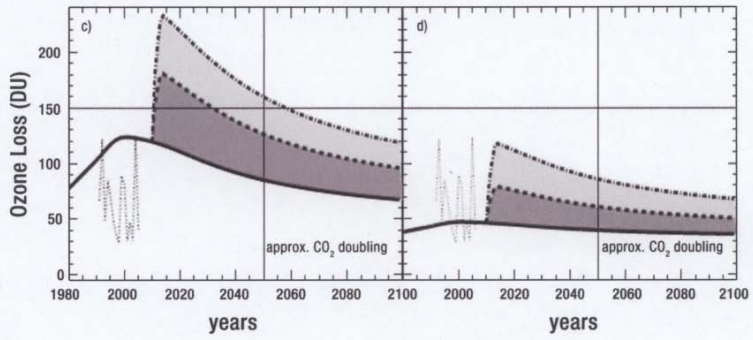


Figure 4. Researchers have projected the chemical loss over time of column ozone in the Arctic, for a base case (solid line) and two scenarios of climate geoengineering by the injection of stratospheric sulfate aerosols (dashed and dash-dot lines), for very cold (left) and moderately cold (right) conditions in the Arctic stratosphere during winter. The very cold conditions are similar to lower stratospheric temperatures during the Arctic winter of 2005, while the moderately cold conditions approximate lower stratospheric temperatures during the Arctic winter of 2003. These results demonstrate that severe loss of ozone could result from geoengineering of climate by the injection of sulfate aerosols into the stratosphere. The geoengineering scenarios represent different but plausible estimates of the amount and size of sulfate aerosols necessary to counter the surface warming that is likely to result from a doubling of atmospheric carbon dioxide. The projections are based on empirical relationships between ozone loss and stratospheric sulfate aerosol levels derived from measurements. The dotted lines in the left and right panels show the ozone loss estimated from the empirical relationship and observed sulfate loading and chlorine levels. These empirical relationships were derived almost entirely from data acquired by NASA satellites and aircraft, without which the projections would not have been possible. Data from the Halogen Occultation (HALOE) instrument, which flew on board the NASA Upper Atmosphere Research Satellite (1991–2004), was used to define the amount of chemical ozone loss that occurred during each Arctic and Antarctic winter. Concurrent data from the NASA Stratospheric Aerosol and Gas Experiment II (SAGE II) on board the Earth Radiation Budget Satellite (1984–2005) were used to develop the relationship between chemical ozone loss and the potential for chlorine activation, which is very sensitive to the amount of sulfate aerosol loading of the stratosphere. Measurements from the NASA Airborne Arctic Stratospheric Expedition II (October, 1991–March, 1992) campaign were also used to corroborate the satellite measurement-based relationships used in the study. (Tilmes, S., R. Muller, and R. Salawitch, The sensitivity of polar ozone depletion to proposed geoengineering schemes, Science, 320, 1201, 2008.)

Research Area: Climate Variability and Change

A unique NASA contribution to climate science is the frequent near-global coverage of observations from space of many properties of the integrated Earth system, including ice sheets, sea ice, sea level, clouds, snow cover, solar radiation, and humidity. NASA's role in characterizing, understanding and predicting climate variability and change is centered around providing the global scale observational data sets on the higher-inertia components of the climate system (oceans and ice), their forcings, and the interactions with the entire Earth system. Understanding these interactions goes beyond observations, to include the development and maintenance of modeling capabilities that allows for the effective use, interpretation, and application of the data. The ultimate objective is to enable predictions of change in climate on time scales ranging from seasonal to multi-decadal. As NASA pioneers new satellite measurements to enable this capability, we work with our agency partners to transition our demonstrated observational capabilities to operational capabilities run by other agencies.

Climate Change and Variability Research Highlight: ICESat Tracks Changes in Ice Cover and Ice Type in the Arctic

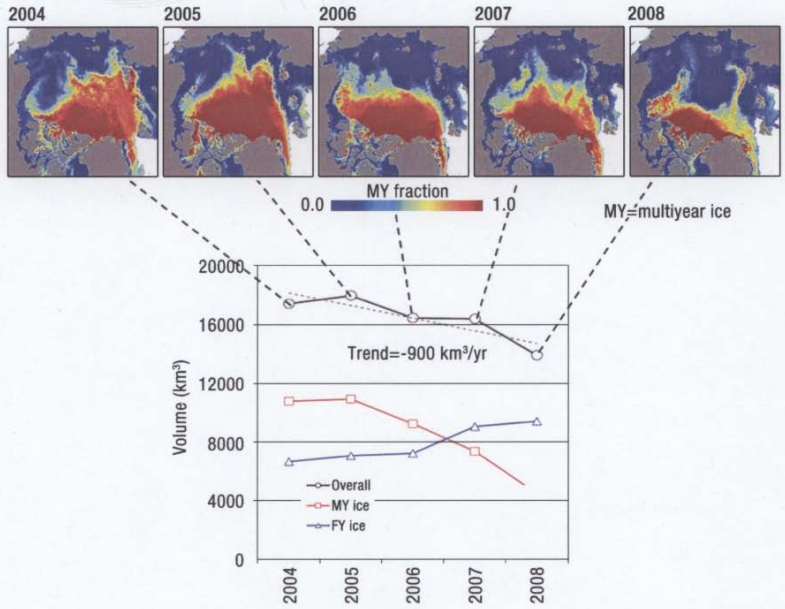


Figure 5. Using NASA's Ice, Cloud and land Elevation Satellite, known as ICESat, scientists have made the first basin-wide estimate of the thickness and volume of the Arctic Ocean's ice cover. The new results provide further evidence for the rapid, ongoing transformation of the Arctic's ice cover as Arctic sea ice thinned dramatically between the winters of 2004 and 2008, with thin seasonal ice replacing thick older ice as the dominant type for the first time on record. During the study period, the relative contributions of the two ice types to the total volume of the Arctic's ice cover were reversed. In 2003, 62 percent of the Arctic's total ice volume was stored in multi-year ice, with 38 percent stored in first-year seasonal ice. By 2008, 68 percent of the total ice volume was first-year ice, with 32 percent multi-year. The research team attributes the changes in the overall thickness and volume of Arctic Ocean sea ice to the recent warming and anomalies in patterns of sea ice circulation. (Kwok, R., and G. F. Cunningham (2008), ICESat over Arctic sea ice: Estimation of snow depth and ice thickness, J. Geophys. Res., 113, C08010, doi:10.1029/2008JC004753.)

Research Area: Water and Energy Cycles

The Water and Energy Cycle Focus Area studies the distribution, transport and transformation of water and energy within the Earth System. The water cycle involves water in all three of its phases, including clouds and precipitation; ocean-atmosphere, cryosphere-atmosphere, and land-atmosphere interactions; mountain snow; and groundwater. Since solar energy drives the water cycle and energy exchanges are modulated by the interaction of water with radiation, the energy cycle and the water cycle are intimately entwined. The long-term goal of this focus area is to enable improved predictions of the global water and energy cycles. This key goal requires not only documenting and predicting means and trends in the rate of the Earth's water and energy cycling as well as predicting changes in the frequency and intensity of related meteorological and hydrologic events such as floods and droughts.

Water and Energy Cycles Research Highlight: GRACE Calculates Groundwater Depletion Rates in India

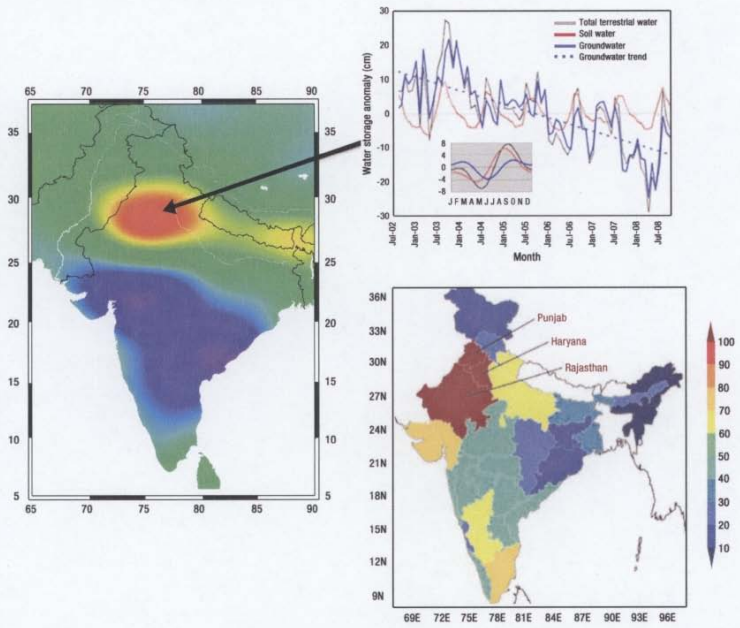
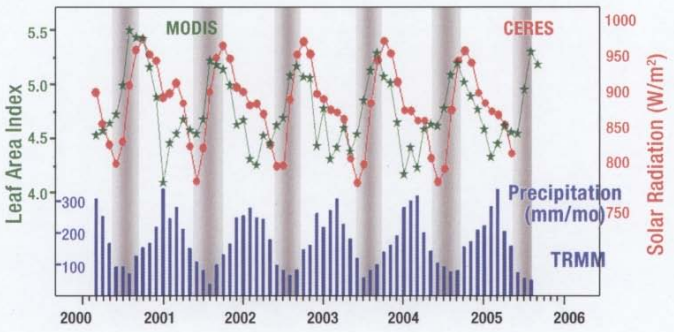


Figure 6. Gravity Recovery and Climate Experiment (GRACE) data can be used to track groundwater depletion rates over regional scales. The map shows the rate of change of groundwater storage in India during 2002–08, with losses shown in deepening shades of red and gains in blue. The estimated rate of depletion of groundwater in northwestern India (averaged over the states of Rajasthan, Punjab, and Haryana, which includes the national capital of New Delhi) is 4.0 centimeters of water per year, equivalent to a water table decline of about 33 centimeters per year. Increases in groundwater in southern India are due to greater than normal rainfall in the past few years, whereas northwestern India received close to normal rainfall throughout the study period. (M. Rodell et al. Nature doi:10.1038/nature08238; 2009)

Research Area: Carbon Cycle and Ecosystems

The Carbon Cycle and Ecosystems Focus Area addresses the distribution and cycling of carbon among the land, ocean, and atmospheric reservoirs and ecosystems as they are affected by humans, as they change due to their own biogeochemistry, and as they interact with climate variations. Through a series of direct measurements and models, NASA helps to characterize and quantify greenhouse gases and related controlling processes in the terrestrial, near-surface aquatic, and atmospheric environments. Given the importance of understanding how carbon cycles through the environment, NASA maintains a vigorous research program to study the distribution and the forces determining the atmospheric concentrations of carbon dioxide and other key carbon-containing atmospheric gases (especially methane), as well as carbon-containing aerosols. NASA improves understanding of the structure and function of global marine and terrestrial ecosystems, their interactions with the atmosphere and hydrosphere, and their role in cycling biogeochemical elements.

Carbon and Ecosystems Research Highlight: NASA Satellites Show Unexpected Seasonal Growing



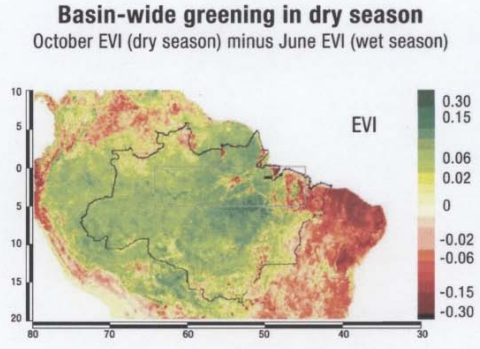


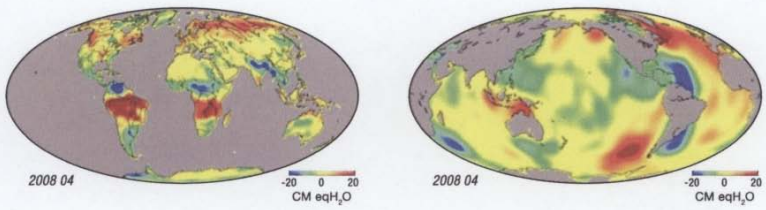
Figure 7. Two research teams studying the Amazon Rain Forest from space have demonstrated fundamentally new understanding of the seasonality of rain forest ecosystems. In one study (above), measurements of leaf area index from MODIS on Terra, precipitation from TRMM, and solar radiation from CERES (also on Terra), show that leaf area is high when solar radiation is high and low when rainfall (and cloudiness) is high. This shows that the productivity of these tropical forests is light limited, not water limited. (Myneni, et al. Large seasonal swings in leaf area of Amazon rainforests. PNAS 2007 104:4820-4823; doi:10.1073/pnas.06113381042007.) In the second study (left), MODIS was used to show that seasonal patterns of forest productivity in the Amazon are opposite to what had been previously understood; the forests are more productive in the dry season when more light is available. They concluded that the forest trees are able to tap deep soil water and avoid the water limitations that pastures in the region experience during the short dry season. (Huete, et al. (2006), Amazon rainforests green-up with sunlight in dry season, Geophys. Res. Lett., 33, L06405, doi:10.1029/2005GL025583.)

Research Focus Area: Earth Surface and Interior

The goal of the Earth Surface and Interior focus areas is to assess, mitigate, and forecast the natural hazards through a better understanding of the transport of mass and energy within the Earth System. The Earth's surface and its interior are fundamental components of the Earth system that both influence and react to the dynamics of our oceans and atmosphere. Therefore, an understanding the dynamics of the solid Earth is essential to developing an interconnected view of Earth science and its applications that ranges from natural hazards and climate change to fundamental physics. Space geodetic science and its associated geodetic ground networks and satellite missions such as GRACE, LAGEOS, and soon DESDynI provide the measurements to monitor crustal deformation, sea level change, water storage, ice dynamics and ablation and numerous other influences from the transport of mass and energy through the Earth System. Though these topics are very interdisciplinary in nature, the Earth Surface and Interior Focus Area provides the primary support for the development of Space Geodetic science and associated missions and infrastructure.

Earth Surface and Interior Research Highlight: Monthly Assessments of Earth's Gravity Field

Figure 8. NASA's Gravity Recovery and Climate Experiment (GRACE) provides monthly to semi-monthly estimates of variations in the Earth's gravity field with unprecedented accuracy and precision. This figure shows the Earth's gravity field in April 2008 for land variations (left) and ocean variations (right). Land gravity field variations are stronger than those for the ocean. Such monitoring capabilities are essential for understanding seasonal anomalies and other variations in the Earth's gravity field. GRACE itself depends upon NASA's space geodetic networks for its precise positioning requirements.



Research Focus Area: Weather

Our weather system includes the dynamics of the atmosphere and its interactions with the oceans and land. The Weather focus area is important to the NASA Earth Science for two reasons. First, the improvement of our understanding of weather processes and phenomena is crucial in gaining an understanding of the Earth system. It is directly related to the Climate and Water/Energy Cycle focus areas. In both cases, the dynamics are to a large degree controlled by "weather processes." Second, there is an infrastructure in the U.S. for operational meteorology at NOAA, the FAA, the DoD, and others that requires the introduction of new technologies and knowledge that only NASA can develop.

Weather Research Highlight: AIRS Data Improves Hurricane Forecasting for Cyclone Nargis

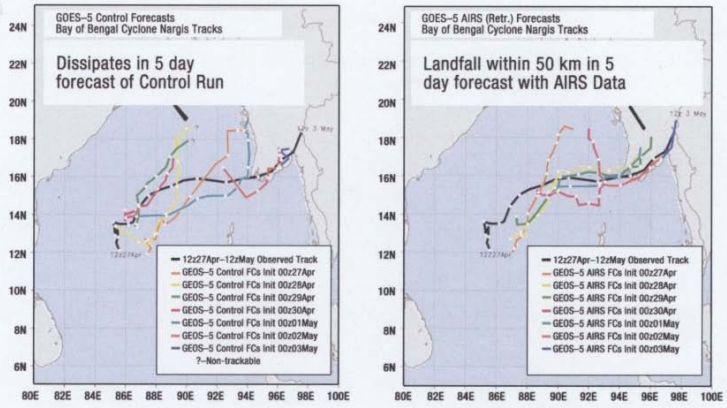


Figure 9. Recent studies using NASA's Atmospheric Infrared Sounder (AIRS) on the Aqua spacecraft have demonstrated the tremendous value of hyperspectral infrared observations to improving weather forecast. In a study performed by scientists at NASA's Goddard Space Flight Center (GSFC), AIRS temperature profiles were assimilated into the GEOS-5 forecasting system to evaluate the forecast improvement of tropical cyclone Nargis that caused the worst natural disaster in the history of Burma. The 5 day forecast control run without AIRS data (left) showed the cyclone dissipating prior to landfall in a position 200 km north of the actual track. After assimilation of AIRS cloud-cleared temperature profiles the cyclone produced an accurate track in 5 of the 7 runs during the forecast period (right). In fact, in the 108 hour forecast, the displacement error at landfall time is less than 50 km with the coordinates of the storm at that time 16.44°N, 94.7°E in the AIRS run, against the observed of 16.00°N, 94.7°E in the actual position recorded. (Reale, O., W. K. Lau, J. Susskind, E. Brin, E. Liu, L. P. Riishojgaard, M. Fuentes, and R. Rosenberg (2009), AIRS impact on the analysis and forecast track of tropical cyclone Nargis in a global data assimilation and forecasting system, Geophys. Res. Lett., 36, L06812, doi:10.1029/2008GL037122.)

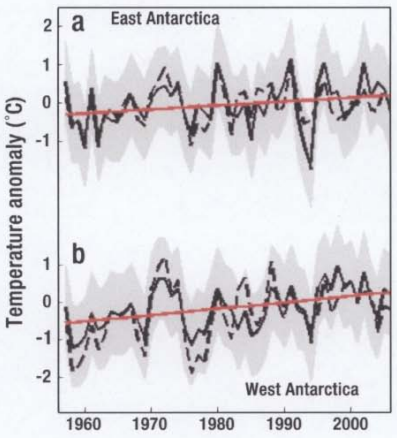
Disciplinary and Interdisciplinary Research Programs

Underlying the Science Focus Areas that explore key climate and Earth system interactions are a core set of foundational Earth science disciplinary and interdisciplinary research programs. These are primarily comprise competitively-selected research grants issued in response to NASA Research Announcements, particularly the annual omnibus Research Opportunities in Space and Earth Sciences (ROSES). These programs include:

- Cryospheric science
- Land use/land cover change
- Ocean biology and biogeochemistry
- Terrestrial ecology
- Physical oceanography
- Terrestrial hydrology
- Precipitation science
- Atmospheric modeling and analysis
- Interdisciplinary research in Earth science

On average, NASA sponsors 1100 research grants and thousands of researchers in universities and industrial and government labs around the nation conducting Earth Science research.

Quantitative understanding of Earth system processes and feedbacks is codified in climate models. The Earth System Modeling Framework—which was initiated in 2002 by NASA and now is an interagency activity—enables shared infrastructure and interoperability of model components and interface.

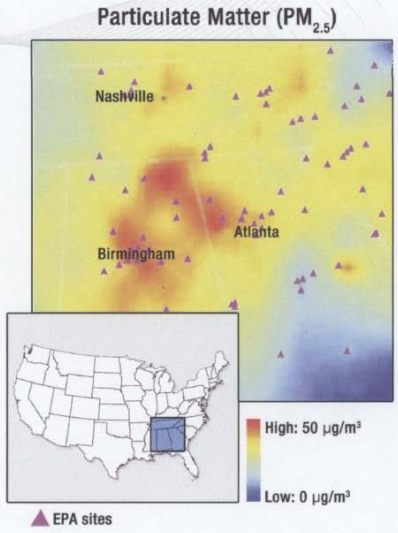


Interdisciplinary Research Highlight:
Unexpected Warming in Antarctica

Fundamental work shows that East Antarctica—long thought to be cooling—is warming. Reconstructed temperatures using Advanced Very High Resolution Radiometer (AVHRR) and station data shows a warming trend of 0.1oC per decade overall in Antarctica but with a stronger warming trend of 0.2oC per decade in West Antarctica. (Steig, E.J., D.P. Schneider, S.D. Rutherford, M.E. Mann, J.C. Comiso and D. T. Shindell (2009) Warming of the Antarctic ice sheet surface since the 1957 International Geophysical Year, Nature, 457, 459-463.)

Applied Sciences

NASA develops and demonstrates practicable applications of its research satellite observations and model results for use by decision makers. NASA works directly with decision makers throughout the development of applications. Examples include improved public health tracking systems for deadly diseases with the Center for Disease Control; advances in prediction of weather conditions for airplane pilots through the National Weather Service and the Federal Aviation Administration; improved tracking of air pollutants with the Environmental Protection Agency for decision-making on biomass burning and industrial practices; improving the Department of Agriculture's Global Economic Forecasting; and providing tools for better disaster management by state and local first responders.

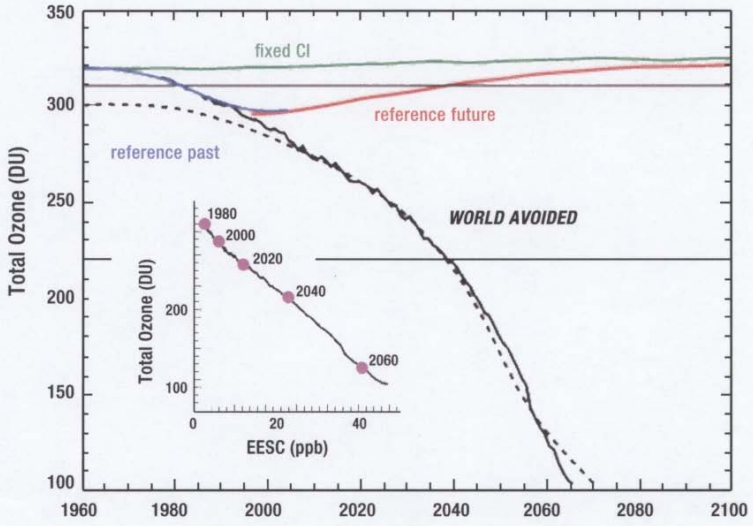


Applied Sciences Research Highlight: NASA and CDC Partner to Provide Improved Public Health Tracking

Accurately monitoring concentrations of 2.5 micron particulate mater ($PM_{2.5}$) are difficult using ground observations alone. Similarly, 10 micron PM (from naturally occurring dust) are associated with asthma and other respiratory distress in the desert Southwest. NASA and the CDC have been partners in linking $PM_{2.5}$ and PM10 and health observations to enhance public health surveillance through the CDC Environmental Public Health Tracking Network (EPHTN). The EPHTN, a surveillance tool that scientists, health professionals, and—for the first time—members of the public can use to track environmental exposures and chronic health conditions, went operational in July 2009. NASA was an integral partner in enhancing the capabilities of this system as it was developed, using surfacing algorithms, modeling capabilities, and observations FROM A VARIETY OF NASA EARTH SCIENCE SATELLITES AND SENSORS INCLUDING MODIS, ABOARD THE NASA TERRA AND AQUA SATELLITES. (The Application of Satellite Derived Environmental Data to Improve Environmental Public Health Surveillance Systems. NASA Tech. Report, 2006.; Al-Hamdan, et al.; and Niskar, A. 2009. "Methods for Characterizing Fine Particulate Matter Using Ground Observations and Remotely Sensed Data: Potential Use for Environmental Public Health Surveillance. Journal of the Air & Waste Management Association". 59:865–881.)

Information Useful to Policy Makers

The climate science data and results produced by NASA's Earth Science program have broad applicability beyond research, including the provision of a scientific basis for policy concern and policy choices. NASA observations are the principal source of global observations for the U.S. Global Change Research Program, and NASA observations and research provided a substantial portion of the input to the scientific assessments of the Intergovernmental Panel on Climate Change (IPCC), which are created for policy purposes. In addition, NASA partners with the World Meteorological Organization to produce a triennial assessment of the health of the Earth's stratospheric ozone layer, which shields the surface from harmful ultraviolet radiation.



Policy Highlight: NASA Researchers Evaluate Impacts of the Montreal Protocol

Figure 12. A team of NASA scientists have simulated "what might have been" if chlorofluorocarbons (CFCs) and similar chemicals were not banned through the Montreal Protocol. CFCs are known to deplete ozone in the atmosphere, which results in an increase in ultraviolet radiation reaching the surface of the Earth. The simulation used a comprehensive model that included atmospheric chemical effects, wind changes, and radiation changes. Annual average concentrations of global ozone are shown for the "World Avoided" (solid black), a modeled future with ozone regulation (red), atmospheric chlorine at a fixed amount (green), and a simulation of past observations (blue). The inset shows how ozone concentrations decrease as the amount of chlorine in the atmosphere—effective equivalent stratospheric chlorine (EESC)—grows over time. The simulation has shown that, without regulation, by 2065, 67% of the overhead ozone would be destroyed in comparison to 1980. Large ozone depletions in the polar region would become year-round rather than just seasonal, as is currently observed in the Antarctic ozone hole. Ozone levels in the tropical lower stratosphere remain constant until about 2053 and then collapse to near zero by 2058 as a result of "polar ozone hole" chemical processes developing in the tropics. In response to ozone changes, ultraviolet (UV) radiation increases, tripling the "sun-burning" radiation in the northern summer mid-latitudes by 2065. (Newman et al. What would have happened to the ozone layer if chlorofluorocarbons (CFCs) had not been regulated?, Atmospheric Chemistry and Physics, 9, 2113-2128, 2009)

Policy makers, of course, ultimately determine what is of most use to them. But recent experience points to the following as examples of observing data and research results capturing policy makers' attention:

- Global average temperature records and regional variations
- Weather forecasting, including tracking extreme weather events
- Relative strengths of climate "forcings" (especially the ability to distinguish natural from anthropogenic causes of climate change, e.g., by measuring solar irradiance)
- Sea-level rising faster than expected
- Sea-ice extent (especially rapid decline in Arctic summer sea ice extent in recent years)
- Greenland and Antarctica ice mass, especially ice shelf collapse in the Antarctic peninsula
- Inter-regional and intercontinental transport of air pollution
- Precipitation and drought patterns
- Rates of deforestation/reforestation and urbanization
- Stratospheric ozone recovery, and the impact of climate change on rate of recovery
- Carbon sources and sinks.

Sufficiency of Observing Activities Over the Next 5–7 Years

NASA's Earth Science program conducts observation and research programs to answer climate and Earth system science questions formulated through engagement with the science community. Observing activities are planned to optimize progress on these questions within the available resources. The Nation has other Earth observation needs in areas such as weather forecasting and natural hazard management, to which NASA observing missions and research can contribute, along with those of other agencies. This results in collaborative programs such as the Landsat series and NPOESS. Thus, while NASA can address sufficiency from the standpoint of its research goals, other agencies are better positioned to address sufficiency of observing activities for their needs.

Some science questions require research satellite measurements longer than the normal operating period of a satellite mission. The NASA strategy for long-term data acquisition has two facets. On some occasions, NASA will re-fly a proven satellite instrument measurement capability. An example in the attachment is the Clouds and the Earth's Radiant Energy System (CERES) instrument for measurement of total solar irradiance at the top of the atmosphere. On other occasions, NASA works with operational agencies like NOAA to continue a satellite measurement capability that NASA developed and tested. The tables in Appendix D show the measurements obtained through currently operational missions and display NASA's current research missions (Table 3) and identify what planned foundational missions (Table 4) and future Decadal Survey missions (Table 5) would continue those measurements.

As shown in the table below, NASA transferred to NOAA the operational control of health and safety of the Ocean Surface Topography Mission (OSTM) satellite, which was launched by NASA. The OSTM nadir sea surface topography measurement capability is sustaining the high accuracy global sea level data produced by NASA's TOPEX/Poseidon (August 1992–October 2005) and Jason (December 2001–present) missions. NOAA has become the U.S. lead for the OSTM follow-on mission called Jason-3.

Appendix A—NASA Earth Science Missions Currently In Operation

Active Cavity Radiometer Irradiance Monitor (ACRIMSAT)
Launch Date: December 20, 1999
Web Site: http://acrim.jpl.nasa.gov

ACRIMSAT, with its ACRIM III instrument, studies total solar irradiance from the Sun. It is theorized that as much as 25 percent of the Earth's total global warming may be solar in origin due to small increases in the Sun's total energy output since the last century. By measuring incoming solar radiation and adding measurements of ocean and atmosphere currents and temperatures, as well as surface temperatures, climatologists will be able to improve their predictions of climate and global warming over the next century. NASA has been measuring total solar irradiance via the ACRIM instrument since the launch of ACRIM I on the Solar Maximum Mission in 1980. The Upper Atmospheric Research Satellite (UARS), launched in 1991, flew ACRIM II.

Aqua
Launch Date: May 04, 2002
Home Page: http://aqua.nasa.gov

Aqua was launched with six state-of-the-art instruments to observe the Earth's oceans, atmosphere, land, ice and snow covers, and vegetation, providing high measurement accuracy, spatial detail, and temporal frequency. In particular, the Aqua data includes information on water vapor and clouds in the atmosphere, precipitation from the atmosphere, soil wetness on the land, glacial ice on the land, sea ice in the oceans, snow cover on both land and sea ice, and surface waters throughout the world's oceans, bays, and lakes. Such information helps scientists improve the quantification of the global water cycle and examine such issues as whether or not the cycling of water might be accelerating.

Aura
Launch Date: July 15, 2004
Web Site: http://aura.gsfc.nasa.gov

NASA's Aura mission seeks to understand and protect the air we breathe by making truly comprehensive measurements of the Earth's atmosphere. Aura's four instruments enable daily global observations of Earth's atmospheric ozone layer, air quality, and key climate parameters. Aura is able to monitor five of the six Environmental Protection Agency principle pollutants to be monitored: carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and particulates (aerosols). Aura provides data of suitable accuracy to improve industrial emission inventories, and also to help distinguish between industrial and natural sources. Together, Aura's instruments provide global monitoring of air pollution on a daily basis.

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)
Launch Date: April 28, 2006
Home Page: http://www-calipso.larc.nasa.gov

The CALIPSO satellite helps scientists answer significant questions and provide new information about the effects of clouds and aerosols (airborne particles) on changes in the Earth's climate. Understanding the behavior of these components is essential for a better understanding of the Earth's climatic processes and improving the accuracy of climate model predictions used to make informed policy decisions about global climate change. CALIPSO measurements taken in conjunction with the Aqua satellite enable new observationally based assessments of the radiative effects of aerosol and clouds that will greatly improve our ability to predict future climate change. CALIPSO measurements taken in conjunction with CloudSat provide a thorough characterization of the structure and composition of clouds and their effects on climate under all weather conditions.

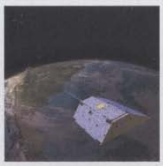
CloudSat
Launch Date: April 28, 2006
Web Site: http://cloudsat.atmos.colostate.edu

Unlike ground-based weather radars that use centimeter wavelengths to detect raindrop-sized particles, CloudSat's radar allows us to detect the much smaller particles of liquid water and ice that constitute the large cloud masses that make our weather. CloudSat's advanced radar "slices" through clouds to see their vertical structure, providing a completely new observational capability from space. Because clouds have such a large impact on Earth's radiation budget, even small changes in cloud abundance or distribution could alter the climate more than the anticipated changes in greenhouse gases, anthropogenic aerosols, or other factors associated with global change. Changes in climate that are caused by clouds may in turn give rise to changes in clouds due to climate: a cloud-climate feedback. These feedbacks may be positive (reinforcing the changes) or negative (tending to reduce the net change), depending on the processes involved. These considerations lead scientists to believe that the main uncertainties in climate model simulations are due to the difficulties in adequately representing clouds and their radiative properties.

New Millennium Program Earth Observing-1 (EO-1)
Launch Date: November 21, 2000
Web Site: http://eo1.gsfc.nasa.gov

EO-1 is an advanced land-imaging mission that demonstrates new instruments and spaccraft systems, which contribute to a significant reduction in cost of follow-on Landsat missions and other satellites. The EO-1 mission includes three advanced land imaging instruments and five revolutionary cross-cutting spacecraft technologies. EO-1 had a 1-year primary mission but was so successful that it continues to operate as a testbed for automated sensor web applications, and to collect unique hyperspectral data (more than 220 spectral colors) of the land surface, useful both for algorithm development and disaster response.

Gravity Recovery and Climate Experiment (GRACE)
Launch Date: March 17, 2002
Web Site: http://www.csr.utexas.edu/grace



The primary goal of the GRACE mission is to accurately map variations in the Earth's gravity field over its planned 5-year lifetime. The gravity variations that GRACE studies include: changes due to surface and deep currents in the ocean; runoff and ground water storage on land masses; exchanges between ice sheets or glaciers and the oceans; and variations of mass within the Earth. Another goal of the mission is to create a better profile of the Earth's atmosphere. The results from this mission yield crucial information about the distribution and flow of mass within the Earth and it's surroundings.

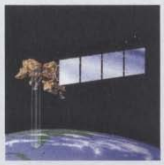
Ice, Clouds, and Land Elevation Satellite (ICESat)
Launch Date: January 12, 2003
Web Site: http://icesat.gsfc.nasa.gov

The primary goal of ICESat is to quantify ice sheet mass balance and understand how changes in the Earth's atmosphere and climate affect polar ice masses and global sea level. ICESat also measures the distribution of clouds and aerosols, as well as surveys land topography, sea ice, and global ice mapping. The ICESat mission provides multi-year elevation data needed to determine ice sheet mass balance as well as cloud property information, especially for stratospheric clouds common over polar areas. It also provides topography and vegetation data around the globe, in addition to the polar-specific coverage over the Greenland and Antarctic ice sheets. Future missions will extend and improve assessments from ICESat, as well as monitor ongoing changes.

Jason-1
Launch Date: December 07, 2001
Web Site: http://sealevel.jpl.nasa.gov/mission/jason-1.html

Jason is an oceanography mission to monitor global ocean circulation, improve global climate predictions, and monitor events such as El Niño conditions and ocean eddies. Earth's oceans are the greatest influence on global climate, yet only from space can we observe our vast oceans on a global scale and monitor critical changes in ocean currents and heat storage. Accurate observations of sea-surface height and ocean winds provide scientists with information about the speed and direction of ocean currents and about the heat stored in the ocean that, in turn, reveals global climate variations. Continuous altimetry data from satellites like Jason-1 help us understand and foresee the effects of the changing oceans on our climate and on climate events such as El Niño and La Niña. Jason-1 is a follow-on mission to the highly successful TOPEX/Posiedon mission (decommissioned in 2005) and precursor to OSTM/Jason 2 (launched in 2008).

Landsat 7
Launch Date: April 15, 1999
Web Site: http://landsat.gsfc.nasa.gov



The Landsat 7 Project is a joint initiative of the U.S. Geological Survey (USGS) and the NASA to gather Earth resource data, and is the most recent in a long series of Landsat satellites going back 30 years to 1974. Landsat 7 systematically provides well-calibrated, multispectral, moderate resolution, substantially cloud-free, Sun-lit digital images of the Earth's continental and coastal areas with global coverage on a seasonal basis. Landsat's Global Survey Mission is to establish and execute a data acquisition strategy that ensures repetitive acquisition of observations over the Earth's land mass, coastal boundaries, and coral reefs; and to ensure the data acquired are of maximum utility in supporting the scientific objectives of monitoring changes in the Earth's land surface and associated environment.

Ocean Surface Topography Mission (OSTM, Jason-2)
Launch Date: June 20, 2008
Web Site: http://sealevel.jpl.nasa.gov/mission/ostm.html

OSTM is an international effort to measure sea surface height by using a radar altimeter mounted on a low-Earth orbiting satellite called Jason-2 and is a follow-on to the Jason-1 and TOPEX/Poseidon missions. This satellite altimetry mission provides sea surface heights for determining ocean circulation, climate change and sea-level rise. The research satellites, TOPEX/Poseidon and Jason-1, have been instrumental in meeting NOAA's operational need for sea surface height measurements necessary for ocean modeling, forecasting El Niño/La Niña events, and hurricane intensity prediction. OSTM takes oceanographic studies of sea surface height into an operational mode for continued climate forecasting research and science and industrial applications.

Quick Scatterometer (QuikSCAT)
Launch Date: June 19, 1999
Web Site: http://winds.jpl.nasa.gov/missions/quikscat

QuikSCAT is the primary source of global ocean surface wind vectors and wind stress for science applications such as ocean and climate model forcing, air-sea interaction studies, and hurricane studies. QuikSCAT data are routinely assimilated in operational numerical weather prediction models at meteorological agencies worldwide, and have revolutionized the analysis and short-term forecasting of winds over the oceans. SeaWinds, the main instrument on QuikSCAT, measures near-surface wind speed and direction under all weather and cloud conditions over Earth's oceans. The instrument collects data over ocean, land, and ice in a continuous, 1,800-kilometer-wide band, making approximately 400,000 measurements and covering 90% of Earth's surface in one day. QuikSCAT can acquire hundreds of times more observations of surface wind velocity each day than can ships and buoys, and can provide continuous, accurate and high-resolution measurements of both wind speeds and direction regardless of weather conditions.

SeaWiFS
Launch Date: August 01, 1997
Web Site: http://oceancolor.gsfc.nasa.gov/SeaWiFS/SEASTAR/SPACECRAFT.html

The commercial SeaStar satellite carries the SeaWiFS instrument, which is designed to monitor the color of the world's oceans, and is a follow-on to the Coastal Zone Color Scanner (CZCS). Various ocean colors indicate the presence of different types and quantities of marine phytoplankton, which play a role in the exchange of critical elements and gases between the atmosphere and oceans. The satellite monitors subtle changes in the ocean's color to assess changes in marine phytoplankton levels, and provides data to better understand how these changes affect the global environmental and the oceans' role in the global carbon cycle and other biogeochemical cycles. Complete coverage of the Earth's oceans occurs every two days.

Solar Radiation and Climate Experiment (SORCE)
Launch Date: January 25, 2003
Web Site: http://lasp.colorado.edu/sorce

Solar radiation is the dominant, direct energy input into the terrestrial ecosystem, and it affects all physical, chemical, and biological processes. SORCE provides state-of-the-art measurements of incoming x-ray, ultraviolet, visible, near-infrared, and total solar radiation. The measurements provided by SORCE specifically address long-term climate change, natural variability and enhanced climate prediction, and atmospheric ozone and UV-B radiation. These measurements are critical to studies of the Sun, its effect on our Earth system, and its influence on humankind. Data obtained by the SORCE experiment is used to model the Sun's output and to explain and predict the effect of the Sun's radiation on the Earth's atmosphere and climate.

Terra
Launch Date: December 18, 1999
Web Site: http://terra.nasa.gov

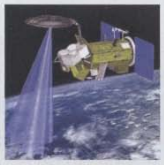
Terra provides global data on the state of the atmosphere, land, and oceans, as well as their interactions with solar radiation and with one another. Terra's five instruments simultaneously study clouds, water vapor, aerosol particles, trace gases, terrestrial and oceanic surface properties, biological productivity of the land and oceans, the interaction among them and their effects on atmospheric radiation and climate. Comprehending these interactive processes is essential to understanding global climate change.

Tropical Rainfall Measuring Mission (TRMM)
Launch Date: November 27, 1997
Web Site: http://trmm.gsfc.nasa.gov

TRMM is the world's foremost satellite for the study of precipitation and associated storms and climate processes in the tropics and subtropics, contributing to a better understanding of where and how much the winds blow, where the clouds form and rain occurs, where floods and droughts. The tropical regions make up about two thirds of the total rainfall on Earth and are responsible for driving our weather and climate system. TRMM has evolved from an experimental mission focusing on tropical rainfall climatology into primary satellite in a system of research and operational satellites used for analyzing precipitation characteristics on time scales from 3-hr to inter-annually and beyond.

Appendix B—NASA Earth Science Foundational Missions Currently In Development

Aquarius
Launch Date: May 2010
Web Site: http://aquarius.gsfc.nasa.gov

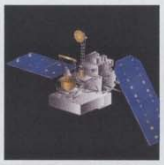


Aquarius is a mission to measure changes in global sea surface salinity equivalent to about a "pinch" (i.e., 1/6 of a teaspoon) of salt in 1 gallon of water. By measuring sea surface salinity over the globe with such unprecedented precision, Aquarius will answer long-standing questions about how our oceans respond to climate change and the water cycle. Monthly sea surface salinity maps will give clues about changes in freshwater input and output to the ocean associated with precipitation, evaporation, ice melting, and river runoff. Aquarius data will also be used to track the formation and movement of huge water masses that regulate ocean circulation and Earth's climate. Within two months of starting observations, Aquarius will collect as many sea surface salinity measurements as the entire 125-year historical record from ships and buoys, and provide measurements over the 25 percent of the ocean where no previous observations have been made.

Glory
Launch Date: Late 2010
Web Site: http://glory.gsfc.nasa.gov

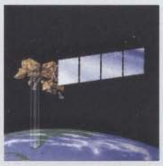
Glory is designed to help understand the Earth's energy balance and the effect on climate requires measuring black carbon soot and other aerosols, and the total solar irradiance. These measurements continue and improve upon NASA's research of the forcings influencing climate change in the atmosphere. Measurements produced by this mission and the scientific knowledge such observations will provide are essential to predicting future climate change, and to making sound, scientifically based economic and policy decisions related to environmental change.

Global Precipitation Measurement (GPM)
Launch Date: June 2013
Web Site: http://gpm.gsfc.nasa.gov



Building upon the success of the Tropical Rainfall Measuring Mission (TRMM), GPM will initiate further measurement of global precipitation, a key climate factor. GPM Constellation consists of a core spacecraft to measure precipitation structure and to provide a calibration standard for the constellation spacecraft, an international constellation of NASA and contributed spacecraft to provide frequent precipitation measurements on a global basis, calibration/validation sites distributed globally with a broad array of precipitation-measuring instrumentation, and a global precipitation data system to produce and distribute global rain maps and climate research products. These measurements will help improve the accuracy of weather and precipitation forecasts through more accurate measurement of rain rates and latent heating.

Landsat Data Continuity Mission (LDCM)
Launch Date: December 2012
Web Site: http://ldcm.nasa.gov



LDCM is a joint initiative of the U.S. Geological Survey (USGS) and the NASA to gather Earth resource data, and is a follow-on to Landsat 7, the most recent in a long series of Landsat satellites going back 30 years to 1974. One of the key objectives of LDCM is to make all Landsat-type data available at affordable cost. This will enable the many different sectors of the population—farmers, business leaders, scientists, educators, state and federal governments and many others to continue to utilize this data for high quality research and applications.

NPOESS Preparatory Project (NPP)
Launch Date: January 2011
Web Site: http://jointmission.gsfc.nasa.gov

The five sensors on NPP will collect data on atmospheric and sea surface temperatures, humidity, biological productivity, cloud and aerosol properties, the Earth's energy bud¬get, and atmospheric ozone. These data will be used for long-term climate and global change studies and serve as a continuation of measurements from NASA's Terra and Aqua satellites. In addition, NPP provides the agencies developing NPOESS with early access to the next generation of operational sensors, thereby greatly reducing the risks incurred during the transition. This will permit testing of the advanced ground operations facilities and validation of sensors and algorithms while the current operational and scientific systems are still in place. This new system will provide nearly an order of magnitude more data than the current operational system and will move a subset of critical climate quality Earth system data records into operational production.

Appendix C—NRC Decadal Survey Tier 1 Missions

Climate Absolute Radiance and Refractivity Observatory (CLARREO)
Launch Date: TBD
Web Site: http://clarreo.larc.nasa.gov

CLARREO is a joint NASA-NOAA mission recommended in the Decadal Study report of the National Research Council (NRC), "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond", to measure solar irradience. The NOAA component involves the continuity of measurements of incident solar irradiance and Earth energy budget by flying two sensors that were removed from NPOESS. The NASA portion involves the measurement of thermal infrared and reflected solar radiation at high absolute accuracy. These measurements will provide a long-term benchmarking data record for the detection, projection, and attribution of changes in the climate system. In addition, these measurements will provide a source of absolute calibration for a wide range of visible and infrared Earth observing sensors, greatly increasing their value for climate monitoring.

Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI)
Launch Date: TBD
Home Page: http://desdyni.jpl.nasa.gov

DESDynI was recommended in the Decadal Study report of the National Research Council (NRC), "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond", for measuring surface deformation, which is linked directly to earthquakes, volcanic eruptions, and landslides. Observations of surface deformation are used to forecast the likelihood of earthquakes occurring as a function of location, as well as predicting both the place and time when volcanic eruptions and landslides are likely. Advances in earthquake science leading to improved time-dependent probabilities would be significantly facilitated by global observations of surface deformation, and could result in significant increases in the health and safety of the public due to decreased exposure to tectonic hazards. Monitoring surface deformation is also important for improving the safety and efficiency of extraction of hydrocarbons, for managing our ground water resources, and, in the future, providing information for managing CO_2 sequestration.

Ice, Cloud, and land Elevation Satellite II (ICESat-II)
Launch Date: Late 2014/early 2015
Web Site: http://icesat.gsfc.nasa.gov/index.php

As envisioned by the Decadal Study, the ICESat-II mission will deploy an ICESat follow-on satellite to continue the assessment of polar ice changes by providing multi-year elevation data needed to determine ice sheet mass balance as well as cloud property information, especially for stratospheric clouds which are common over polar areas. ICESat-II is also expected to measure vegetation canopy heights, allowing estimates of biomass and carbon in above ground vegetation in conjunction with related missions, and allow measurements of solid earth properties.

Soil Moisture Active-Passive (SMAP)
Launch Date: Late 2013/early 2014
Web Site: http://smap.jpl.nasa.gov

The SMAP mission was recommended by the NRC Earth Science Decadal Survey Panel to provide direct measurement of surface soil moisture amd freeze-thaw state. Direct measurements of these properties are necessary to improve our understanding of regional water cycles, ecosystem productivity, and processes that link the water, energy, and carbon cycles. Soil moisture information at high resolution enables improvements in weather forecasts, flood and drought forecasts, and predictions of agricultural productivity and climate change.

Appendix D — Current Measurements and Planned Replacements for Data Continuity

Table 3. NASA Earth Science Missions Currently in Operation

Mission/ Launch Year	Instruments	Measurements	Potential Replacements
TRMM–1997		Global distribution of tropical rainfall*	GPM (2013, 2015)
	Precipitation Radar	Rain rate, rain drop size	PR: on GPM (2013)
	VIRS	Cloud coverage, height, and temperature	
	TMI	Microwave brightness temperatures	GMI: on GPM (2013, 2015)
	LIS	Lightning incidence	
	CERES (inoperative)	Earth radiation budget	CERES: on NPP (2011), NPOESS (2013)
Landsat 7–1999	NOTE: Operated by U.S. Geological Survey		
	ETM+	Land cover	LDCM (2012)
QuikSCAT–1999	SeaWinds	Ocean surface wind speed and direction	NOAA's XOVWM (TBD): possibly on JAXA GCOM-W2
Terra–1999	MODIS	Multiple (vegetation, clouds, ocean color, etc.)	VIIRS: on NPP (2011), NPOESS C1 (2013)
	MISR	Aerosol distributions	APS: on Glory (2010); ACE (Tier 2 mission in Decadal Survey)
	MOPITT (Canada)	Carbon monoxide and methane	
	ASTER (Japan)	Land surface imaging	OLI & TIRS: on LDCM (2012)
	CERES	Earth radiation budget	CERES: on NPP (2011), NPOESS C1 (2013)
ACRIMSAT–1999	ACRIM III	Total solar irradiance	SORCE since 2003; TIM: on Glory (2010); TSIS: on NPOESS C1 (2013)
EO-1–2000	ALI	Land cover	
	Hyperion	Hyperspectral land imaging	HyspIRI (Tier 2 mission in Decadal Survey)
	LAC	Atmospheric correction	
Jason–2001		Ocean surface topography*	OSTM since 2008; NOAA's Jason-3 (TBD); NASA's SWOT (Tier 2 mission in Decadal Survey)
	Poseidon-2 Altimeter (France)		
	Jason Microwave Radiometer		
	DORIS (France)		
	TurboRogue Space Receiver (a GPS)		
	Laser retroreflector		

Mission/ Launch Year	Instruments	Measurements	Potential Replacements
GRACE–2002		Earth's gravity field*	GRACE II (Tier 3 mission in Decadal Survey)
	High Accuracy Intersatellite Ranging System		
	ONERA SuperStar accelerometer		
	BlackJack GPS Receiver		
	Star Camera Assembly		
	Ultra Stable Oscillator		
Aqua–2002	MODIS	Multiple (vegetation, clouds, ocean color, etc.)	VIIRS: on NPP (2011), NPOESS C1 (2013)
	AIRS		
	AMSU-A	Upper atmosphere temperature profiles	ATMS, CrIS: on NPP (2011), NPOESS C1 (2013)
	HSB (Brazil) (inoperative)	Humidity profiles thru the atmosphere	ATMS, CrIS: on NPP (2011), NPOESS C1 (2013)
	AMSR-E (Japan)	Microwave brightness temperatures (winds, SST, ice, etc.)	JAXA's AMSR: on GCOM-W1 (2012); MIS: on NPOESS C2 (2016)
	CERES	Earth radiation budget	CERES: on NPP (2011), NPOESS (2013)
ICESat–2003	GLAS	Ice sheet topography	ICESat II (2014/2015)
SORCE–2003	TIM	Total solar irradiance	TIM: on Glory (2010); TSIS: on NPOESS C1 (2013)
	SOLSTICE, SIM, XPS	Solar spectral irradiance*	
Aura–2004	MLS	Upper atmosphere chemistry	GACM (Tier 3 mission in Decadal Survey)
	TES	Lower atmosphere chemistry	GEO-CAPE, GACM (Tier 2 & 3 missions in Decadal Survey)
	HIRDLS (UK) (not collecting data)	Upper atmosphere chemistry	
	OMI (Netherlands)	Total ozone and aerosols	Total ozone OMPS: on NPP (2011), NPOESS (2013)
CloudSat –2006			
	Cloud Profiling Radar	Cloud structure & radiative properties*	ACE (Tier 2 mission in Decadal Survey)
CALIPSO–2006		Vertical structure & properties of clouds & aerosols*	APS: on Glory (2010)
	Cloud-Aerosol Lidar		
	Wide Field Camera		
	Imaging Infrared Radiometer		

Mission/ Launch Year	Instruments	Measurements	Potential Replacements
OSTM–2008	NOTE: Operated by	Ocean surface topography*	NOAA's Jason-3 (TBD); NASA's SWOT
	Poseidon-3 Altimeter (France)		
	Advanced Microwave Radiometer		
	DORIS (France)		
	GPS		
	Laser Retroreflector		

* All the instruments in this suite are used to produce the key measurement.

Table 4. NASA Earth Science Foundational Missions

Mission/ Launch Year	Instruments	Measurements	Precursor Missions
Aquarius–2010	Note: Joint NASA-Space Agency of Argentina (CONAE) mission	Sea surface salinity	
	Aquarius on SAC-D spacecraft		
Glory–2010		Aerosols; solar irradiance	
	Aerosol Polarimetry Sensor		Terra (MISR), CALIPSO
	Total Irradiance Monitor		ACRIMSAT, SORCE (TIM)
LDCM–2012	Note: Joint NASA-USGS mission	Multi-spectral land data	
NPP–2011			
	VIIRS	Multi-spectral imager/radiometer	Terra (MODIS), Aqua (MODIS)
	CrIS	Atmospheric profiler	Aqua (AIRS, AMSU-A, HSB)
	ATMS	Atmospheric profiler	Aqua (AIRS, AMSU-A, HSB)
	OMPS	Ozone monitoring	Aqua (OMI)
GPM–2014		Precipitation	
	GPM Microwave Imager		TRMM (TMI)
	Dual-frequency Precipitation Radar		TRMM (Precipitation Radar)

Table 5. NASA Earth Science Decadal Survey Missions

Mission/Launch Year	Measurements	Precursor Missions
SMAP - Late 2013/Early 2014	Soil moisture and freeze/thaw	
ICESat-II – Late 2014/Early 2015	Ice sheet height	ICESat
DESDynI (Tier 1 mission)	Surface and sea ice deformation; vegetation structures	
CLARREO (Tier 1 mission)	Solar radiation	
HyspIRI (Tier 2 mission)	Land surface composition	EO-1 (Hyperion)
ASCENDS (Tier 2 mission)	CO_2	
SWOT (Tier 2 mission)	Ocean, lake, and river water levels	OSTM
GEO-CAPE (Tier 2 mission)	Atmospheric gas; ocean color	Aura (TES)
ACE (Tier 2 mission)	Aerosol and cloud profiles; ocean color	Terra (MISR), CloudSat, CALIPSO (Cloud-Aerosol Lidar)
LIST (Tier 3 mission)	Land surface topography	
PATH (Tier 3 mission)	Temperature and humidity	
GRACE-II (Tier 3 mission)	Gravity fields	GRACE
SCLP (Tier 3 mission)	Snow accumulation	
GACM (Tier 3 mission)	Ozone and related gases	Aura (MLS, TES)
3D-Winds (Tier 3 mission)	Tropospheric winds	

Senator MIKULSKI. Well, I think it's impressive. I'm really proud of NASA and what they've done in this. And they have been truly a tremendous voice to—not only scientists—but for those who have stewardships about their individual nations' futures. And NASA is really loved and appreciated because of what it does do, along with NOAA and the National Science Foundation.

This, though, takes me then to other science, which is in addition to our Earth science, planetary science, astrophysics and heliophysics. Is there concern at NASA that, with our emphasis on green science, and also on dealing with the global climate crisis, that other scientific projects will be crowded out?

You know, to keep the shuttle going, there was a lot of rearrangement of the money, and science suffered over the years. The President has made a significant investment in this year's budget, and we really appreciate this, because it's then not left up to the Congress to restore science, which it has been in the last decade.

Mr. SCOLESE. We believe we have a balanced program and, of course, as you know probably better than most, there's always many more missions that people want to do, many more investigations.

Senator MIKULSKI. Every science wants their own rocket ship.

Mr. SCOLESE. But we believe we have a balanced program, and we'll be looking at that, and have it informed by the decadal surveys that are coming up, to establish those priorities and determine what we can do. I think you'll see heliophysics is going up, astrophysics is staying about the same, and planetary is about the same. So Earth science and heliophysics have a little bit better, and the others are kind of balancing out to historical percentages.

NASA EDUCATIONAL EFFORTS

Senator MIKULSKI. Which then takes me to education. What is in the President's request for the NASA educational efforts?

Mr. SCOLESE. I was going to say $125 million and David tells me it's $126 million. So, we have $126 million in that budget. It covers everything from, support for formal education, K–12, universities, grants for graduate students and undergraduates, as well as informal education, in terms of, support to museums and other activities along those lines. And we can get you the specifics.

Senator MIKULSKI. Well, I understand that it is $126 million, that there's been a reduction of $43 million. Do you know why, and what will go by the wayside with that $43 million cut, or would you like to go back and talk to your team?

Mr. SCOLESE. I think I need to go back and talk to my team about that.

[The information follows:]

NASA EDUCATION PROGRAM

The fiscal year 2010 budget request for NASA's Education Program is $126.1 million, up from $116.0 million in the fiscal year 2009 request. As part of NASA's fiscal year 2010 budget request, the Agency preserved high-priority investments in Higher Education STEM (science, technology, engineering, mathematics) Education, K–12 STEM Education, and Informal STEM Education.

Higher Education STEM Education includes STEM Opportunities, Minority University Research and Education Program (MUREP), Space Grant, and Experimental Program to Stimulate Competitive Research (EPSCoR). These projects will build, sustain, and provide a skilled, knowledgeable, diverse, and high performing workforce to meet the current and emerging needs of NASA and the Nation.

K–12 STEM Education includes three main areas. STEM Student Opportunities engage and help retain students in STEM disciplines through flight opportunities, hands on research and engineering experiences, and increased knowledge of NASA science and technology content. STEM Teacher Development uses NASA's content and resources to provide pre-service and classroom teachers with learning experiences to build STEM skills and better motivate students to pursue STEM careers.

Informal STEM Education supports NASA Center efforts involving scouting groups, community based organizations, and other informal education providers who use NASA content to engage their audiences in STEM experiences. NASA also supports the Nation's museums, science centers and planetariums in developing innovative educational experiences that help the American public understand NASA's exploration mission.

A summary of NASA's fiscal year 2010 request for the Education Program follows:

FISCAL 2010 BUDGET REQUEST

[Dollars in Millions]

	Fiscal year 2008 actual	Fiscal year 2009 enacted	Fiscal year 2010	Fiscal year 2011	Fiscal year 2012	Fiscal year 2013	Fiscal year 2014
Fiscal Year 2010 President's Request	146.8	169.2	126.1	123.8	123.8	123.8	125.5
Higher Ed. STEM Education	92.0	107.7	80.6	80.6	80.6	80.7	80.7
K–12 STEM Education	41.3	47.5	43.3	41.0	41.0	41.0	42.7
Informal STEM Education	13.5	14.0	2.1	2.1	2.1	2.1	.....
Fiscal Year 2009 President's Budget Request	146.8	115.6	126.1	123.8	123.8	123.8	.....
Education	146.8	115.8	126.1	123.8	123.8	123.8	.....
Total Change From Fiscal Year 2009 Request	.....	53.6	.....	.....	.....	.....	.....

Compared with NASA's fiscal year 2009 budget request, the fiscal year 2010 budget request includes increases for:

—Higher Ed. STEM Education (+$14.202 million)

—K–12 STEM Education (+$4.365 million)

—Informal STEM Education (+$0.113 million)

NASA's fiscal year 2010 budget request does not include continuation of fiscal year 2009 Congressional augmentations for:

—Global Climate Change Education (fiscal year 2009 +$10 million)

—K–12 Competitive Educational Grant Program (fiscal year 2009 +$16 million)

—Science Museums and Planetarium Grants (fiscal year 2009 +$7 million)

—NASA Visitors Centers (fiscal year 2009 +$7 million)

—Space Grant (fiscal year 2009 +$12.268 million)

—EPSCoR (fiscal year 2009 + $11.72 million)

NASA will be able to address the intended outcomes of these initiatives, as well as NASA's stated education goals, through programs for which the Agency is requesting fiscal year 2010 funding.

Senator MIKULSKI. Let me say why I'm raising this. I'm a big supporter, as you know, of the National Academy of Sciences, and this is why we so like the decadal studies, that we're guided by—in our endeavors and what we should be exploring and doing through the National Academy of Sciences, then it's not out of politics or State interest and so on, that we're really working for the Nation.

And, in the "Rising Above the Gathering Storm", another Augustine-led effort was, we talked about how could America maintain its competitive edge, how could we continue innovation? And they talked about a triad of increased money for research, really a focus on education, K–12, to make sure—even earlier—that our young people focused on so-called STEM disciplines, science, technology, engineering, and mathematics, and that we have an innovation-friendly government, patent reform, tax policy.

Education, here we're doing all this fantastic research, we have a President that's making major investments in education, and through his own charisma, and that of the First Family, are creating, I think, a renewed interest in education. Their own girls, the

way they feel about the rest of America. How can we use now, the power of NASA, while we're doing the research part, and our job of being innovative-finally, to be part of education?

I feel that education at NASA has not been as sharply focused, and perhaps not as wise in its use of dollars, when we've got not only a great story to tell about education, but a great way to motivate our young people to be interested in that. I want to hear from the astronauts because of their courage, the spectacular thing they've done, but I want people to think, "Wow, there's a telescope, that I use the pictures in my classroom, and there's an astronaut that maybe I'm going to be, or maybe I'm going to work at Houston and work that's going to happen on the space station, to find a cure for breast cancer," which is challenging one of our most beloved colleagues here.

So, you see where I am? I'm into motivation, I'm into inspiration, using this story. So, where—what do you see about this?

Mr. SCOLESE. Well, I agree, clearly, the program, as I mentioned it, it tries to encompass all those things in various forms, with our teacher training programs that we do. We try and bring teachers down to launches, so that they can see what's actually going on, along with going out and providing forums where teachers can come in for the summers, for instance, and participate at NASA Centers, to learn about what we do and how we do it. That's sort of on the formal training program of the teachers.

We have the grants students in minority universities, as well as in other universities, to encourage undergraduate and graduate work. As you mentioned about, the informal education, you know, encouraging museums in getting NASA content and activities out, so that the broader public can see them.

And of course, directly, as our people go out there and talk to students, astronauts, scientists, engineers are out there talking at schools as well, and we encourage that as part of what we do as an agency, because we do realize the strong motivation that people see when they get to meet somebody that flew in space or somebody that works at NASA and does some interesting stuff.

I, myself, even had an opportunity to talk to a bunch of seventh grade students just a little bit ago——

Senator MIKULSKI. Harder than testifying before Congress?

Mr. SCOLESE. Yeah, they ask some interesting questions. But the good thing, and this is going to be kind of funny, is that the NASA portion of it, which I did, was rated against everybody else, and we beat out the mortician and the fireman. So, we ended up doing pretty good in the view.

But, actually is something that when people can get out there and see the looks on the students when they see what we can do, is really great.

So, I think we're doing all of those things, and we'll get you a better detailed list.

[The information follows:]

NASA EDUCATION PROGRAM

The President's fiscal year 2010 budget request for NASA's Education Program is $126.1 million, up from $116 million in the fiscal year 2009 request. The Office of Education administers national education efforts that draw on content from

across the Agency. It also disseminates education content and activities developed by the Mission Directorates, Centers and education partners.

The NASA Education Program addresses three outcomes:

—to strengthen NASA's and the Nation's workforce;

—to attract and retain students in STEM disciplines; and

—to engage Americans in NASA's mission.

As part of the fiscal year 2010 budget request—Education projects have been reorganized into three programs to better meet the needs of targeted audiences:

—Higher Education STEM Education;

—K–12 STEM Education; and,

—Informal STEM Education.

NASA's Higher Education STEM Education budget supports the targeted development of individuals who are prepared for employment in disciplines needed to achieve NASA's mission and strategic goals. Graduates of these projects have had in-depth and hands-on experience with research and engineering that support NASA's scientific and exploration missions. Experiences include NASA/industry internships, scholarships, competitions, and engineering design work. These students, drawn from national audiences, are interested in, prepared for, and able to contribute immediately to the NASA/aerospace workforce.

The Office of Education budget builds academic infrastructures and supports NASA-grounded research that builds the scientific and engineering competitiveness of the Nation. These investments also build the future STEM workforce by providing future workers the opportunity to contribute to research of interest to NASA. Target audiences in research capability-building include community colleges and Minority Serving Institutions (MSI's). This type of efforts is funded through both the HE and the MUREP budgets.

K–12 STEM Education activities are based on NASA missions and stimulate excitement in students. Educator training and professional development programs improve teacher proficiency and confidence in teaching NASA and STEM content. Education technologies that foster educator training and student engagement opportunities are developed through the K12eED Program, but the tools and infrastructures serve all NASA Education programs.

NASA Informal STEM Education programs build STEM-interest in the general public by providing NASA exhibits, workshops, and special activities at museums, science centers, planetariums, and the activities of community organizations and clubs.

Senator MIKULSKI. Well, I think that's very interesting. What I would like to ask, is that you make available, the Dr. Joyce Winterton, Assistant Administrator for Education, to meet with our staff so that we really have an idea of the comprehensive scope that you are doing, and how we can be supportive of that in, again, looking at the National Academy, "Rising Above" the Gathering Storm. And when they looked at the education of students, they looked at exactly what you said, teacher training, and how we can help with that. And then, hands-on kinds of things for young people to be able to either see or witness, and so on the inspiration part of NASA.

And number three, what is it about the development of curriculum and so on that you can help? One of the things that really so touched me about what NASA did—and I'll just tell this little story.

Dr. Weiler, as you know, Mr. Space, science, and Goddard, et cetera, used part of his education budget to work with the National Federation of the Blind in Baltimore. And working with the National Federation of the Blind in Baltimore and the National Air and Space Museum—the space part of the Smithsonian—they developed a textbook for blind children on astronomy. And it's called "Touch the Invisible Sky."

Now I have seen the textbook, and the Federation is headquartered in Baltimore, and what that has meant to boys and girls, and what it's meant to parents, where their children can

learn science, and actually touch the Hubble, and also think about careers in science, where particularly those things in the digital world that they could participate. This is—this is stunning, and it will—it impacts thousands of lives. So, we appreciate that.

Mr. SCOLESE. Thank you.

ACQUISITION PROCESS

Senator MIKULSKI. I'm going to have one other set of questions related to acquisition, and then—what time—what time do we link up with *Atlantis*? Twelve twenty-nine? I'm afraid to let everybody go, it's my Catholic school education, that if you go, you won't come back.

And, here's Bill Nelson, Bill we've got a few minutes, here. We're actually not going to be early, but we're just asking questions about cost difference.

Do you want to explain to Senator Nelson where we are while I finish?

Senator Voinovich raised the question about the acquisition process. Do you think we need a Commission on this? Do you think with acquisition cost overruns and schedule upages, we need a national Commission, where an effort like the Pentagon has just completed with their acquisition?

Mr. SCOLESE. I'm not sure we need a national Commission on it. I can tell you what we are doing. The Government Accountability Office, of course, has been reviewing NASA, and we recognized the issues that are associated with acquisition and acquisition reform. One of our biggest is the early cost estimates for our missions. There tends to be a lot of exuberance and enthusiasm for the missions, and as a result, we tend to say we can do more for less than we can really do it.

So, we're working very hard to fix that very early portion of it. And that's a combination of working with our colleagues in the external community, in the science community, as well as working internally to develop better cost estimates, and we're doing that. With the National Academy, we're sitting down so that they can develop better cost estimates, we can work with them so that we can develop them. We can develop cost estimates that can be compared against each other, as opposed to having one estimator do it one way, one group do it another way, we can get them all on common footings, so that we can look at them in terms of a common base, to understand which is really more expensive or more risky than the other.

In addition, we've revised our acquisition strategy. We now have essentially three meetings that we do before we go off with a procurement. One to look at what it is that we really want to accomplish and do we have the resources to accomplish it, both within NASA and in the industry as a whole. Is it available to us? Because often times we find out that we start something before we have the people or the resources available to support it. And then we develop the best way to go off and procure that, whether it be a fixed-price activity, and in-house activity, where it's built within NASA, or whether we go out of house to contractors.

In addition, we're looking at how we monitor our performance, so that we can catch problems early, rather than finding them out

late in the game when they're very expensive. So we're having monthly reporting, so that we can go off and look at all of those activities. And of course, we're working with industry and academia to go off and address those from their perspective as well.

So, that's what NASA is doing, and we're working with our colleagues in other agencies, most closely with NOAA, of course, because we buy some of their satellites.

HUBBLE SPACE TELESCOPE

Senator MIKULSKI. Well, thank you, again. I want to just thank you again for your service. I'm not going to recess the committee. What I'm going to do is ask you some questions about the Hubble.

Mr. SCOLESE. Okay.

Senator MIKULSKI. Then I'm going to, essentially, as we get ready to link up with *Atlantis*, talk about the biographies of the astronauts, and I'm going to ask our colleague—we're happy to be joined by our colleague, Senator-astronaut Bill Nelson, to, perhaps while we're waiting to hook up, you might talk about what it feels like to be an astronaut. Everybody sees it, they see it weightless, et cetera, but you've actually known, in our conversations, it can be pretty dangerous. And so, by that time, we'll be ready to hook up with them, and we would also invite you to engage in the conversation with them.

So, we're getting ready now and lining up to connect to our astronauts, on the *Atlantis* mission.

You've watched Hubble, and I am so proud of Hubble. You know, it's gone where no telescope has gone before. It's taken us to pictures of galaxies, and the great information of the Hubble has gone out to people in school—the scientists and school children around the world, whether it was in south Baltimore or South Africa. And, what I would like, if you could share with us, from the science viewpoint, what you think have been the major accomplishments of the Hubble mission?

Mr. SCOLESE. Probably the most significant accomplishment, as I look around, is the inspiration it's given to people to go off and pursue science, engineering, math, technology careers. You look at every textbook and you see a Hubble image, whether it's, of some planetary nebula or some nebula someplace, or just the Hubble Space Telescope with an astronaut floating next to it. It just has an incredible encouragement to people, to go off and do those things, because it does represent an icon.

When Hubble was first launched, you remember, more than anybody else, the difficulties that we had when it was first launched, and the perseverance——

Senator MIKULSKI. You mean when it went up and it wouldn't work?

Mr. SCOLESE. When it went up and it wouldn't work. I didn't want to say it quite that way. It was the techno-turkey of the time, yet it was resurrected.

Senator MIKULSKI. That was my phrase.

Mr. SCOLESE. Yes. It's been resurrected and I think people have seen that and recognized that with hard work and perseverance, you can overcome almost anything. And watching our crews, just this week and in previous weeks, we tend to get most of our atten-

tion with Hubble missions, because they are so dynamic, they are so interesting.

We can practice and practice and practice, yet at some point in a mission, you always know that something's going to come up that wasn't quite the way you practiced it. And I'm sure Mike Massimino how he had to use some elbow grease to remove a handrail.

So, I think that's probably our biggest contribution, because I see it when I talk to children and I see it when I talk to people who are now graduates from college, that, you know, looking at the Hubble. In my generation it was going to the moon. I think in this generation it's been, you know, what the Hubble Space Telescope can do.

And then, of course, I can't do the justice that an Ed Weiler could do to how it's revolutionized our understanding of the universe. But it clearly has done that. It's rewritten every textbook that's been out there in astronomy and cosmology, and to some extent, in physics as well.

Senator MIKULSKI. Well, I understand that the Hubble has led to 7,000 scientific papers, and that the information on Hubble, even that which continues to be analyzed, could fill two Libraries of Congress, and has taken us to the discovery of new galaxies, and also the whole issues of black holes and dark energy, things that will help us understand the universe, and in understanding the universe, understand physics, quantum physics, tremendous scientific expansion——

Mr. SCOLESE. All those.

Senator MIKULSKI [continuing]. That then enable us, also, to go to far more practical implications. Isn't that correct?

Mr. SCOLESE. Absolutely. I'm surprised it's only 7,000, considering all the things that it's done.

Senator MIKULSKI. The other thing that was required, in addition to the astronauts, was these tools. When one goes into space to do this work, because what the Hubble did on this mission, was five space walks, and that's what we're going to talk with them about, five space walks that took hours. It's just not like suiting up and walking out and—did you do space walk or did you stay inside?

I think I'd stay inside, too. Could you imagine trying to find a little space suit in, you know, in 14 petite? Well, they did it for Sally and some of the others.

But anyway, could you tell us about the technology that was developed to be able to refurbish the Hubble?

Mr. SCOLESE. Just an incredible number of tools. For every mission, one has to think about, taking a screwdriver with a ski glove on, and a pressure suit, where you're in a balloon trying to move in order to do this work. So, it's not at all like putting a suit on or just having a glove on, it's pressurized, and you're fighting that each and every time you move. And the astronauts can describe it a heck of a lot better than I can describe it. But that's the limitation that one has to work with.

And then think about the fact that you can't see everything. You've got this hood over your head. So, you have to develop tools that will allow the crews to be able to work with those limitations,

limitations in viewing, limitations in their ability to grasp things. So every mission, you have to come up with a new set of tools, a new set of guides to allow them to see where they want to go. And this mission was no different, to go off and do that.

Then you have to remember you have to take the power with you. It doesn't come along, you can't plug it into the wall like our Black and Decker, these are largely battery-operated. So while they're floating around in space, they have to have these tools. When they remove a screw, they have to capture it, otherwise it's going to go floating around in space. Because on this mission, and on other missions, we repaired things that weren't designed to be repaired in space. If you design it to be repaired in space, you'll have big fasteners that you can grasp with a gloved hand and everything will stay in place.

We were removing hundreds, 150, 160-some screws, little screws, that if they got into the wrong place——

Senator MIKULSKI. Talk about having a screw loose.

Mr. SCOLESE [continuing]. Yes—they could damage the telescope or damage the orbiter or damage the suit that the astronauts were in.

So, in addition to being able to remove the screw, we had to make sure that that screw didn't float away and go someplace we didn't want it to go. So, we had components that allowed us to capture those screws.

And then, as we mentioned, think about pulling a circuit card out of your computer, if you've ever had to go off and do that, put in a board for graphics if you wanted to do gaming or something along those lines. And think of how small that is. We had the astronauts retrieve that.

Needless to say, they couldn't use their gloved hand, so we had to develop a tool that would allow them to go in there, grasp it, pull it out, and then put a new box in.

So, there's an incredible amount of effort with the engineers on the ground developing these tools and understanding what's going on, working with the astronauts to refine those tools so that they can use them effectively. And then, while the mission is going on, adjusting when things change.

SPACE SHUTTLE CREW INTRODUCTION

Senator MIKULSKI. And it's the big deal.

What I'd like to do now is—first of all, that was an excellent description—I'd like to talk about these astronauts and who they are, as we get ready to connect to them, a few words about, really, what they did, just as you've described it. And while we're waiting, in the 4 minutes for the hookup, as you said, this is not a Swiss watch factory, to connect to them.

Well, first of all, there were seven astronauts, and of the seven, three had been on previous Hubble experiences. One is Scott Altman, he's the commander of the mission. He flew the Shuttle during its capture and release of Hubble. He was also the commander of the last Hubble servicing mission, in March 2002, when we installed that Hubble advanced camera that made the mission worthwhile.

The other is John Grunsfeld, who's considered like one of the fathers or godfathers or grandfathers of the Hubble. He led the space walking team, and he's conducted three space walks, in addition to the five others he did on previous serving missions. He's done two previous Hubble missions, in December 1999 and March 2002, which was so important, again, to reboot, reinvigorate Hubble.

And then there's Mike Massimino, who will be leading the conversation today. Now he's conducted two space walks, and guess what? He's the first astronaut to Twitter from space. Oh boy, engaging thousands of people and he also was the one who persevered during Sunday's nail-biting, hold your breath, oh my gosh, Sunday space walk. And I've never been so glad ever to hear someone say, "Disposable bag, please," which said that he had accomplished it. He had to deal with a stuck bolt, a tool battery that died, but he kept on going. Mike flew on the last Hubble servicing mission in March 2002, again, when we did that advanced camera.

Now, we've had three other Hubble astronauts on their first shuttle mission. Megan McArthur, one of the women on the trip, operated the shuttle's robotic arm during the capture and release of the rejuvenated Hubble. She became an astronaut in 2000. She has an unusual background. Dr. McArthur has a Ph.D. in oceanography and worked at the Script's Oceanographic Institute, so, from inner space to outer space.

We have Drew Feustel, who conducted three space walks, and on the third space walk—that was Saturday—he and Grunsfeld installed that new spectrograph that looks deeply into the early universe how profound. He became an astronaut in 2000, he began his education at a community college, he worked as an auto mechanic, and now he's a mechanic in space. He then went on to an undergraduate degree and a masters in Earth science and geophysics from Purdue, and a Ph.D., specializing in seismology, from Queens University in Canada. These are incredible backgrounds.

Then there's Greg Johnson, the pilot of the mission. He orchestrated the photographic and video documentation of the mission. He became an astronaut in 1998. He's a Navy captain, he landed on 500 carriers, and we're going to count on him to land safely and smartly tomorrow, at around 10 o'clock eastern standard time.

And last, but not at all least, Michael Good, who conducted two space walks, including Sunday's, which lasted more than 8 hours. It is the sixth longest NASA space walk in history. He comes as Air Force colonel and a test pilot.

We're about 2 minutes away, and as you can see, this is really an incredible amount of talent, and also, talent and dedication and courage and diligence. So, that's who we'll be talking to in space, the very first hearing from space. And as we get ready for our uplink, I'd like to turn to our astronaut-Senator, Bill Nelson.

And Senator, if you could share, maybe, your thoughts on this occasion, of the rejuvenation of Hubble, and your own experiences in space?

Senator NELSON. Madam Chairwoman, this is——

Senator MIKULSKI. And this is the way we ought to be at the table, I might add, authorizers and appropriators, not only celebrating, but really working together for the good of the country.

THE ASTRONAUT EXPERIENCE

Senator NELSON. And thank you for this opportunity, Madam Chairwoman. This is an incredible example of the interlinking of humans and machines, to accomplish great things. As you were reading the biographies of these astronauts, they are exceptionally qualified people, they are, all of them, overachievers, and yet, they are just the visible example of a space team that is, every one of them, overachievers.

A lot of that team is in your State, at the Goddard Space Flight Center, and this particular mission is symbolic of the expertise at Goddard, that putting together all of those with the team that gets them up there, that creates the vehicle to get them there, and then to do the work once in orbit.

Now, in this case, these astronauts have not had a minute to spare, every minute is scheduled. As a matter of fact, usually it's very typical of crews that they have to fight for time to get to the window to gaze back at this incredible creation that we call our home, the planet. In our particular case, I had to cheat on my sleep to find time, just to go and float in front of the window, and see our home.

One of the greatest examples of this teamwork, came out of tragedy, Madam Chairwoman, and that was Apollo 13.

Senator MIKULSKI. Right.

Senator NELSON. We thought that that was going to be three dead men on the way when that explosion occurred on the way to the moon, and yet that incredible team, on the ground, working with the astronauts in real-time, who's lives were on the line, we brought them back and brought them back safely.

And so, what these new lens, these new computers, these new instruments on Hubble are going to do for us, is help us gaze out even further, to sample cosmic rays and understand in greater detail, what is this infinite place called the universe, and how do we relate to it. And that's why I'm so excited for the success of this mission.

Thank you, Madam Chairwoman.

SPACE SHUTTLE ATLANTIS TESTIMONY

Senator MIKULSKI. Well, that was really eloquent, and it shows how—to be an astronaut, you have to be daring, you have to be courageous, you have to be agile.

So, anyway, that was a great job, and now we'll just wait to hear from Houston, a familiar sound to you.

Now remember, we're going to be able to see the astronauts, but they can't see us. This is going to be for them, an audio link.

Mr. VENTRY. Atlantis, this is Houston, are you ready for the event?

ASTRONAUT. We are now ready for the event. Voice check.

Mr. VENTRY. Atlantis, this is Don Ventry at the U.S. Senate, how do you hear me?

ASTRONAUT. Space Shuttle *Atlantis* has you loud and clear, sir.

Mr. VENTRY. *Atlantis*, please stand by for Senator Barbara Mikulski.

Senator MIKULSKI. Hello to all of our astronauts on Space Shuttle *Atlantis*. You are taking part in something quite historical, not only have you given the Hubble a new life, but you're going to give the Senate a new lease on life. You are the very first astronauts to testify from space, at an official hearing.

I'm joined by my colleague, Senator Bill Nelson, a brother astronaut to you. I'm going to lead off the conversation by first of all, thank you for this stunning and successful mission. As you closed the hatch on the Hubble, you have now opened a new door to a new era of scientific discovery.

Hubble is the people's telescope, and it wanted to have another chance to be able to educate a new generation of scientists and school children. What you've done to refocus and recharge the Hubble Space Telescope is appreciated. We appreciate the daring and the difficult and the dangerous things that you've done to install the cameras, the computers, the batteries, and the gyroscopes.

Hubble is the greatest scientific instrument since Galileo's telescope, but you are some of the greatest astronauts that we could get hooked up with.

We want to hear from you about what those experiences are like, but before I do, Bill, Senator Nelson, did you want to say something to your brother astronauts in space?

Senator NELSON. Hey guys, I wish I were up there with you.

Senator MIKULSKI. So, Mike Massimino, are you the one that's going to lead it off?

So, okay, well that works, we see you very clearly. I feel like—if only the Hubble is going to work as good as this link.

So tell us, what was it like to be up there? What was the greatest nail-biting thing that you had? What were those space walks like? What's it been like up there?

Mr. MASSIMINO. Well, Senator, I'd just say, first of all, we're very honored to be able to appear before the committee today. It's an honor for us, it's also an honor to be part of this mission. Many people worked very hard on it, including all the folks at Goddard, and of course, your efforts, Senator, keeping Hubble alive, are much appreciated. We're a beneficiary of that vision that you share with all. Hubble is a part of the spirit of exploration that I think is an American dream we all share. So, thank you so much.

HUBBLE REPAIR MISSION

Senator MIKULSKI. Well, tell us, what was the most—for all of you to jump in—what were some of the most thrilling moments of the mission, what were some of the most nail-biting? We sure liked that disposable bag comment, because we knew you had been able to fix that whole computer situation. Mike?

From what I see, we're getting a lot of enthusiasm.

Mr. MASSIMINO [continuing]. Ground trying to help us. When I wasn't able to get the bolt to turn for the handle, to take the handle off, to continue with the repair of the instrument, the space telescope imaging spectrograph, and we had practiced this so many times as a crew, to do this repair, and never expected—we try to think of every problem we could come up with, and we were prepared, I thought, for everything, but we never expected that particular bolt to give us trouble. And when it did, and when we start-

ed getting the suggestions from the ground, I really thought that we were in trouble. I couldn't see how we were going to be able to continue the repair at that point.

But, the folks at the Goddard Space Flight Center did a great job, along with the folks at the Johnson Space Center, and people from around the country, I'm sure, were all involved, trying to figure out how we could do this. And we didn't have much time because we were running late into this space walk, but they figured out a way for us to fix it, we got the tools we needed, and we were able to get access to the board by breaking off the handle in a way that we would never have imagined to do it. When we launched, we never thought we'd have to do that, but we did it.

And for me, that was a feat, that we could continue——

Senator MIKULSKI. Well, listen, Space Shuttle *Atlantis,* we're having a hard time hearing you.

Mr. MASSIMINO [continuing]. Nail-biters out there, to be sure.

Mr. JOHNSON. Senator Mikulski, this is Greg Johnson, the pilot. It, too, is an honor to testify before your subcommittee. I can tell you, from the flight deck, Scooter and I and Megan were watching, and every single EVA, to me, was a nail-biter. I was trying to photo document them, some of it with IMAX, and the two points that really come to mind are Bueno closing the door when the arm started to slip, as he pushed as hard as he could.

And then Mike Massimino going to get contingency tools, in areas that he hadn't really gone to before, and then breaking that bolt. You should have seen the action out the back window, it was—I'm sure it was better up close, but from the pilot's perspective, I was on the edge of my seat the—all five EVAs, actually.

Senator MIKULSKI. Dr. McArthur, did you want to say anything?

Mr. JOHNSON. And I guess I'll let Megan comment, and then if you have any more questions for——

Dr. MCARTHUR. Yes, ma'am.

Hello, Senator Mikulski, and Senator Nelson, and all of the Senators on the committee. It's great to be chatting with you today about our experiences. I think you've heard a lot about how the EVAs were pretty much all nail-biters, and that's certainly true. Those guys did great work out there though, and we're real proud of them.

Operating the arm, that was my primary task during the flight, and it actually went very nominally, very much as expected and as we had trained, it's pretty incredible to me to be thinking about this amazing stuff that we're doing, moving this giant telescope around in space with a robotic arm, and have it be nominal. So, I just take away that sense of wonder at doing the incredible and having it be nominal, that's sort of the big impression that it has made on me.

HUBBLE'S CONTRIBUTIONS

Senator MIKULSKI. Well, guys—first of all, thank you. It's really exciting to hear you. And we really, again, want to salute your daring and your bravery and your courage.

And this takes me to a question about all of your work, personally. You know, you've been training for this now for several years. You've had the support of devoted families and we've had delayed

takeoffs, setbacks, challenges in space. My question to you is, when you've literally put your lives on the line for this scientific endeavor. Could you tell me why you wanted to service the Hubble, and why, knowing at times, the uncertainty of the risk involved here, that you were willing to risk your lives to fix an aging telescope who seemed like its best days were behind it?

ASTRONAUT. Senator, it's really wonderful to appear before your committee and all the Senators there today. I really appreciate you taking the time to hear us.

You know, Hubble really has struck a fundamental chord in the human hearts around the world. It would be hard to find a K–12 school room anywhere in the United States of America that doesn't have a Hubble picture up on the wall.

From a science perspective, as you opened the hearing, it's probably the most significant scientific instrument of all time, in terms of its productivity. And astronomers try and answer, using Hubble, fundamental questions that we've had, since the beginning of human history. Where do we come from? Where are we going, what's the history of the universe, what is the stuff that we're made of, how was it made, what's the universe made of? All these very, deep philosophical questions that everybody has a curiosity about.

That's what Hubble and the other science, basic science that we do in this great country is all about. And Hubble is at the pointy end of that. And so, from a perspective of risk, we all take risks every day, driving up 295 to Baltimore, there's a certain risk there every morning in the commute. And we don't think about those risks, we think about the risks when, the stakes are a little bit higher, as they are for our space program. But when you look at the importance of what we do, things like Hubble, the International Space Station, our exploration program, our climate observing, observing the Earth, the dynamic Earth, all of these things are so very important to our country and to the world, that the risks are definitely worth it.

ASTRONAUT. And I would just add, quickly, that we're not leaving an aging telescope, we're leaving a newly refurbished telescope, with new instruments, instruments that have been repaired, a telescope that is now at the apex of its capabilities, and will be for a long time to come.

Senator MIKULSKI. Bill, did you have a question?

Senator NELSON. Hey guys, I just want you to know that you have made the spring in the step of every American a little bit bouncier by what you all have accomplished. And, what you said about us understanding this universe that we are a part of, and where did we come from, is now going to be better understood by the success of your mission. So, congratulations to all of the team.

Senator MIKULSKI. I, too, want to conclude this conversation, by again thanking you for your dedication, your sense of duty, and you really—when we talk about the Hubble and giving it, essentially, a new life and a new way of going and seeing the universe, you've touched our hearts, and you've also made history.

We want to wish you a very safe landing, and we look forward, Senator Nelson and I, to welcoming you at the Capitol, where we can give you a great big Hubble hug, and welcome you back home.

This concludes our part of the conversation.

Mr. MASSIMINO. Thank you very much, we've enjoyed it.

Mr. VENTRY. Atlantis, this is Houston ACR. That concludes the event, thanks.

Mr. MASSIMINO. Thank you, Senator Mikulski.

Senator MIKULSKI. Wow, wasn't that a hearing?

And, Senator Nelson, we were glad you were here.

Senators may submit additional questions for this subcommittee. We're going to request NASA's responses within 30 days.

SUBCOMMITTEE RECESS

This subcommittee will now stand in recess until Thursday, June 4, at 9:30 a.m., when we'll take testimony from the Director of the FBI.

Before I put down the gavel, wasn't that just wonderful? I mean, don't you all feel that that was pretty exciting?

So, thank you, again, Administrator Scolese, and thank you for your job, thank you for your service, and let's go where no Senate's gone before, and get this job done.

[Whereupon, at 12:50 p.m., Thursday, May 21, the subcommittee was recessed, to reconvene at 9:30 a.m., Thursday, June 4.]